THERAPEUTIC EXERCISE

MOVING TOWARD FUNCTION

Lori Thein Brody
Carrie M. Hall

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To my father, Jack, whose motto
"Never say can't; do it and say it was hard"
has sustained me throughout my life,
and is carried forward by his grandchildren Nathaniel,
Louisa, Benjamin, and Ethan.

—Lori Thein Brody

I would like to dedicate this book to
my three daughters, Caroline, Gabrielle, and Jillian,
who encourage me daily to be my best; my patients, who continuously
teach me about the complexity of the movement system;
my amazing colleagues who challenge me to stay current
and maintain a growth mind-set;
and my mother Carol,
who lived her life with courage and resolve and continues to
serve as my daily inspiration.

—Carrie M. Hall

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Preface to the First Edition

Choosing the title of this book was not easy, but once it was decided, the choice seemed obvious. *Therapeutic Exercise: Moving Toward Function* is the title that encapsulates the premise of this book. The emergence of managed care in the United States has altered the delivery of health care. Although value has always been important, its role in today's health care management is even more critical. Value can be defined as patient satisfaction (i.e., functionally meaningful patient outcomes), divided by the financial and social costs of providing care (Kasman GS, Cram JR, Wolk SL. Clinical Applications in Surface Electromyography. Rockville: Aspen, 1998). Physical therapists are challenged daily to provide value to their patients in delivering care to improve function and quality of life. Among the many interventions available to the physical therapist, therapeutic exercise is the cornerstone in providing patients with the means to improve their functional capabilities and, ultimately, their quality of life. Although other interventions can improve these elements, it is the assumption of this book that only through careful therapeutic exercise prescription can an individual make the permanent changes necessary to maintain, optimize, or prevent future loss of function. It is the premise of this book to use therapeutic exercise for patients with musculoskeletal dysfunction for the sole purpose of achieving functionally meaningful patient outcomes.

It was our decision to write this book as a textbook and not a manual of activities and techniques. The latter deals with providing activities and techniques without the theoretic framework to make decisions about what would or could be the best possible course of treatment and the possible alternatives. *Therapeutic Exercise: Moving Toward Function* attempts to provide a conceptual framework for learning how to make clinical decisions regarding the prescription of therapeutic exercise—from deciding which exercise(s) to teach to how to teach them to the dosage required for the best possible outcome. The common thread throughout the text is to treat, with the use of therapeutic exercise and related interventions, the impairments that correlate with functional limitations and disability and to work toward the most optimal function possible.

Because this book was written primarily as a textbook, decisions were made to provide the reader and instructor with a variety of educational features:

- Extensively illustrated. Therapeutic exercise is a visual intervention. This book uses photographs and line drawings to illustrate examples of therapeutic exercises.
- Selected Interventions. Featured at the end of pertinent chapters, these are activities or techniques written for the student and are included to provide examples of application of the therapeutic exercise intervention model presented in Chapter 2. Faculty can use the Selected Interventions as models for the student to develop exercise prescriptions.
- Self-Management boxes. These are activities or techniques written for the patient. These are included as examples to show the student how to write an exercise for a patient so that all the important features of an exercise prescription are clearly understood.
- Patient-Related Instruction boxes. These are similar to Self-Management boxes. The primary difference is that these are not exercises, but rather educational features to assist in the carryover of exercise into functional activities.
- Key Points. This feature summarizes key concepts the author wants to convey in the chapter. A thorough understanding of the Key Points should be realized following the reading of each chapter.
- Critical Thinking Questions. These were provided to stimulate the reader's thinking after studying the chapter. Case Studies are used to create hypothetical situations to which concepts can be applied.
- Lab Activities. These provide examples of applied use of the concepts to practice teaching and execution of selected activities and techniques.
- Case Studies. The final unit of the book provides the reader with a description of 11 cases. These cases are used in Critical Thinking Questions and Lab Activities to provide the student with real-life situations in which to apply concepts learned in the relevant chapter.

The book is organized into seven units. The purpose of each unit is as follows:

- Unit 1 provides the foundations of therapeutic exercise, beginning with a presentation of the disablement model to provide conceptual clarity for the remainder of the book, and ending with concepts of patient management. In the second chapter, a proposed therapeutic exercise intervention model is presented. This model attempts to separate the clinical reasoning process into the individual but cumulative steps to take in order to prescribe an effective therapeutic exercise. Chapter 3 describes two crucial elements of patient management: motor learning and self-management.
- Unit 2 provides the reader with a functional approach to therapeutic exercise for physiologic impairments. Although we attempted to include a somewhat extensive review of the scientific literature on muscle performance, balance, endurance, mobility, posture, movement, and pain, our purpose was not to publish a review of the material. Instead, we have selected pertinent literature to illustrate the concepts needed for a basic knowledge of physiologic impairments as it relates to therapeutic exercise prescription.
- Unit 3 presents special physiologic considerations to heed when prescribing therapeutic exercise. They include soft tissue injury, postoperative issues, arthritis, fibromyalgia

syndrome and chronic fatigue, and obstetrics. Although this list is not comprehensive, we chose these special considerations because of the frequency with which the clinician encounters them.

- Unit 4 provides the reader with selected methods of intervention. Although there are numerous schools of thought regarding the prescription of exercise, we chose these methods to provide the reader with examples of a variety of contrasting methods—each has its own merits. The authors have attempted to illustrate how each method can be incorporated into a cohesive program of therapeutic exercise prescription.
- Units 5 and 6 provide the reader with a regional approach to therapeutic exercise prescription. Each chapter is organized into a brief review of anatomy and kinesiology, examination and evaluation guidelines, therapeutic exercise for common physiologic impairments affecting the region, and therapeutic exercise for common medical diagnoses affecting the region. The anatomy, kinesiology, and examination and evaluation sections set the foundation for prescription of therapeutic exercise for physiologic impairments. Therapeutic exercise for physiologic impairments provides the reader with examples of exercises to improve physiologic capability and, ultimately, function. Therapeutic exercise for common medical diagnoses provides the reader with examples of comprehensive interventions, including therapeutic exercise for common medical conditions affecting the region.
- Unit 7 consists of 11 Case Studies, which are used in Critical Thinking Questions and Lab Activities at the end of selected chapters. Faculty can use these Case Studies for a variety of learning experiences.
- Appendices 1 and 2 give the student a quick reference for red flags of serious pathology or visceral referred symptoms and clinical actions to take in the event of serious signs and symptoms in the exercising patient.

We worked diligently to provide a comprehensive textbook designed to prepare the foundation of knowledge and skills necessary to prescribe therapeutic exercise. We urge our readers to write to us to tell us how well we accomplished our goal. We hope that subsequent editions can address your comments as well as the ever-changing needs of those involved in therapeutic exercise prescription.

Carrie M. Hall
Lori Thein Brody

Preface to the Fourth Edition

Therapeutic exercise remains the primary intervention provided by physical therapists and physical therapist assistants around the world. Although the exercises may appear simple in application, the processes that drive the decisions that ultimately result in an exercise program are complex. Therapeutic exercise is applied at the impairment, activity limitation, and participation restriction levels, and ranges from simple stretching to complex multijoint and system-level integrated activities. Therapeutic exercise is employed in the care of patients ranging from the youngest infants to the oldest seniors, across a broad range of abilities, needs, and goals, in a variety of settings.

This multidimensionality underscores the complexity of successful therapeutic exercise application in the patients we care for. Although determining that a patient with impaired quadriceps muscle performance needs quadriceps strengthening activities, choosing the appropriate type and dosage of therapeutic exercise is far more challenging. Consider the following examples of patients with impaired quadriceps performance: a young athlete post knee ligament reconstruction; an elderly woman recovering from a femur fracture resulting from a fall; a young man with a recent below knee amputation. The starting point, rate of progression, program focus, and goals may be different, and therefore require different exercise programs, all with the goal of improving an impairment. Remediation of the impairment is only one level of consideration; activity limitations (stair descent, rising from a chair, extending the knee during gait) and performance restrictions (return to sport, performing instrumental activities of daily living, return to work) are also part of the therapeutic exercise prescription. In addition, impairments rarely exist in singularity. The complexity of evaluation and therapeutic exercise prescription of the entire movement system, with integrated and interdependent impairments, is a complex, high-level decision-making process requiring skilled intervention to reach the desired outcome of function and participation in society. Choosing and dosing the exercise is only the beginning. The patient then must learn the motor control to carry out the specificity of the prescription, adhere to the dosage, and be progressed appropriately to reach his or her personal desired outcome. We continuously hear that students struggle with the daunting task of the decision-making process, teaching, and developing compliance with therapeutic exercise prescription in their varied patient populations. Although we are unable to fully impart all the skills necessary to prescribe and teach therapeutic exercise in a textbook, the fourth edition of *Therapeutic Exercise: Moving Toward Function* continues to emphasize the *decision-making process* necessary for successful outcomes of therapeutic exercise programs.

Successful outcomes require consideration of the therapeutic exercise prescription (exercise choices, frequency, intensity, duration, progression), motivators and barriers to adherence, adjunctive interventions, and evidence to support choices within the framework of a third-party payer system. The focus of this text is on providing the foundational information, and examples, to help clinicians decide where on the continuum of exercise to start a specific patient and how to progress that patient through rehabilitation to and including wellness. Although wellness has often been considered separate from rehabilitation, it should be considered concurrently with remediation of impairments and activity limitations. Wellness is multidimensional, including physical health, emotional health, spirituality, and social connectivity. Physical therapists who place therapeutic exercise within the context of wellness provide that patient with the opportunity to choose a lifetime of physical activity, which is a cornerstone of public health. Availability and individual preferences notwithstanding, consider the difference between an exercise program prescribed to be performed alone at home and one to be performed at a community center. A therapeutic exercise program that is initiated and/or progressed to an environment that allows a seamless transition to wellness is a successful program and one that is vital to the management and prevention of chronic disease

The World Health Organization (WHO) (www.who.int) and the Centers for Disease Control and Prevention (www.cdc.gov) both emphasize the many facets of wellness including physical activity. The WHO's International Classification of Functioning, Disability, and Health (ICF) includes all people in its classification from a continuum of people with no known disease to those with disease-related impairments, activity limitations, and participation restrictions. All people are served by participating in health and wellness-promoting activities, with some requiring the unique skills of a physical therapist in order to participate successfully. The WHO is currently in the process of developing a companion publication, the International Classification of Health Interventions (ICHI) that categorizes interventions associated with impairments of body structures and functions as well as interventions for activity limitations and participation restrictions. Like the ICF, the ICHI will provide a common language for further research into the effectiveness of different types and dosages of therapeutic exercise in patient groups.

With this backdrop, the changes to this edition of *Therapeutic Exercise: Moving Toward Function* capitalize on initiatives such as the ICF, ICHI, and work by the American Physical Therapy Association (APTA) and other professional organizations. Our goal is to deepen the reader's understanding of the complexities of therapeutic exercise prescription in health care today, and to provide examples and evidence of its application to promote a healthy population.

CHANGES AND ADDITIONS IN THE FOURTH EDITION

The changes and additions to the fourth edition of this text reflect extensive user feedback. These changes and additions are consistent with commitment to improve the delivery of successful, evidence-based therapeutic exercise interventions to patients. Language used throughout the book is consistent with that of the ICF and the APTA's Guide to Physical Therapist Practice. This provides a consistent and common language when discussing physical therapy interventions and evidence.

The therapeutic exercise model has been updated to improve clarity and ease of use. APTA has embraced the concept of the movement system as the primary system treated by physical therapists. The premise of the updated model is that ideal movement can be thought of as the result of a complex interaction of several subsystems (support, passive, active, neural, cognitive/emotional) of the larger encompassing movement system. Organizing impairments into subsystems of the movement system will assist the practitioner in systematizing the complex interaction of impairments and guide prioritization, sequencing, and progression of the therapeutic exercise intervention.

Chapter 3 has been expanded beyond patient-related education to include a broader range of information on improving patient outcomes. Patient education and instruction in home exercise programs are just a couple of the strategies to improve patient outcomes. Listening and the many components of communication are critical to ensure that information is delivered in a manner that respects and motivates patients. This chapter describes several opportunities to engage the patient in the therapeutic exercise decision-making process.

Chapter 14, previously labelled "Closed Kinetic Chain," has been revised to "Kinetic Chain Applications in Functional Movement." This change reflects further development in the body of evidence around the kinetic chain and functional movement assessments and interventions. This chapter includes an in-depth discussion of the rationale for and application of kinetic chain concepts, both open and closed kinetic chain. Integrating open and closed chain activities in functional movements is a foundational concept in therapeutic exercise prescription.

All chapters have expanded references and a new feature, **Evidence and Research (EAR) Boxes.** Each chapter continues to be extensively referenced to provide the best current evidence for the reader. We understand that the reader may want to know more details of some research studies. Rather than embedding extensive details in the body of the text, key research is highlighted in EAR boxes throughout the chapter. In this way, the interested reader can readily access the evidence supporting the chosen intervention. These boxes, along with the citations and reference lists, provide a strong evidence resource for the reader.

The look of the text has changed significantly, with more streamlined writing and bulleted lists for ease of finding information quickly. The easily identifiable boxes such as Patient-Related Instruction, Building Blocks, Case Studies, Self-Management, and Selected Interventions remain as strong pedagogical features designed to integrate therapeutic exercise applications into the many facets of effective patient care. ThePoint website contains videos of selected exercises to view and listen to a practitioner teach exercise. The website also contains supportive anatomy, kinesiology, and examination information that provides background knowledge as an easily accessible refresher for the reader. New to this edition is a change to full color images to provide greater clarity in photos and to better engage the reader.

We hope that these changes and additions will make for better reading and help to provide a comprehensive, effective therapeutic exercise program for patients and clients.

ONLINE INSTRUCTOR RESOURCES

Adopting instructors will be given access to the following resources on thePoint:

- Image Bank
- PowerPoint Presentations
- Test Generator
- Answers to Building Blocks

ONLINE STUDENT RESOURCES

Students who have purchased *Therapeutic Exercise: Moving Toward Function*, Fourth Edition, will have access to the following resources:

- Video clips showing various therapeutic exercise techniques
- Additional chapter material not found in text

Materials for students and instructors can be found online at thePoint.lww.com/BrodyHall4e.

Lori Thein Brody
Carrie M. Hall

Acknowledgments

In addition to all those individuals who helped create the first three editions, we wish to thank many people for their contributions to this revision. This book was made possible through the individual and collective contribution of many individuals.

We are privileged to have had so many knowledgeable and dedicated chapter contributors. We are indebted to their contribution to the original work and revisions to create an outstanding fourth edition. We are also acutely aware that the fourth edition could not have been done without input from the reviewers. We appreciate the insights they offered to finalize the content and design of the text. A special thanks is extended to Jill Thein-Nissenbaum who provided additional expertise and extensive editing crucial to the consistency and structure of the fourth edition. A book of this magnitude with its large numbers of figures, legends, displays, tables, special feature boxes, and references cannot be produced without the cohesive efforts of the talented editorial and production teams. For this we thank the editorial and production staff and the art department at Lippincott, Williams & Wilkins. We would like to extend a special thanks to production manager, John Larkin, who, among many other vital functions, played the critical behind-the-scenes role of keeping us organized and on schedule in a professional, kind, and respectful manner.

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Last, but most certainly not least, we would like to especially thank our family, friends, and colleagues who offered their emotional support and gave of their time generously to allow us to complete this project.

Lori Thein Brody
Carrie M. Hall

Each coauthor would like to extend her personal acknowledgments:

As we publish the fourth edition of our book, it is more evident now than ever that I am who I am because of the numerous influential and inspirational researchers, practitioners, instructors, business owners, administrators, and advocates, whom I have had the pleasure to work with over my 30+ year career. I was particularly fortunate to work with some of the best and brightest in our field during my formative years at Washington University in St. Louis. I would particularly like to thank Shirley Sahrmann, PhD, PT, FAPTA, for her incredibly insightful theories and devotion to the field of physical therapy. Her philosophy toward exercise prescription is woven into my thoughts and writing. Dr. Sahrmann has planted seeds that are found in research and clinical practice around the world. She is an icon in the field of physical therapy, and I am immensely indebted to her for teaching me how to view education, clinical practice, business acumen, and even advocacy through a movement system lens. I consider this book a result of the responsibility I feel to pay it forward to the next generation of practitioners whom I am confident will take the field of physical therapy into primary care and demonstrate our critical value to public health. I view therapeutic exercise as a cornerstone of our professional identity, and believe that movement is medicine and that physical therapists are uniquely qualified to integrate the biopsychosocial elements of the movement system into a therapeutic and transformative intervention.

The writing of a textbook takes tremendous time and energy away from work, friends, and family. Words cannot express my appreciation for my colleagues at Movement Systems Physical Therapy and my close friends whose support has been truly remarkable. I especially thank my clinic Administrator, Scott Spradling, who kept my business thriving during the hours I spent on research and writing, my three children whose unconditional love keeps me going every day, and my dog, Winston, who kept me running to maintain my fitness and mental clarity.

Carrie M. Hall

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Lori Thein Brody

Brief Contents

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Foundation of Therapeutic Exercise

UNIT 1

CHAPTER

1 Introduction to Therapeutic Exercise and the Model of Functioning and Ability

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Among the many interventions available to physical therapists, therapeutic exercise has been shown to be fundamental to improving function and decreasing disability.[1–7] It is the premise of this text that, through carefully prescribed therapeutic exercise intervention, an individual can make significant changes in functional performance and disability, and that physical therapists have the unique educational training to be the preferred clinician for prescribing therapeutic exercise.

DEFINITION OF PHYSICAL THERAPY

The Federation of State Boards of Physical Therapy[8] defines physical therapy practice as (with updated language provided by the authors)

1. Examining, evaluating, and testing individuals with mechanical, physiologic, and developmental impairments; activity limitations and participation restrictions or other health and movement-related conditions in order to determine a diagnosis, prognosis, and plan of treatment and intervention; and assessing the ongoing effects of intervention.
2. Alleviating impairments, activity limitations, and participation restrictions by designing, implementing, and modifying treatment interventions that may include, but are not limited to therapeutic exercise, functional training in self-care and in home community or work integration or reintegration, manual therapy including soft tissue and joint mobilization/manipulation, therapeutic massage, prescription, application, and, as appropriate, fabrication of assistive, adaptive, orthotic, prosthetic, protective, and supportive devices and equipment, airway clearance techniques, integumentary protection and repair techniques, debridement and wound care, physical agents or modalities, mechanical and electrotherapeutic modalities, and patient-related instruction.
3. Reducing the risk of injury, impairment, activity limitation, and participation restriction including the promotion and maintenance of fitness, health, and wellness in populations of all ages.
4. Engaging in administration, consultation, education, and research.

Physical therapists examine, evaluate, diagnose, and intervene at the level of *impairment, activity limitation*, and *participation restriction*. Physical therapists then use their knowledge and clinical skills to prevent, reduce, or eliminate impairments, activity limitations, and participation restrictions and to enable patients and clients to achieve the most optimal quality of life possible.

This chapter focuses on the goals of improving function and reducing disability through the use of therapeutic exercise. The physical therapist must consider what impairments are related to reduced function and disability for *this patient* and which exercises can *improve functional performance* by addressing the appropriate impairments. Therapeutic exercises described throughout this book can remediate both impairments and activity limitations. For example, a squat exercise can address the impairment of quadriceps weakness as well as the activity limitation of difficulty with transfer skills.

To understand the relationships among health conditions, impairments, activity limitations, and participation restrictions, a model using common language put forward by the World Health Organization (WHO) called the International Classification of Functioning, Disability and Health (ICF) will be used throughout this book. The model is an updated version of the International Classification of Impairments, Disabilities, and Handicaps (ICIDH) first published by the WHO in 1980. The reader is encouraged to use this model to think about how disability relates to decisions regarding therapeutic exercise intervention.

THERAPEUTIC EXERCISE INTERVENTION

Therapeutic exercise is a health service intervention provided by physical therapists to patients and clients as part of physical therapist practice.

- **Patients** are persons with diagnosed impairments or activity limitations.
- **Clients** are persons who are not necessarily diagnosed with impairments or activity limitations but who are seeking physical therapist services for prevention or promotion of health, wellness, and fitness.

Interventions for these clients can include any of the following:

- Education regarding body mechanics provided to a group of persons involved in strenuous occupational activity
- Preventative education and exercise prescription for persons diagnosed with a musculoskeletal disease such as rheumatoid arthritis
- Exercise recommended for a group of high-level athletes to prevent injury or enhance performance

Therapeutic exercise is considered a core element in most physical therapist plans of care and is defined as:

> The systematic performance or execution of planned physical movements, postures, or activities intended to enable the patient/client to (1) remediate or prevent impairments, (2) enhance function, (3) reduce risk, (4) optimize overall health, and (5) enhance fitness and well-being.[9]

Therapeutic exercise may include aerobic and endurance conditioning and reconditioning; balance, coordination, and agility training; body mechanics and posture awareness training; muscle lengthening; range of motion techniques; gait and locomotion training; movement pattern training; or strength, power, and endurance training.

Although therapeutic exercise can benefit numerous systems of the body, this text focuses primarily on treatment of the musculoskeletal system. Concepts of therapeutic exercise intervention specifically for the cardiovascular/pulmonary, neurologic, and integumentary systems are not covered in this text, except when they relate to impairments of the musculoskeletal system.

Decisions regarding therapeutic exercise intervention should be based on individual goals that provide patients or clients with the ability to achieve optimal functioning in home, work (job/school/play), and community/leisure activities. To implement goal-oriented treatment, the physical therapist must

- Provide comprehensive and personalized patient management sufficient to meet patient goals
- Rely on clinical decision-making skills
- Implement a variety of therapeutic interventions that are complementary (e.g., active warm-up before joint mobilization, followed by active exercise to use new mobility)
- Promote patient independence whenever possible through the use of home treatment (e.g., home spine traction, heat or cold therapy), self-management exercise programs (e.g., in the home, fitness club, community-sponsored group classes, school-sponsored or community-sponsored athletics), and patient-related instruction
- Avoid extraneous interventions and promote health care cost containment

In some cases, patient independence is not possible, but therapeutic exercise intervention is necessary to improve or maintain health status or prevent complications. In these situations, training and educating family, friends, significant others, or caregivers to deliver appropriate therapeutic exercise intervention in the home can greatly reduce health care costs by limiting in-house physical therapist intervention.

THE LANGUAGE OF HEALTH: ABILITIES AND DISABILITIES

The purpose of defining a model of functioning and disability in a text on therapeutic exercise is to provide the reader with an understanding of the complex relationships of health conditions (i.e., pathology, disease, genetic anomalies), impairments, activity limitations, and participation restrictions and to provide a conceptual basis for organizing elements of patient/client management that are provided by physical therapists. This text will use a biopsychosocial model that provides both the theoretical framework for understanding physical therapist practice and the classification scheme by which physical therapists make diagnoses.

Historically, traditional "medical models" viewed disability as an individual problem caused by disease, genetics, or injury, to be treated by individualized medical care. As a patient-centered perspective with the individual as the focus of intervention, little regard is given to the societal aspects of disability beyond public policy health care guidelines (i.e., vaccinations). This contrasts with "social models" that view disability as a socially created problem where disability is created primarily by the social environment and is *not* an attribute of the individual. Therefore, policies and interventions are directed toward society at large, making environmental modifications necessary to allow persons with disabilities to fully participate in all aspects of social life. The ICF is a "biopsychosocial" model embracing both of these perspectives, addressing factors at both the individual and the social level[10] (**Fig. 1-1**).

Terminology of the Biopsychosocial Model of Functioning and Disability

Although previous models of functioning and disability have focused on disability, ICF model focuses on both the positive and negative aspects of health, viewing health as a continuum. Rather than including only people with "disability," the ICF includes *all* people in its model. The ICF is a model of **both** *functioning* and *disability*.[11,12] The following sections define and describe the components of the ICF model.

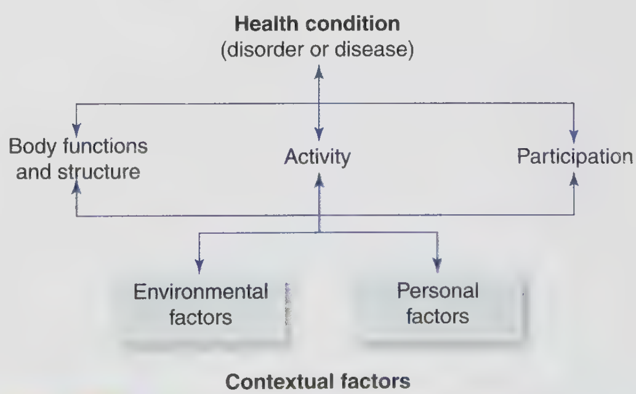

FIGURE 1-1 The WHO model of function and disability.

- **Functioning** is an umbrella term for body structures and function, and activities and participation (Part 1 of the ICF). It represents the *positive* aspects of the interaction between the individual with a health condition and that person's environmental and personal factors (Part 2 of the ICF, "Contextual Factors").
- **Disability** is a parallel umbrella term describing the negative aspects of this same interaction. It is described by terms such as *impairment*, *activity limitation*, and *participation restriction*.

Health Condition

In the medical model, health conditions focused on the negative aspects of health such as infection, trauma, metabolic imbalance, degenerative disease process, or diseases.[13,14] The ICF uses the term *health condition* as an umbrella term for disease, disorder, injury, or trauma, as well as states such as pregnancy, aging, congenital anomalies, or genetic predispositions.[10(p.212)]

Impairment

Impairment refers to a loss or abnormality in a body structure or in a physiologic function at the tissue, organ, or body system level. Impairments frequently treated by physical therapists include impaired range of motion, joint mobility and integrity, or muscle performance. Body function impairments might include pain, mobility or stability of joints, muscle power or endurance functions or gait pattern functions (**Table 1-1**).

TABLE 1-1

Two-Level Classification of Body Functions Related to the Motor System

NEUROMUSCULOSKELETAL AND MOVEMENT-RELATED FUNCTIONS

Functions of the joints and bones (b710–b729)[a]
- b710 Mobility of joint functions
- b715 Stability of joint functions
- b720 Mobility of bone functions
- b729 Functions of the joints and bones, other specified and unspecified

Muscle functions (b730–b749)
- b730 Muscle power functions
- b735 Muscle tone functions
- b740 Muscle endurance functions
- b749 Muscle functions, other specified and unspecified

Movement functions (b750–b799)
- b750 Motor reflex functions
- b755 Involuntary movement reaction functions
- b760 Control of voluntary movement functions
- b765 Involuntary movement functions
- b770 Gait functions
- b780 Sensations related to muscles and movement functions
- b789 Movement functions, other specified and unspecified
- b798 Neuromusculoskeletal and movement-related functions, other specified
- b799 Neuromusculoskeletal and movement-related functions, unspecified

[a]The letter "b" denotes Body Functions.
From World Health Organization. International Classification of Functioning, Disability and Health. Geneva, Switzerland: World Health Organization, 2001.

Activity Limitation

The ICF uses the term *activity limitation* to describe difficulties an individual may have in executing activities. These limitations range from mild to severe and are measured against a population standard. Examples of activity limitations delineated in the ICF model include changing and maintaining body position, carrying, moving and handling objects, walking and moving, moving around using transportation, and self-care.

Participation Restriction

The ICF uses the term *participation restriction* to describe problems an individual may experience in involvement in life situations. Deficits are determined by measuring against societal standards.

Participation restrictions are reserved for social rather than individual functioning and people with similar activity limitations may have very different participation restrictions. For example, two persons with similar levels of impairment and activity limitation may have two different levels of participation restriction. One person may remain very active in all aspects of life (i.e., personal care and social roles), have support from family members in the home, and seek adaptive methods of continuing with occupational tasks, whereas the other individual may choose to limit social contact, depend on others for personal care and household responsibilities, and have a job where no modifications to support ongoing participation are possible. Contextual factors play an important role in these differences.

The distinction between activity limitation and participation restriction is the difference between viewing the individual in isolation (activity limitation) and viewing the individual in relation to the larger world (participation restriction). An activity limitation is primarily a reflection of the characteristics of the individual person. An activity limitation is measured at the level of the individual and compared against a population standard. Participation restriction, however, has a relational characteristic in that it describes the individual's limitation in relation to society and the environment. Persons with similar individual profiles (e.g., disease, impairments, activity limitations) can present with different participation profiles. Factors such as age, general health status, personal goals, motivation, social support, and physical environment influence the level of disability the person experiences (**Evidence and Research 1-1**).

EVIDENCE and RESEARCH 1-1

A total of 100 patients rated as high risk for low back pain because of structural and psychosocial variables were prospectively followed for 4 to 6 years to determine the impact of these variables on disability. Psychosocial variables strongly predicted future disability, whereas the structural variables had no association with future disability and medical care.[15]

INTERNATIONAL CLASSIFICATION OF FUNCTIONING, DISABILITY, AND HEALTH

The ICF model is an advancement of previous models in its ability to apply to all people, not just people with disabilities. The ICF describes health and health-related states of all people, and *everyone* can be classified within the ICF system. Identifying the underlying causes of participation restrictions is essential to understanding the complex relationship between the individual with a health condition and that individual's response to that condition. The ICF addresses this in Part 2, "Contextual Factors." Contextual factors include environmental and personal factors.

The language of the ICF reflects a significant change from previous models, recognizing the stigmatizing and potentially negative aspects of the terms "handicap" and "disability." Therefore, the WHO has decided to completely drop the term "handicap" and remove the term "disability" from a component, but retain it as the overall, umbrella term.[10] Moreover, the WHO emphasizes that the ICF is not a classification of *people* but a classification of "people's health characteristics within the context of their individual life situations and environmental impacts. It is the interaction of the health characteristics and the contextual factors that produces disability."[10]

Like the *International Classification of Diseases, Tenth Revision* (*ICD-10*),[11] the ICF uses an alphanumeric system to classify and categorize the levels of functioning and disability.[10] This enhances the system's usefulness for worldwide research and provides a common language. The letters b, s, d, and e are used to denote Body Functions, Body Structures, Activities and Participation, and Environmental Factors, respectively. The letters are followed by a chapter number (e.g., Chapter 7 for Body structures related to movement) followed by three or more numbers with specific descriptors and scales. Because of the complexity of the system, the details of the grading scales will not be covered in this text. For further information on this system, the reader is referred to www.who.org. An example of the two-level classification for *Body Structures* and *Body Functions* can be found in **Tables** 1-1 and **1-2**, respectively.

TABLE 1.2

Two-Level Classification of Body Structures Related to the Motor System

STRUCTURES RELATED TO MOVEMENT

- s710 Structure of head and neck region[a]
- s720 Structure of shoulder region
- s730 Structure of upper extremity
- s740 Structure of pelvic region
- s750 Structure of lower extremity
- s760 Structure of trunk
- s770 Additional musculoskeletal structures related to movement
- s798 Structures related to movement, other specified
- s799 Structures related to movement, unspecified

[a]The letter "s" denotes Body Structures.
From World Health Organization. International Classification of Functioning, Disability and Health. Geneva, Switzerland: World Health Organization, 2001.

The ICF classification has two major *parts*, Part 1 termed "Functioning and Disability" and Part 2 termed "Contextual Factors." *Functioning* indicates the positive aspects of health (including all body functions, activities, and participation), and *disability* indicates the negative aspects of health (impairments, activity limitations, and participation restrictions). The parts are further divided into components, with or without further division into constructs (see **Table 1-3**). A list of definitions for the essential terms can be found in **Table 1-4**.

Part 1: Functioning and Disability

Part 1 of the ICF addresses the majority of issues that physical therapists typically encounter in practice including the body's functions and its structures. Both the body structure and body function components have a positive and a negative aspect. This is one way in which both the "ability" and "disability" aspects of the functioning continuum are incorporated into the ICF.

Component A: Body Functions and Structures

- **Body functions** are the physiologic functions of body systems.
- **Body structures** are the anatomic parts of the body such as organs and limbs.

The body functions and the body structures components are designed to be used in parallel. For example, the body function component includes categories such as "mobility of joint functions" and the related body structures might be "joints of the shoulder region." The ICF would describe a healthy system (positive aspect) as having functional and structural integrity. The negative aspects of body functions and structures are termed impairments.

- **Impairments** are problems in body function or structures that are deviations from generally accepted population standards, such as an anomaly, defect, loss, or other abnormality (**Fig. 1-2A** and **B**).
  - **Physiologic impairment** is an alteration in any physiologic function such as:
    - Aerobic capacity
    - Muscle performance (strength, power, endurance)
    - Joint mobility (i.e., hypomobility/hypermobility)
    - Balance
    - Posture
    - Motor function
    - Mental function

    Physical therapist practice interventions can most significantly modify physiologic impairments. Unit 2 of this text provides a more thorough discussion of each of these physiologic impairments and examples of therapeutic exercise interventions to remediate or prevent these impairments.
  - **Structural impairment** is an abnormality or loss of structure, such as hip anteversion, structural subtalar varus, structural genu varum, or congenital or traumatic loss of a limb.

    Modifications to structural impairments can be made to improve function despite these existing impairments. The physical therapist should be aware of the presence of structural impairments to be able to provide an

TABLE 1-3

Overview of the ICF

	PART 1: FUNCTIONING AND DISABILITY		PART 2: CONTEXTUAL FACTORS	
COMPONENTS	BODY FUNCTIONS AND STRUCTURES	ACTIVITIES AND PARTICIPATION	ENVIRONMENTAL FACTORS	PERSONAL FACTORS
Domains	Body functions Body structures	Life areas (tasks, actions)	External influences on functioning and disability	Internal influences on functioning and disability
Constructs	Change in body functions (physiologic) Change in body structures (anatomic)	Capacity: Executing tasks in a standard environment Performance: Executing tasks in the current environment	Facilitating or hindering impact of the physical, social, and attitudinal world	Impact of attributes of the person
Positive aspect	**Functioning**		Facilitators	Not applicable
	Functional and structural integrity	Activities Participation		
Negative aspect	**Disability**		Barriers and hindrances	Not applicable
	Impairment	Activity limitation Participation restriction		

From World Health Organization. International Classification of Functioning, Disability and Health. Geneva, Switzerland: World Health Organization, 2001; Table 1, p. 11.

TABLE 1-4

Relevant Definitions from the ICF

TERM	DEFINITION
Body functions	Physiologic functions of body systems, including psychological functions. The standard is the statistical norm for humans.
Body structures	The structural or anatomic parts of the body such as organs, limbs, and their components classified accordingly by systems. The standard is the statistical norm for humans.
Impairment	The loss or abnormality in body structure or physiologic function. Abnormality refers to a significant variation from established statistical norms.
Activity	The execution of a task or action by an individual. It is the individual perspective of functioning.
Activity limitations	Difficulties an individual may have in executing activities. The limitations may range from slight to severe in terms of quality or quantity.
Participation	A person's involvement in a life situation. It is the societal perspective of functioning.
Participation restriction	Problems an individual may experience in the involvement in life situations. Participation restrictions are determined by comparing an individual's participation against what is expected of an individual without a disability in that culture or society.
Environmental factors	These make up the physical, social, and attitudinal environment in which people conduct their lives.
Health condition	An umbrella term for disease (acute or chronic), disorder, injury, or trauma. It may also include other situations such as pregnancy, aging, stress, congenital anomaly, or genetic predisposition.
Well-being	A general term encompassing the total universe of human life domains including physical, mental, and social aspects that make up a "good life." Health domains are a subset of the total universe of human life.

appropriate prognosis and determine the best plan of care. Therapeutic exercise intervention in the presence of structural impairments will be discussed in selected chapters in Units 5 and 6.

Impairments are not the same as pathology, but may be expressions of the pathology. However, not all impairments result from pathology. For example, congenital anatomic deformities, immobilization, or faulty movement patterns can result in impairments of body structures and functions, but are not the result of pathology.

Impairments can be considered to be *primary* or *secondary*.

- **Primary impairments** result from pathology, disease, or genetics.
- **Secondary impairments** arise from other impairments.

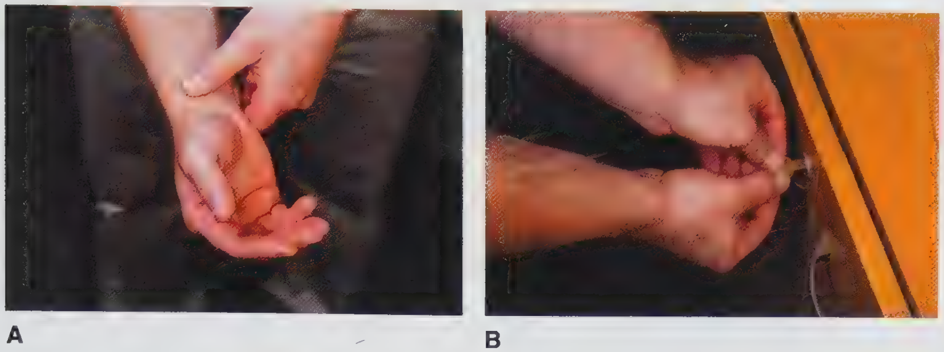

FIGURE 1-2 **(A)** Patient has a loss of forearm supination, a physiologic impairment in range of motion and joint mobility. **(B)** Patient has an activity limitation of inability to turn a key because of this mobility loss.

For example, impairment of the muscles in the lower half of the body (e.g., paraparesis) may result in impairments of the protective functions of the skin (e.g., decubitus ulcers). Likewise, impairment of the control of voluntary movement functions (e.g., from stroke or neurologic disease) may result in impairments of heart functions because of a lack of exercise, or impaired heart functions can lead to impaired respiratory functions. Secondary impairments can also lead to an additional or secondary health condition.

Impairments can be **temporary** or **permanent**, **intermittent** or **continuous**. For example, impaired joint mobility following a total knee replacement is a *temporary* condition, amenable to rehabilitative intervention. A joint that has been fused will have a *permanent* joint function impairment. Impaired joint stability such as occasional episodes of giving way following an anterior cruciate ligament tear is an *intermittent* impairment and may be activity related. An example of a *continuous* body function impairment is a shoulder that remains subluxed following a stroke. Impairments can also be described as progressing, regressing, or static.

Component B: Activities and Participation

The second major component of the ICF Functioning and Disability portion is activities and participation.

- **Activity** is the execution of a task or action by an individual.
- **Participation** is involvement in a life situation.
- **Functioning** is the positive aspect of activities and participation, implying the ability to perform individual activities and to participate in socially appropriate situations.
- **Activity limitations** and **Participation restrictions** are the negative aspects of activities and participation, suggesting that the individual is unable to participate in socially appropriate situations.

The Activities and Participation component has nine domains that encompass all life areas (**Table 1-5**). Each domain has a number associated with it, and within each domain there are several subclassifications. For example, domain 4, Mobility, has four categories, with four to six more specific descriptors. An example of one category can be found in **Table 1-6**.

Both activities and participation have two qualifiers that represent important aspects of assessing abilities. The qualifiers are *performance* and *capacity*.

- **Performance** describes what a person actually does in his or her current environment including all aspects (psychosocial and environmental) of the person's situation. Performance describes what the individual is currently able to do within the context (environmental and personal) of their world.
- **Capacity** is a standardized measure of an individual's ability to execute a task or action. Capacity measures attempt to capture the highest possible level of functioning that a person could attain at a given point in time.

The disparity between performance and capacity provides insight into the environment's contribution to activity limitations and participation restrictions. This information can prove useful in determining how the environment can be modified to improve performance.

TABLE 1-5

Activities and Participation Domains and Qualifiers

	QUALIFIERS	
DOMAINS	PERFORMANCE	CAPACITY
d1 Learning and applying knowledge		
d2 General tasks and demands		
d3 Communication		
d4 Mobility		
d5 Self-care		
d6 Domestic life		
d7 Interpersonal interactions and relationships		
d8 Major life areas		
d9 Community, social, and civic life		

TABLE 1-6

An Example of a Category Within the Mobility Domain of the Activities and Participation Component of the ICF

WALKING AND MOVING (d450–d469)

- d450 Walking
- d455 Moving around
- d460 Moving around in different locations
- d465 Moving around using equipment
- d469 Walking and moving, other specified and unspecified

Part 2: Contextual Factors

Contextual factors encompass the background of the individual's personal life and environment. The two components are *environmental factors* and *personal factors*. Environmental factors reflect the external influences on functioning and disability, whereas personal factors reflect the internal influences. These factors can have a tremendous impact on a person's health and health status.

- **Environmental factors** are those features that comprise the physical, social, and attitudinal environment in which people live and function and include:
  - Close and personal such as the physical neighborhood in which the person lives, attitudes of coworkers, physical structure of the neighborhood,
  - Broader societal attitudes toward people with differing abilities.

Environmental factors can be positive, helping to improve a person's activity levels and participation, or they can be negative, producing barriers to participation. There are five categories of environmental factors (see **Table 1-7**).

Environmental factors are considered at two major levels, the *individual* and *societal*.

- The **individual** perspective is comprised of environmental settings such as home, school, or the workplace. The physical layout of the home, school, workplace, or environment, or people encountered can support or hinder participation.
- The **societal** perspective includes both formal and informal social structures, community services, community and work organizations, government agencies, communication and transportation services, informal social networks, as well as laws, regulations, and policies, both formal and informal.

Some work or other social structures may be positive, thereby improving a person's functioning, whereas others may be negative, creating barriers.

- **Personal factors** are the elements in an individual's background that are not part of the health condition or health states.

Examples of personal factors include gender, race, age, other health conditions, fitness, lifestyle, personal habits, coping styles, social background, education, profession, individual psychological assets, and life experiences. Like environmental factors, personal factors can have a positive or negative influence.

TABLE 1-7

Domains of Environmental Factors Impacting Functioning and Disability

ENVIRONMENTAL FACTORS	
Chapter 1	Products and technology
Chapter 2	Natural environment and human-made changes to environment
Chapter 3	Support and relationships
Chapter 4	Attitudes
Chapter 5	Services, systems, and policies

These factors can help the person to be resilient or can create barriers to function.

APPLICATION OF THE MODEL TO PHYSICAL THERAPIST PRACTICE

The model put forward by the ICF provides a common language and classification for describing function across a continuum of abilities. An application of this model to physical therapist practice can be found in **Figure 1-3**. The concept of function, disability, and health refers to the "various impact(s) of chronic and acute conditions on the functioning of specific body systems, on basic human performance, and on people's functioning in necessary, usual, expected, and personally desired roles in society."[11,12] Understanding of the factors that influence functioning and disability as well as the timing of the intervention is fundamental to restoring or improving function and reducing disability in the individual seeking physical therapy services (**Evidence and Research 1-2**).

EVIDENCE and RESEARCH 1-2

The timing of intervention may impact psychosocial aspects of the patient's function. A study of patients with low back pain found that those patients randomized to an assess/advise/treat group demonstrated greater improvements in disability, mood, general health, and quality of life than patients in the assess/advise/wait group.[16] The authors felt that the timing of the intervention impacted the development of psychosocial features.

Therapeutic exercise intervention must consider the patient's functional loss and disability in addition to disease or impairments; although a specific therapeutic exercise intervention may be selected to remediate or prevent impairment, it must also improve a functional outcome and the person's role in a specific sociocultural context and physical environment. **Display 1-1** describes a patient with adhesive capsulitis of the shoulder. Physical examination shows impairments of body functions related to mobility and muscle power. A number of activities may be impacted depending upon the severity of the problem, limb dominance, and the patient's work and lifestyle. Display 1-1 lists a number of commonly limited activities, but many more possibilities exist. In this example, physical therapist interventions should be directed not only at the impairments (i.e., loss of mobility, loss of muscle power) but at the activity limitations such as the ability to use both arms to care for one's hair, or the ability to lift and carry loads. If full use of both upper extremities is required for the patient's occupation, then significant participation restrictions can result, especially if environmental factors (i.e., e330 People in positions of authority; e430 Individual attitudes of people in positions of authority; e5902 Labor and employment policies) have a negative impact. The therapist must acknowledge these factors and have a dialogue with the patient about the prognosis at all levels of function. Understanding the relationships among health conditions, impairments, and function for each patient enables the therapist to make sound decisions about therapeutic exercise intervention.

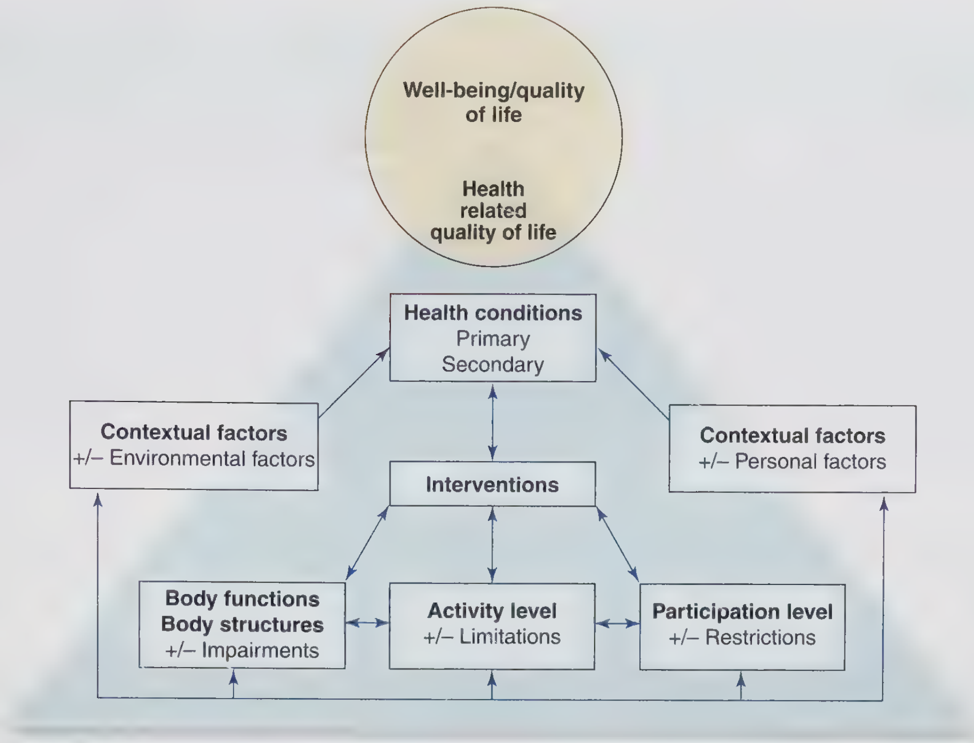

FIGURE 1-3 Modified physical therapy model of function and disability.

DISPLAY 1-1

Example of ICF and ICD-10 with Coding and Descriptors of Components Relative to Patient Care

International Statistical Classification of Diseases and Related Health Problems		
Primary ICD-10	m75.0	Adhesive capsulitis of the shoulder
Secondary ICD-10	m75.1	Rotator cuff syndrome
	m75.5	Bursitis of the shoulder
International Classification of Functioning, Disability and Health		
Primary ICF Codes		
Body functions	b7100	Mobility of a single joint
	b7101	Mobility of several joints
	b7200	Mobility of scapula
	b7301	Power of muscles of one limb
Body structure	b29014	Pain in upper limb
	s7201	Joints of the shoulder region
	s7203	Ligaments and fasciae of the shoulder region
Activities and participation	d4300	Lifting
	d4301	Carrying in the hands
	d4302	Carrying in the arms
	d4303	Carrying on shoulders, hip, and back
	d4305	Putting down objects
	d4452	Reaching
Secondary ICF Codes		
Body functions	b7401	Endurance of muscle groups
	b7800	Sensation of muscle stiffness
	b7809	Sensations related to muscles and movement functions, unspecified
Body structure	b2804	Radiating pain in a segment or region
Activities and participation	s7202	Muscles of the shoulder region
	s7200	Bones of the shoulder region
	s7209	Structure of shoulder region, unspecified

(*continued*)

DISPLAY 1-1

Example of ICF and ICD-10 with Coding and Descriptors of Components Relative to Patient Care (*continued*)

d4201	Transferring oneself when lying
d4450	Pulling
d4451	Pushing
d4454	Throwing
d4455	Catching
d4451	Climbing
d4550	Crawling
d4554	Swimming
d5100	Washing body parts
d5202	Caring for hair
d5400	Putting on clothes

Since the publication of the ICF in 2001, a large body of research has been published identifying "core sets" categories specific to certain health conditions or population groups.[17–28] These core sets provide consistency for patient care and policy and research decisions. An example of a core set for low back pain can be found in **Display 1-2**.

DISPLAY 1-2

An Example of a Core Set for Low Back Pain

International Classification of Functioning, Disability and Health (ICF) categories included in the Brief ICF Core Set for low back pain. The categories per component are listed according to the conceded rank order.

ICF Component	Rank Order	ICE Code	ICF Category Title
Body functions	1	b280	Sensation of pain
	2	b152	Emotional functions
	3	b730	Muscle power functions
	4	b710	Mobility of joint functions
	5	b455	Exercise tolerance functions
	6	b134	Sleep functions
	7	b740	Muscle endurance functions
	8	b135	Muscle tone functions
	9	b7l5	Stability of joint functions
	10	b130	Energy and drive functions
Body structures	1	s120	Spinal cord and related structures
	2	s760	Structure of trunk
	3	5770	Additional musculoskeletal structures related to movement
Activities and participation	1	6415	Maintaining a body position
	2	8430	Lifting and carrying objects
	3	8410	Changing basic body position
	4	6450	Walking
	5	6850	Remunerative employment
	6	d859	Work and employment, other specified and unspecified
	7	6640	Doing housework
	8	d540	Dressing
	9	6240	Handling arms and other psychological demands
	10	d760	Family relationships
	11	d530	Toileting
	12	6845	Acquiring, keeping, and terminating a job
Environmental factors	1	e580	Health services, systems, and policies
	2	e570	Social security services, systems, and policies
	3	e355	Health professionals
	4	e450	Individual attitudes of health professionals

DISPLAY 1-2

An Example of a Core Set for Low Back Pain (*continued*)

ICF Component	Rank Order	ICE Code	ICF Category Title
Environmental factors	5	e410	Individual attitudes of immediate family members
	6	c135	Products and technology for employment
	7	e110	Products or substances for personal consumption
	8	e310	Immediate family
	9	e155	Design, construction, and building products and technology of buildings for private use
	10	c550	Legal services, systems, and policies

From Cieza A, Stucki G, Weigl M, et al. ICF Core Sets for low back pain. J Rehabil Med 2004;(44 Suppl):69–74. Open Access

Health Conditions

Health conditions (disease, disorder, or condition) refer to an ongoing pathologic/pathophysiologic state that is:

- Characterized by a particular cluster of signs and symptoms
- Recognized by the patient or the practitioner as "abnormal"
- Primarily identified at the cellular, tissue, and organ levels
- Are often the physician's medical diagnosis.

It is, however, within the scope of physical therapist practice to diagnose such conditions at the tissue level using clinical tests and measures such as those outlined by Cyriax (e.g., supraspinatus tendonitis).[29] Furthermore, the complexity of the interrelationships among the ICF components highlights the extensive pathology and pathophysiology knowledge necessary to perform optimal patient management. For example, in the case of a patient referred to a physical therapist with shoulder pain, the physical therapist performs an examination/evaluation to diagnose the condition. The physical therapist's knowledge that different clusters of signs and symptoms are consistent with pathology at the tissue (e.g., tendonitis), organ (e.g., myocardial infarction), or cellular (e.g., lung cancer) level is critical for the diagnosis and management of the patient's condition. If the clinical findings on examination suggest a pathologic or pathophysiologic condition that is not within the scope of physical therapist practice (e.g., myocardial infarction, lung cancer) that has not been addressed by the appropriate practitioner, an immediate referral is necessary (see Appendix 1).

In many instances, the health condition cannot be diagnosed and the physical therapist must rely on clusters of impairments to formulate a diagnosis and intervention. A pathology-based diagnosis does not, by itself, delineate the impairments, activity limitations, or participation restrictions that will guide the physical therapist intervention (see Chapter 2). Therefore, the therapist must collect as much data as possible in each of the ICF components, acknowledge the complex multidirectional and cyclical nature of the biopsychosocial model, and apply interventions in the components of the model that will most efficiently and effectively achieve physical therapy goals.

Additionally, *secondary conditions* may develop as a result of a primary health condition. A secondary condition may be a type of health condition, impairment, activity limitation, or participation restriction. By definition, secondary conditions only occur in the presence of a primary condition. Commonly encountered secondary conditions include pressure sores, contractures, urinary tract infection, cardiovascular deconditioning, and depression. Each of these secondary conditions can lead to additional activity limitations and participation restriction.

Impairments of Body Functions and Structures

Impairments are defined as losses or abnormalities of physiologic, psychological, or anatomic structure or function. Health conditions may result in impairment, but not all impairments originate from a disease, disorder, or health condition. The presence of an impairment does not necessarily mean a loss of function. For example, someone with a congenitally missing fifth finger may live a fully functioning life. In contrast, a person with a fifth metacarpal fracture in their dominant hand may be fully disabled in a job requiring hand power and dexterity. Many physical therapist interventions are directed directly at the measurable body function impairments such as mobility (i.e., range of motion measures), muscle power (i.e., strength testing), pain (i.e., pain scales), or balance (i.e. balance scales). Although it may be easy to measure progress in these impairments of body functions, it is essential to link these impairment improvements to increases in activity limitations and/or participation restrictions (**Fig. 1-4**).

Activity Limitations, Participation Restrictions, and Quality of Life

Activity limitations and participation restrictions are limitations in individual functioning and/or functioning in society. The therapist must look beyond impairments to the activity limitations to design a rehabilitation and therapeutic exercise program to address these limitations. Examples of functional activities include basic mobility (moving around, changing positions,

FIGURE 1-4 **(A)** Patient performing a quadriceps strength test. **(B)** Functional quadriceps strength measured by ability to ascend the stairs.

etc.), carrying and moving objects, walking and moving, and self-care (i.e., BADL, IADL). Examples of important categories of function from the ICF can be found in **Table 1-8**.

Physical therapists utilize therapeutic exercise to improve skills such as walking on different surfaces, moving around within the home, pushing with the lower extremities, throwing and reaching, and transfers. Exercise should focus on remediating impairments linked to activity limitations and to improving functional skills like transferring from supine to sit. Additionally, consideration must be given to the contextual factors that may impact activities and participation.

TABLE 1-8

Expansion of the Categories Within the "Walking and Moving" Category of the Mobility Domain

d450 Walking
- d4500 Walking short distances
- d4501 Walking long distances
- d4502 Walking on different surfaces
- d4503 Walking around obstacles
- d4508 Walking, other specified
- d4509 Walking, unspecified
- d455 Moving around

d4450 Crawling
- d4551 Climbing
- d4552 Running
- d4553 Jumping
- d4554 Swimming
- d4558 Moving around, other specified
- d4559 Moving around, other unspecified

d460 Moving around in different locations
- d4600 Moving around within the home
- d4601 Moving around within buildings other than home
- d4602 Moving around outside the home and other buildings
- d4608 Moving around in different locations, other specified
- d4609 Moving around in different locations, unspecified

d465 Moving around using equipment
d469 Walking and moving, other specified and unspecified

The ultimate goal for people in any health state is to maximize one's health-related quality of life (HRQL). The ICF defines **well-being** as an umbrella term encompassing the total universe of human life. HRQL is a subset of well-being related to health domains. It contains three major components[30,31]:

- *Physical function component*, which includes BADLs and IADLs
- *Psychological component*, which includes the "various cognitive, perceptual, and personality traits of a person" and
- *Social components*, which involves the interaction of the person "within a larger social context or structure."

Assessments of quality of life attempt to capture how limitations in function affect physical, psychological, and social roles as well as perceptions of health status.[32–34] A person may argue that issues related to quality of life are not distinct from disability, but quality of life is considered broader than disability, encompassing more than well-being related to health such as education and employment. Other contextual variables contribute to an individual's sense of well-being and overall quality of life. Such factors include economic status, individual expectations and achievements, personal satisfaction with choices in life, and sense of personal safety. The model (see Fig. 1-3) displays HRQL as a small part of the quality of life or well-being, and general quality of life overlaps with components of the ICF.

Contextual Factors and Interventions

The main pathway from a health condition to disability, including quality of life, can be modified by a host of factors such as age, gender, education, income, comorbidities, health habits, motivation, social support, and physical environment. Proper medical care and timely rehabilitation also can eliminate or reduce the impact of each component's effects on one another. Conversely, improper medical care or rehabilitation along with other aforementioned factors can magnify the impact of an impairment or limitation (**Evidence and Research 1-3**).

EVIDENCE and RESEARCH 1-3

Education, age, gender, disease severity, duration of illness and treatment, and comorbidity modify the functional level in persons diagnosed with rheumatoid arthritis,[34–36] and anxiety, depression, and coping style have been related to activity limitations in individuals with hip or knee osteoarthritis.[37]

Contextual factors can become risk factors if they impede progress toward full functioning in society. There are several types of risk factors:

- Demographic, social, lifestyle, behavioral, psychological, and environmental factors
- Comorbidities (e.g., coexisting conditions)
- Physiologic impairments (e.g., short hamstrings, weak abdominal muscles, lengthened lower trapezius)
- Structural impairments (e.g., congenital scoliosis, shallow glenoid fossa, hip anteversion)
- Functional performance factors (e.g., less than optimal workstation ergonomics resulting in poor posture at the workstation, faulty gait kinetics or kinematics, inappropriate lifting mechanics)

The physical therapist must be aware of how any of these factors might alter the individual's response to the health condition and physical therapy intervention. Many of these factors can directly influence the choice of activities or techniques, dosage, and expected functional outcome. For example, consider two individuals involved in a motor vehicle accident and diagnosed with an acceleration injury to the cervical spine with resultant sprain or strain to the cervical soft tissues. One individual is a sedentary, 54-year-old male smoker with diabetes who has a significant forward head and thoracic kyphosis and must return to a data entry job (which he dislikes) at a poorly designed workstation. The other individual is an active and otherwise healthy, 32-year-old man who enjoys his job as a salesman and is engaged in activities such as sitting, standing, and walking throughout the day. The function and disability profiles of these two individuals are quite different, and the prognoses, therapeutic exercise interventions, and functional outcomes differ accordingly.

In addition to the risk factors present before disability, interventions (see Fig. 1-3) can alter the individual's functional level. Interventions may include extraindividual factors (i.e., outside of the individual) such as medications, surgery, rehabilitation, supportive equipment, and environmental modifications or intraindividual factors (i.e., self-induced) such as changes in health habits, coping mechanisms, and activity modifications.[38] The expected outcome is that interventions modify the functioning and disability profile in a positive manner. However, interventions occasionally serve as exacerbators. Exacerbators may occur in the following ways:

- Interventions may go awry.
- Persons may develop negative behaviors or attitudes.
- Society may place environmental or attitudinal barriers in the path of the individual.

Prevention and the Promotion of Health, Wellness, and Fitness

Physical therapists may prevent impairment, activity limitation, and participation restriction as well as improving the HRQL by identifying risk factors during the diagnostic process. Risk factors are typically part of the ICF profile (i.e., other health conditions, impairments, or contextual factors) that place the individual at an increased risk of disability. Identifying these factors allows the therapist to implement a prevention program. Three major types of prevention include[9]

- *Primary prevention*, which is the prevention of disease in a susceptible or potentially susceptible population through specific measures such as general health promotion efforts,
- *Secondary prevention*, which includes efforts to decrease duration of illness, severity of disease, and sequelae through early diagnosis and prompt intervention, and
- *Tertiary prevention*, which includes efforts to decrease the degree of disability and promote rehabilitation and restoration of function in patients with chronic and irreversible diseases.

Therapeutic exercise as an intervention intends to promote primary, secondary, and tertiary prevention as well as health, wellness, and fitness. Prevention, health, wellness, and fitness must be considered critical foundational concepts of therapeutic exercise intervention (see Chapter 4).

SUMMARY

The model of **function and disabilities** (see Fig. 1-3) exhibits the complexity of the relationships among health conditions, impairments, activity limitations, participation restriction, contextual factors, interventions, quality of life, and prevention, wellness, and fitness. A practitioner's understanding of this model is critical to developing a therapeutic exercise program that is effective, efficient, and meaningful for the individual seeking physical therapist services. The amount of data that can be collected during an initial examination or evaluation of an individual can be immense and oftentimes overwhelming. This model allows the physical therapist to organize data pertaining to the patient's impairments, activity limitations, and participation restrictions. It also allows the physical therapist to categorize pertinent aspects of the patient's history, the effect of prior treatment, and the presence of contextual factors. Most important, the clinical presentation can be classified in a way that identifies the impairments impeding the performance of certain functional tasks and activities, thereby focusing the treatment on only those impairments directly related to activity limitation and participation restriction. It also enables the practitioner to clarify contextual factors and interventions that may serve as impediments to improved functional performance, reduced disability, and improved quality of life, thereby serving the role of prevention and promoting health, wellness, and fitness. With this analysis, the practitioner can develop goals that are relevant to the individual's daily life and promote health, wellness, and fitness at any level of ability.

KEY POINTS

- Physical therapists examine patients with impairments, activity limitations, and participation restrictions or other health-related conditions to determine a diagnosis, prognosis, and intervention.
- Physical therapists are involved in alleviating and preventing impairments, activity limitations, and participation restrictions by designing, implementing, and modifying therapeutic interventions.
- Therapeutic exercise intervention engages the individual to become an active participant in the treatment plan.
- Therapeutic exercise should be a core intervention in most physical therapist treatment plans.
- As the health care industry continues to change, the practitioner must recognize that the third-party reimburser for medical care is seeking health care services that are efficient and cost-effective. Prudent use of therapeutic exercise can reduce health care costs by promoting patient independence and self-responsibility.
- A thorough understanding of the process of functioning and disability can assist the practitioner in developing an effective, efficient, and cost-contained therapeutic exercise intervention, meaningful to the person seeking physical therapist services.

CRITICAL THINKING QUESTIONS

Develop a case defining each feature of the physical therapist model of functioning and disability. Given a patient with low back pain, provide a probable history of the condition. Include a brief description of each of the following features:

- Contextual factors
- Health condition
- Impairments (structural, physiologic)
- Activity limitations
- Performance restriction
- Secondary conditions
- Previous interventions (intraindividual, extraindividual, and exacerbators)

How would these elements change if the patient was of a different age, had a different lifestyle, or a different occupation?

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CHAPTER

2 Patient Management

CARRIE M. HALL

The physical therapist is responsible for evaluating and managing an individual's movement system across the life span to promote optimal development; diagnose impairments, activity limitations, and participation restrictions; and provide interventions targeted at preventing or ameliorating activity limitations and participation restrictions.[1]

A clear understanding of the International Classification of Functioning, Disability and Health (ICF) system presented in Chapter 1 enables the clinician to provide optimal patient management by understanding the relationships between movement, body function and structure, functional abilities, and activity participation in the expected environments. Knowledge of the ICF system enables the clinician to

- Develop comprehensive yet efficient examinations and evaluations of impairments and activity limitations relating to the patient's unique participation limitations and environmental and personal factors.
- Reach an accurate diagnosis based on logical classification of pathology, impairments, functional abilities, and participation restrictions.
- Develop a prognosis based on the evaluation and the patient's unique profile.
- Create and implement effective and efficient interventions.
- Reach a desirable functional outcome for the patient (patient experience), promoting fitness, health, and wellness (population health), with effective and efficient service delivery (low cost). This is called the "triple aim" in health care[2] (**Fig. 2-1**).

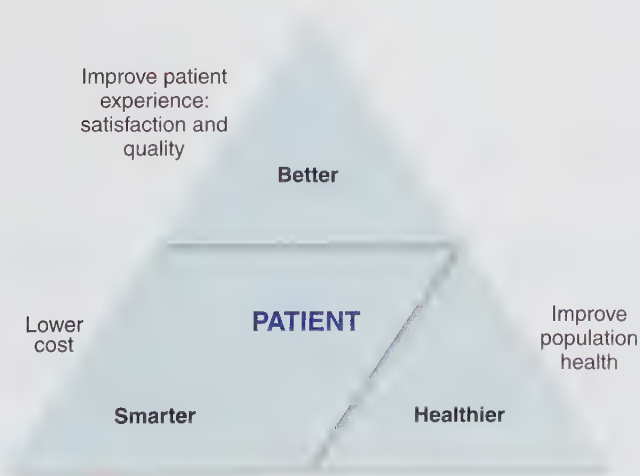


FIGURE 2-1 Triple aim.

Each patient presents with unique anatomic, physiologic, kinesiologic, psychological, and environmental characteristics. Consideration of all these variables is necessary to develop an effective plan of care, but it can be overwhelming, even for the experienced clinician. This chapter presents visual models to assist the clinician in the organization of data and the clinical decision-making process that necessitates development of an effective and efficient therapeutic exercise intervention.

PATIENT MANAGEMENT MODEL

The physical therapist's approach to patient management contains five main elements (**Fig. 2-2**). These five elements of care are integrated in a manner designed to maximize the patient's outcome, which may be conceptualized as patient related (e.g., patient experience) or associated with service delivery (e.g., low cost).

Patient and client management (**Fig. 2-3**) is an ongoing, iterative process that focuses on the evolving needs of each individual. Physical therapists apply the process of patient and client management to rehabilitate, habilitate, maintain health or function, prevent functional decline, and, in healthy individuals, enhance performance.

Examination

Examination is required before the initial intervention and is performed for all patients/clients.

The physical therapist's examination includes:

- **History** (including symptom investigation and review of systems; see **Display 2-1**)
- **Systems review** (a limited examination of the musculoskeletal, neuromuscular, cardiovascular/pulmonary, and integumentary systems)
- **Tests and measures**

Physical therapists conduct a history, perform a systems review, and use tests and measures in order to describe and/or

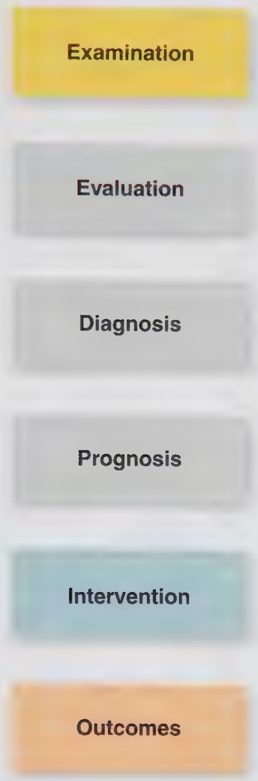


FIGURE 2-2 Patient management model.

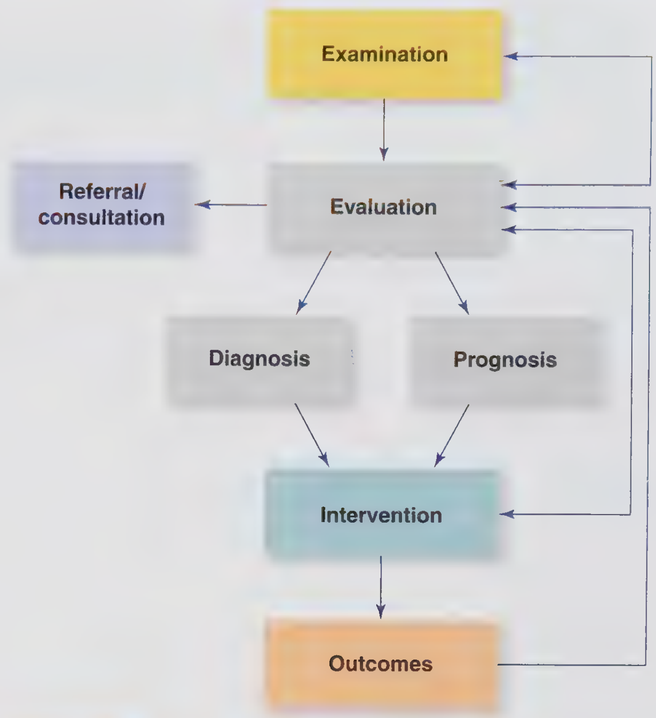


FIGURE 2-3 Process of physical therapy patient and client management.

quantify an individual's need for services. The physical therapist has the responsibility to determine if there is sufficient information to:

- Conclude whether the individual would benefit from physical therapy
- Develop the plan of care
- Progress the plan of care based on the individual's response to intervention

History

The history is a systematic gathering of data—from the past and the present—related to why the individual is seeking the services of the physical therapist. These data can be obtained from the patient, family, significant others, caregivers, and other interested persons through interview or self-report forms, by consulting with other members of the health care team, and by reviewing the medical record. Display 2-1 summarizes the data generated from the history.

Systems Review

During the history-gathering phase, physical therapists also seek information about all major body systems to determine whether there are symptoms that suggest the need for referral for additional medical evaluation. **Display 2-2** summarizes the data generated from a systems review. Reports related to the individual's overall physical (e.g., unexplained weight change, fatigue/lethargy/malaise) and emotional (e.g., anxiety, feelings of hopelessness) well-being are also noted.

Tests and Measures

Tests and measures are the means of gathering data about the individual. Physical therapists use tests and measures to rule in or rule out causes of impairment in body structures and functions, activity limitations, and participation restrictions.

The tests and measures performed as part of an initial examination should be only those that are necessary to (1) confirm or reject a hypothesis about the factors that contribute to making the individual's current level of function less than optimal and (2) support the physical therapist's clinical judgments about the diagnosis, prognosis, and plan of care.

Before, during, and after administering the tests and measures, physical therapists gauge responses, assess physical status, and obtain a more specific understanding of the condition and the diagnostic and therapeutic requirements.

The physical therapist may decide to use one, more than one, or portions of several specific tests and measures as part of the examination, based on the purpose of the visit, the complexity of the condition, and the directions taken in the clinical decision-making process.

Implementation of the examination is based on a prioritized order of tests and measures that depend on medical safety, patient comfort, and medical treatment priorities; the patient's physiologic, emotional, functional, social, and vocational needs; and financial resources. The tests and measures used by physical therapists are organized into 26 categories. Several tests from one category may be performed, whereas the physical therapist may conclude that no tests from another category are indicated (**Table 2-1**).[3]

DISPLAY 2-1

Data Generated from Client History

General Demographics

- Age
- Gender
- Race
- Primary language

Social History

- Cultural beliefs and behaviors
- Family and caregiver resources
- Social interactions, social activities, and support systems

Occupation

- Current or prior work (e.g., job, school, and play) or community activities

Growth and Development

- Hand and foot dominance
- Developmental history

Living Environment

- Living environment and community characteristics
- Projected discharge destination(s)

History of Present Condition

- Concerns that led the individual to seek the services of a physical therapist
- Concerns or needs of the individual requiring the services of a physical therapist
- Onset and pattern of symptoms
- Mechanism(s) of injury or disease, including date of onset and course of events
- Patient's, family's, or caregiver's perceptions of the patient's emotional response to the present clinical situation
- Current and prior therapeutic interventions

Functional Status and Level of Activity

- Prior functional status, and self-care and home management (i.e., activities of daily living [ADLs] and instrumental ADLs)
- Behavioral health risks
- Sleep patterns and positions
- Patient's, family's, or caregiver's functional goals for the therapeutic intervention

Medications

- Current medication list (include dosage information and reason for taking)

Other Tests and Measures

- Review of available records
- Imaging and laboratory test results

Medical or Surgical History

- Endocrine/metabolic
- Gastrointestinal
- Genitourinary
- Pregnancy, delivery, and postpartum
- Prior hospitalizations, surgeries, and preexisting medical and other health-related conditions

Family History

- Familial health risks

Social Habits (Past and Present)

- Level of physical fitness (self-care, home management, community, and work [e.g., job, school, and play] and leisure activities)
- Smoking, alcohol, drug habits

American Physical Therapy Association Board of Directors. Guidelines: Physical Therapy Documentation of Patient/Client Management (BODG03-05-16-41). Available at: http://www.apta.org/uploadedFiles/APTAorg/About_Us/Policies/Practice/DocumentationPatientClientManagement.pdf#search=%22physical%20therapy%20documentation%20of%20patient%20client%20management%22 last updated 05/19/14. Accessed 12/01/2016.

DISPLAY 2-2

Systems Review Data[3]

The systems review includes the following:

- Cardiopulmonary: assessment of heart rate, respiratory rate, blood pressure, and edema
- Musculoskeletal: gross symmetry, gross ROM, gross strength, BMI
- Neuromuscular: gross coordinated movement (e.g., balance, locomotion, transfers, transitions)
- Integumentary: skin integrity, skin color, presence of scar formation
- Communication ability, affect, cognition, language, and learning style: includes the assessment of the ability to make needs known, consciousness, orientation × 3 (person, place, and time), expected emotional/behavioral responses, and learning preferences (e.g., learning barriers, educational needs)

Other information may be required to complete the examination process such as clinical findings of other health care professionals, results of diagnostic imaging, clinical laboratory, and electrophysiologic studies or information from the patient's place of work regarding ergonomic, posture, and movement requirements.

The examination is an ongoing process throughout the patient's treatment to determine the patient's response to intervention. Based on reexamination findings (e.g., new clinical symptoms or failure to respond in the expected manner to the intervention), the intervention may be terminated or modified. Exercise modification is discussed later in this chapter.

Evaluation

Evaluation is the process by which physical therapists:

- Make judgments based on data gathered during the examination
- Interpret the individual's response to tests and measures

TABLE 2-1

Physical Therapy Examinations

- Aerobic capacity/endurance
- Anthropometric characteristics
- Assistive technology
- Balance
- Circulation (arterial, venous, lymphatic)
- Community, social, and civic life
- Cranial and peripheral nerve integrity
- Education life
- Environmental factors
- Gait
- Integumentary integrity
- Joint integrity and mobility
- Mental functions
- Mobility (including locomotion)
- Motor function
- Muscle performance (including strength, power, endurance, and length)
- Neuromotor development and sensory processing
- Pain
- Posture
- Range of motion
- Reflex integrity
- Self-care and domestic life
- Sensory integrity
- Skeletal integrity
- Ventilation and respiration
- Work life

- Integrate the test and measure data with other information collected during the history
- Determine a diagnosis amenable to physical therapist management
- Determine a prognosis, including goals for physical therapist management
- Develop a plan of care

Interpretation of the examination findings is one of the most critical stages in clinical decision-making. In interpreting the data to understand the sources (pathoanatomic) or causes (pathomechanic) of the patient's impairments in body structure or function, limitations in activities, restriction in participation, and environmental barriers, all aspects of the examination must be considered and analyzed to determine the following:

- Progression and stage of the signs and symptoms
- Stability of the condition
- Presence of preexisting conditions (i.e., comorbidities)
- Relationships among involved systems and sites

To remain consistent with the language of the ICF and to link the physical therapy patient management model with the ICF model (see Table 1-3), the following sections provide the reader with examples of examinations and evaluations for each element of the ICF model.

Health Condition (Disorder/Disease/Injury/Trauma)

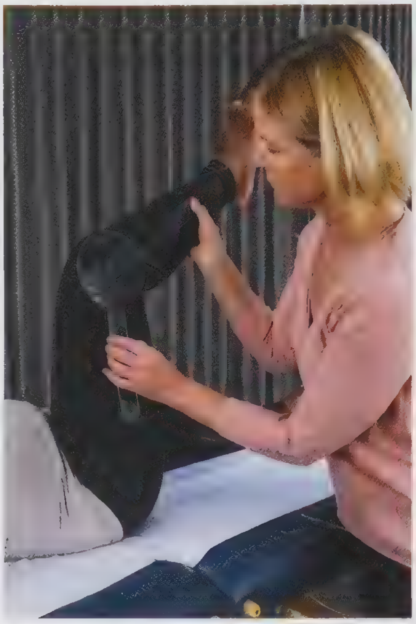
Laboratory tests, imaging studies, and electrophysiologic studies are used to assess the presence and extent of the pathologic process at the organ, tissue, or cellular level. Because some biochemical and physiologic abnormalities may be beyond the scope of medical testing, detection often relies on the examination/evaluation of impairments. One of the frustrations for physical therapists is that underlying pathology associated with the impairments in body function or structure cannot be accurately identified. Imaging, laboratory, or electrophysiologic study results can be negative despite the presence of clinical signs and symptoms (low sensitivity) or positive in the absence of the pathology (low specificity). However, the lack of an identifiable pathology or disease state should not lead the physical therapist to believe that an organic reason for the individual's impairments in body function or structure, activity limitations, or participation restrictions is not present. Even with a diagnosis of pathology or disease, the physical therapist should concentrate on examination and evaluation of impairments in body function and structure, activity and participation levels, and environmental accessibility, because the pathoanatomic or pathophysiologic diagnosis cannot, in and of itself, guide the physical therapist's intervention.

Impairments in Body Function and Structure

Medical procedures to evaluate impairments in body function and structure include clinical examinations, laboratory studies, electrophysiologic studies, imaging procedures, and the patient's medical history and symptom reports. Physical therapy procedures to examine and evaluate impairments should be based on bodily systems most treated by physical therapists including the musculoskeletal, neuromuscular, cardiovascular, pulmonary, and integumentary systems (see **Fig. 2-4**). Many bodily systems are not within the scope of thorough and definitive examination by a physical therapist (e.g., metabolic, renal, and gastrointestinal). However, if pertinent to the physical therapy intervention, this information should be gathered from the patient, other health care professionals, or medical records.

Examinations may reveal a list of impairments that may or may not be amenable to physical therapy treatment. It is tempting to evaluate and treat lists of impairments, but this type of practice may not be the most effective or efficient use of health care dollars. It is therefore prudent to make simultaneous decisions about whether testing or measuring an impairment is pertinent to determining the cause(s) of the activity limitation and participation restriction. To facilitate this decision-making process, ask the following questions:

- **Is the impairment related directly to a limitation in activity level or restriction in participation?** For example, reduced thoracic or hip rotation ROM may be related to low back pain, even though it is not in the region of complaint.
- **Is the impairment a secondary condition of the primary pathology or impairment?** For example, a patient has complaints of shoulder pain and loss of mobility (i.e., physiologic impairments) resulting in reduced function of the upper extremity for ADLs (i.e., activity limitation) and subsequently restriction in sports or recreational activities (i.e., participation restriction). However, the source of the shoulder pain is cervical disk disease (i.e., primary pathology). Loss of mobility of the shoulder is a secondary impairment, and reduced use of the upper extremity during ADLs and sports is a secondary limitation/restriction, both of which developed because of pain in the shoulder originating from the primary condition of cervical degenerative disk disease.




A B

FIGURE 2-4 **(A)** Measurement of ROM and muscle length impairment. The patient shows signs of limited hamstring extensibility. **(B)** Measurement of aerobic capacity impairment. The clinician takes the patient's blood pressure.

- **Can the impairment be related to future limitations in activity or participation restrictions?** Studies have shown that a relationship can exist between current impairment findings and future activity limitations.[4,5] For example, loss of shoulder ROM in the absence of ADL limitation may lead to limitation in the future from exaggeration of the impairment or lead to other impairments, such as neck-related impairments.
- **Is the impairment unrelated to the activity limitation, participation restriction, or environmental barrier and therefore should not be assessed or treated?** For example, a patient complains of shoulder pain and reduced use of the shoulder girdle during ADLs. Hypomobility of the shoulder girdle may be an obvious impairment, but it may not be related to the activity limitation. The patient's pain may occur in the midrange, limiting activity at chest height vs. overhead activity.

In summary, not all impairments result in activity limitation, and not all activity limitations result in participation restriction. In theory, interventions should target only those impairments that will ultimately affect function and reduce the potential for participation restriction. Indeed, it has been suggested that through the examination process, the clinician determines the interactions between impairments, activity limitation, participation restriction, and environmental barriers for a patient with a given diagnosis and that this information then guides treatment.[6] Examples of cervical spine **impairments** include reduced range of cervical spine motion and decreased segmental joint mobility, whereas an **activity limitation** might be inability to rotate the head and neck sufficiently to be able to see behind. A **participation restriction** results when this occurs while driving an automobile in reverse. If an individual is then unable to work because his or her occupation requires automobile use that person has **environmental barriers.**

Activity Limitation and Participation Restriction

Patients ultimately seek the services of a physical therapist typically because impairments and functional limitations result in participation restriction. For example, the patient is probably more concerned about his or her ability to climb the flight of stairs to enter his or her office (i.e., participation) than the adequate knee ROM and quadriceps force or torque production needed to climb the stairs (i.e., physiologic impairment). Furthermore, improved knee ROM and quadriceps torque production may not result in the ability to climb a flight of stairs. The inability to climb stairs may be related to other impairments, such as weak gluteal musculature, lack of ankle mobility, or psychological impairment (e.g., fear, confidence).

One question must be addressed in daily practice and in physical therapy research, "Which and to what degree are impairments in body function and structure linked to activity limitations and participation restriction?" Many studies are attempting to establish the relationships among pathology/disease, impairments, activity limitations, and participation restriction because this question is clinically important to physical therapists (**Evidence and Research 2-1**).

EVIDENCE and RESEARCH 2-1

Information gained from a descriptive study of individuals with arthritis indicates correlations between pathology (i.e., arthritis), impairments (i.e., knee ROM, pain and joint stiffness, and reduced muscle performance), and activity limitations (i.e., performing ADLs including getting down to and up from the floor and ascending/descending stairs).[7] This study indicates that quadriceps muscle performance, joint pain during the activity, perceptions of functional ability, and body weight combined can predict between 39% and 56% of the variance in time to perform four functional tasks in adults with osteoarthritis of the knee. These findings appear to indicate that interventions that improve quadriceps muscle performance, reduce joint pain and body weight, and facilitate perceptions of functional ability may have a positive impact on the ability to get down to and up from the floor and ascend/descend stairs in adults with osteoarthritis of the knee.

In order for investigators to generate meaningful research of disability, valid and reliable measurement tools must be utilized. Measurement of disability requires tests that consider the complexity of variables that affect the person's ability to interact in society. With standardized tests, no single assessment instrument can measure the full range of potential impairments, activity limitations, or participation restrictions. Adequate evaluation usually must rely on a battery of appropriate instruments. It is beyond the scope of this text to discuss the various standardized tests, but a literature search on the specific population you are testing can offer explicit tests and measures for your desired purpose.[8–19]

Tests and measures of function and disability have various formats:

- *Self-reports or proxy reports*
  The standard and most economic procedure for measuring disability is self-reports or proxy reports,[20,21] which include simple ordinal or interval scoring of the degree of difficulty in performing roles within the person's milieu.[18,22–30] Self-reports are increasingly required for third-party reimbursement and are mandated by the Centers for Medicare and Medicaid Services (CMS; available at: http://www.cms.gov/Outreach-and-Education/Medicare-Learning-Network-MLN/MLNMattersArticles/Downloads/SE1307.pdf. Accessed February 10, 2015).
- *Observation and scoring of performance of functional tasks*
  Observation of performance of functional tasks, rating the level of difficulty (e.g., fully able, partially able, and unable), such as measuring distances, weight lifted, number of repetitions, or quality of motion based on kinesiologic standards.[22]
- *Clinical tests of physical mobility*
  Timed walking tests and movement batteries[31–33]
- *Equipment-based evaluation of performance*
  Use of a hand dynamometer to examine grip strength, computer-assisted assessment of balance, use of specialized grids to measure performance of closed chain activities.[23–25,34,35]

Results of a disability measure often reveal aspects of the disability that are beyond physical impairments and activity limitations. In some cases, aspects of an individual's disability are beyond the knowledge, expertise, or experience of the PT, in which case the patient should be referred to the appropriate health care professional. A simultaneous decision must be made as to whether further physical therapy intervention is appropriate or if physical therapy should be deferred until other aspects of disability are adequately managed. For example, a patient with low back pain may have a high level of anxiety or depression associated with the loss of function and the disability. Physical therapy may not be effective until the patient is treated for the anxiety or depression, or physical therapy concurrent with counseling may be determined to be most effective.

Diagnosis

In 1982, the House of Delegates stipulated that physical therapists must establish a diagnosis (American Physical Therapy Association. Diagnosis by physical therapists. Available at: http://www.apta.org.offcampus.lib.washington.edu/uploadedFiles/APTAorg/About_Us/Policies/Practice/Diagnosis.pdf. Updated August 22, 2012, Accessed February 2015). Diagnosis is the process and end result of information obtained in the examination and evaluation. The diagnostic process includes analyzing the information obtained in the examination and evaluation and organizing it into clusters, syndromes, or categories (see **Display 2-3** for definition of terms) to help determine the most appropriate intervention strategy for each patient. The diagnostic process includes the following components[3]:

- Obtaining a relevant history (i.e., examination)
- Performing a systems review (i.e., examination)
- Selecting and administering specific tests and measures (i.e., examination)
- Interpreting all data (i.e., evaluation)
- Organizing all data into a cluster, syndrome, or category (i.e., diagnosis)

The end result of the diagnostic process is establishing a diagnosis. To reach an appropriate diagnosis, additional information may need to be obtained from other health care professionals. In the event that the diagnostic process does not yield an identifiable cluster, syndrome, or category, intervention may be guided by the reduction of impairments and restoring activity and participation levels.

Diagnosis in the physical therapy patient management model is synonymous with the term clinical classification and is not to be confused with the term medical diagnosis.[36] Medical diagnosis is the identification of a patient's pathology or disease by its signs, symptoms, and data collected from tests ordered by the physician. Diagnosis established by a physical therapist is related to the primary dysfunction toward which the physical therapist directs treatment.[36–38] The ability to diagnose clusters, syndromes, or categories can foster the development of efficient treatment interventions and facilitate reliable outcomes research to present to the public, medical community, and third-party payers.

A common medical diagnosis of patients referred to outpatient physical therapy practices is low back pain, which is nothing more than a location of pain. If an outcomes study was performed that included all patients with the diagnosis of low back pain in a given practice, the results would not shed light on the best approach for treating low back pain because of the diverse pathoanatomic sources, pathomechanic causes, stages and severity of the condition, and comorbidities involved. Subclassification of patients based on diagnostic classification paradigms is necessary to provide more efficient patient management strategies and more meaningful outcome data.

DISPLAY 2-3
Definitions of Terms

Cluster: A set of observations or data that frequently occur as a group for a single patient.

Syndrome: An aggregate of signs and symptoms that characterize a given disease or condition.

Diagnosis: A label encompassing a cluster of signs and symptoms commonly associated with a disorder, syndrome, or category of impairment, activity limitation, or disability.

Adapted from American Physical Therapy Association. A guide to physical therapist practice, I: a description of patient management. Phys Ther 1995;75:749–756.

Medical diagnosis (e.g., herniated nucleus pulposus, spondylolisthesis) may not be helpful in directing successful rehabilitation of patients with low back pain.[39] The medical diagnosis, in most cases, does not provide the physical therapist with enough information to proceed with intervention, as the medical diagnosis does not provide any information related to the patient's impairments, limitations in activities, or restriction in participation. The diagnosis made by a physical therapist is reached only after performing a thorough examination and evaluation combined, if necessary, with the results of tests and measures ordered and performed by professionals from other disciplines combined with the medical diagnosis.

While medicine has had hundreds of years to refine diagnostic categories, physical therapy is in the early stages of developing diagnostic classifications. After classifications are developed, much work regarding validity, reliability, and sensitivity of diagnostic classifications needs to be done.

The interaction of these four components results in "diagnostic disablement."[40]

The first step toward agreement regarding diagnostic classifications is to standardize the language that physical therapists use to diagnose conditions within their scope of practice. Leaders in the field of physical therapy are working toward this common language (available at: https://dxdialog.wusm.wustl.edu/Pages/WelcomeDxDialog.aspx. Accessed February 17, 2015). The goal is to be able to one day correlate effective and efficient treatment with the clinical diagnosis made by physical therapists to establish more efficient and cost-effective outcomes.[36–47] Only then can physical therapists promote the efficacy of the profession in today's responsibility-focused health care environment.

Prognosis and Plan of Care

After a diagnosis has been established, the physical therapist determines the prognosis and develops the plan of care. Prognosis is the process of determining the level of optimal improvement that may be obtained from intervention, and the amount of time required to reach that level.[3] For example, an expected short-term outcome for an otherwise healthy 65-year-old person after a hip fracture treated with open reduction and internal fixation may be the ability to walk 300 ft with partial weight-bearing, using a walker, in 3 days; an expected long-term outcome may be the ability to walk independently without a gait deviation in 12 to 16 weeks.

The plan of care consists of statements that specify the interventions to be used and the proposed duration and frequency of the interventions that are required to reach the anticipated goals and expected outcomes.[3] The plan of care is the culmination of the examination, diagnostic, and prognostic processes.

The prognosis and plan of care should be based on the following factors:

- The patient's health status, risk factors, and response to previous interventions
- The patient's safety, needs, and goals
- The natural history and the expected clinical course of the pathology, impairment, or diagnosis
- The results of the examination, evaluation, and diagnostic processes

To ensure that the prognosis and plan of care are based on the patient's safety, needs, and goals, the physical therapist should confer with the patient.[48] During this discussion, the patient must be informed of the diagnosis or prioritized impairment list if a diagnosis cannot be developed. The patient should also be provided with an explanation of the relationship between the diagnosis or impairments and the activity limitations and participation restrictions. This information can assist the patient in developing realistic goals and understanding the purpose of the selected interventions, which may ultimately increase compliance. Agreement between the patient and therapist on the long-term and short-term goals is imperative for successful treatment outcomes. When the physical therapist determines that physical therapy intervention is unlikely to be beneficial, the reasons should be discussed with the patient and other individuals concerned and documented in the medical record.

The prognosis and plan of care are based on the natural history and the expected clinical courses of the pathology, disease, or disorder based on the most current evidence, including literature reviews, research articles, evidence-based clinical practice guidelines, and clinical experience.[49] Following these steps can assist the clinician in developing a sound prognosis and plan of care based on finding the best evidence available in a practical time frame (**Evidence and Research 2-2**).

EVIDENCE and RESEARCH 2-2

Straus succinctly outlined the steps necessary to practice evidence-based patient management in her 1998 article[49]:

- Convert the need for information into clinically relevant, answerable questions
- Find, in the most efficient way, the best evidence with which to answer these questions (whether this evidence comes from clinical examination, published research, medical tests, or other sources)
- Critically appraise the evidence for its validity (closeness to the truth) and usefulness (clinical applicability)
- Integrate the appraisal with clinical expertise and apply the results to clinical practice
- Evaluate your performance

Intervention

Intervention is defined as the purposeful and skilled interaction of the physical therapist with the patient using various methods and techniques to produce changes in the patient's condition consistent with the evaluation, diagnosis, and prognosis.[3] Ongoing decisions regarding intervention are contingent on the timely monitoring of the patient's response to treatment and the progress made toward achieving outcomes. The three major types of intervention are listed in **Display 2-4**. This text focuses on one aspect of direct intervention (i.e., therapeutic exercise) and patient-related instruction as it relates to therapeutic exercise.

The key to a successful intervention and patient outcome is to *do the right things well*.[50] To determine the *right things*, the physical therapist must have a thorough understanding of the patient's activity limitation/participation restriction profile and sound clinical decision-making skills.

DISPLAY 2-4

Types of Physical Therapy Interventions

- Direct intervention (e.g., therapeutic exercise, manual therapy techniques, integumentary repair and protection techniques, motor function training)
- Patient-related instruction (e.g., education provided to the patient and other caregivers involved regarding the patient's condition, treatment plan, information and training in maintenance, and prevention activities)
- Coordination, communication, and documentation (e.g., electronic medical record, patient care conferences)

Clinical Decision-Making for Intervention

The physical therapist is educated and trained to effectively and efficiently treat impairments in body function or structure related to activity limitations and participation restrictions in order to arrive at desirable functional outcomes for the patient. In designing the plan of care, the physical therapist analyzes and integrates the clinical implications of the severity, complexity, and acuity of pathology, disease, or disorder; the extent of the impairment of body function and structure; the types of activities and participations and the environment to which the person wishes to return. Recall that the ultimate functional goal of physical therapy is the achievement of optimal movement and functioning in the activities and participations that are unique to the individual. Physical therapists generally develop treatment interventions with the intention of restoring function and improving participation in desired activities. However, strictly impairment-based interventions often do not achieve functional goals because the focus may not be on the right impairment.

Treating the "Right" Impairments An important clinical decision in the patient management process is to determine the impairment that most closely relates to an activity limitation or participation restriction. Physical therapists are often tempted to include impairments that are not relevant because they assume that the reduction of any or all impairments leads directly to improvement in function.[51] In reality, the treatment of impairments can only lead to improvement in function if the impairments contribute directly to a limitation in activity.

If an impairment seems to be linked to an activity limitation or participation restriction, the therapist must question whether the impairment is amenable to physical therapy intervention. To help determine the answer, the physical therapist should ask several questions:

- Will the patient benefit from the intervention (i.e., can treatment of the impairment improve functioning or prevent functional loss)?
- Are there any possible negative effects of the treatment (contraindications)?
- What is the cost–benefit ratio?

If it is determined that no treatment can be justified, the physical therapist should consider other options such as the following:

- Discussing the decision to decline intervention with the patient to ensure patient agreement and understanding of the decision
- Referring the patient to an appropriate practitioner or resource
- Assisting in modifying the environment in which the individual lives, goes to school, or works to ensure maximal performance despite the impairment, activity limitation, or participation restriction
- Teaching the individual to appropriately compensate for the impairment during activities or participation in more complex social roles

If the impairment is amenable to treatment, decide whether to treat the impairment, activity limitation, or both. **Building Block 2-1** illustrates this point.

BUILDING BLOCK 2-1

Consider a 72-year-old man 4 weeks s/p total knee replacement. He presents with weakness of the quadriceps and reduced flexion ROM of the knee. Would you choose to treat the impairments with specific exercise instruction to increase quadriceps muscle performance and tibiofemoral joint mobility or teach the patient the functional task of sit to stand? Please defend your answer.

Selecting and Justifying Treatment Interventions After a decision has been made to treat a specific impairment or activity limitation, the next step is to select an appropriate intervention or combination of interventions with the proper sequencing (e.g., moist heat before joint mobilization, which is followed by stretching the short or stiff tissue and strengthening the antagonist, ending with a functional task that employs the new mobility).

Physical therapists may select interventions from among the following possibilities[3]:

- Airway clearance techniques
- Assistive technology: prescription, application, and, as appropriate, fabrication or modification
- Biophysical agents
- Functional training in self-care and in domestic, education, work, community, social, and civic life
- Integumentary repair and protection techniques
- Manual therapy techniques
- Motor function training
- Therapeutic exercise

Numerous patient factors must be taken into consideration to determine which of the described interventions are appropriate. This information is obtained from the history and systems review (see Displays 2-1 and 2-2). An awareness of the patient's physical environment for living and/or working, or the recreational activities to which the patient wishes to return is important in developing patient-centered interventions and achieving functional outcomes. For example, a successful outcome may not be reflected in increased strength in the quadriceps measured by a hand-held dynamometer, but may be observed in the use of that strength in a functional manner in the patient's environment, such as walking up a flight of stairs with 20 lb of groceries.

The process of selecting and justifying treatment intervention must be based on the integration of research evidence, clinical expertise, and patient values, called "evidence-based medicine (EBM)."[52] EBM aims to improve health care outcomes by balancing findings from research with clinical experience and patient/family preferences. The Internet has greatly increased the ease with which many clinicians can access and rapidly sort research evidence. Of the numerous databases available, a few are particularly relevant to physical therapy. PubMed is probably the best known database. It is maintained by the National Library of Medicine and is free to the public at www.ncbi.nlm.nih.gov/PubMed. The American Physical Therapy Association's (APTA) PTNow provides access to several databases and health care literature from ProQuest, Joanna Briggs Institute, and the Cochrane Library. More information can be accessed at http://www.apta.org/EvidenceResearch/Tools.

Patient-Related Instruction

Patient-related instruction is the process of imparting information and developing skills to promote independence and to allow care to continue after discharge.[3] It must be an integral part of any physical therapy intervention (**Fig. 2-5**) and will be featured in this text to enhance the therapeutic exercise intervention.

When patient education is not possible (e.g., the patient is an infant, comatose, there is a cognitive deficit or language barrier), educating family members, significant others, friends, or other caregivers is essential. Patient-related instruction offered to a support person, even when educating the patient is possible, can promote compliance by teaching the support person to intervene in an appropriate manner and encouraging the display of appropriate attitudes toward the patient's activity limitations and disabilities.

Patient-related instruction is critical to enhance compliance in following through with interventions and preventing future limitations in activity or restrictions in participation. Imparting your knowledge of the patient's function/disability process enables the patient to gain confidence in your skills, which further enhances compliance. Patient-related instruction may include the following:

- Education pertaining to the
  - Pathologic process and impairments contributing to activity limitation and participation restriction
  - Prognosis
  - Purposes and potential complications of the intervention
- Instruction and assistance in making appropriate decisions about management of the condition during ADLs (e.g., workstation ergonomic modifications, altered movement patterns and body mechanics, and altered sleep postures)
- Instruction and assistance in implementing interventions under the direction of the physical therapist (e.g., training a support person in techniques of therapeutic exercise in the event that cognitive, physical, or resource status of the patient requires assistance to perform a home management program)

FIGURE 2-5 Patient-related instruction is an integral part of physical therapy intervention. By helping the patient understand her impairment and activity limitations, the clinician promotes patient compliance with the therapeutic intervention program. In addition, patient satisfaction is promoted by taking the time to educate the patient regarding the cause(s) of his condition, self-management techniques, and prevention.

Patient-related instruction confers several benefits that promote the triple aim in health care (patient satisfaction, healthy population, low cost):

- Increased patient, significant other, family, and caregiver knowledge about the patient's condition, prognosis, and management
- Acquisition of behaviors that foster healthy habits, wellness, and prevention
- Improved levels of performance in employment, recreational, and sports activities
- Improved physical function, health status, and sense of well-being
- Improved safety for the patient, significant others, family, and caregivers
- Reduced participation restriction, secondary conditions, and recurrence
- Enhanced decision-making about the use of health care resources by the patient, significant others, family, or caregivers
- Decreased service use and improved cost containment

Patient-related instruction represents the first and *most important step* toward directing responsibility for treatment outcome from the physical therapist to the patient. A thorough understanding of the individual's disablement process and the factors that may impede improved functional outcome are necessary to provide comprehensive and personalized patient-related instruction. The successful practitioner is one who is skilful in the delivery of an active treatment approach based on treatment specific to the individual's profile and on education that places the patient (or caregiver) in the position of taking responsibility for the outcome.

Outcome

In the new age of collaborative care with performance-based and bundled payment systems and accountable care organizations and medical homes, physical therapists must consider themselves primary caregivers for the neuromusculoskeletal system. The physical therapist treats patients across their life span, similar to primary care physicians. Although a patient may be discontinued from an episode of care, the patient is not discharged from the care of his/her physical therapist, similar to a dental model where a patient is treated for a cavity, but never discharged from the care of the dentist. The neuromusculoskeletal system is managed with periodic "booster" sessions and the patient's physical therapist is available to manage any new conditions or injuries that occur on a timely basis, again similar to the dental model of preventive care.

As the patient/client reaches the end of the episode of care, the physical therapist measures the global outcomes of the physical therapy services by characterizing or quantifying the impact of the physical therapy interventions on the following domains[3]:

- Health condition (disorder or disease)
- Body functions/structures
- Activities
- Participation
- Risk reduction/prevention
- Health, wellness, and fitness
- Personal/environmental factors
- Patient/client satisfaction

An outcome is considered successful when the following conditions are met:

- Activity and participation is improved or maintained whenever possible.
- Activity limitation or participation restriction is minimized or slowed when the status quo cannot be maintained.
- The patient is satisfied.

At each step of the patient management process, the physical therapist considers the possible patient outcomes. This ongoing measurement of patient outcomes is based on the examination and evaluation of impairments, functional status, and level of participation restriction. To evaluate the effectiveness of the intervention, the physical therapist must select criteria to be tested (e.g., impairments and activity limitations) and interpret the results of the examination. Outcomes can be measured through outcome analysis. This is a systematic examination of patient outcomes in relation to selected patient variables (e.g., age, sex, diagnosis, interventions, and patient satisfaction). It can be part of a quality assurance program, used for economic analysis of a practice, or used to demonstrate efficacy of intervention.

Modification

On January 15, 2014, the CMS issued an update to clarify skilled nursing facility, inpatient rehabilitation facility, home health agencies, and outpatient therapy coverage requirements pursuant to the settlement agreement in the case of *Jimmo v. Sebelius*. This landmark case changed the definition of medical necessity in physical therapy from a purely restorative care to including the skilled care necessary to prevent a slow decline in a condition (available at: http://www.cms.gov/Outreach-and-Education/Medicare-Learning-Network-MLN/MLNMattersArticles/Downloads/MM8458.pdf. Accessed February 17, 2015). Positive outcomes are not synonymous with improved impairment measures, but impairments and functional status should be measured to determine the efficacy of the intervention plan. By measuring both variables, the therapist can determine whether changes in the impairment, or maintenance of status, are associated with improved, or the prevention in the decline of, functional status.[51] If functional status has not improved when expected to, or declines when maintenance was the goal, consider modifying the intervention plan. Modification of intervention is based on the status relative to the expected outcome and the rate of progress. **Display 2-5** illustrates additional factors to consider with respect to modification of an intervention.

Prudent clinical reasoning assists the clinician in determining the need for modification and the best adjustments to implement. In determining and implementing revised goals and interventions, the clinician uses the additional data gathered from the reevaluation. This reevaluation and modification process continues until the completion of the episode of care.

DISPLAY 2-5

Factors to Consider When Modifying an Intervention

- Medical safety
- Patient comfort
- Patient's level of independence with the intervention (especially related to therapeutic exercise intervention)
- Effect of the intervention on the functional activities and participation restrictions
- New or altered symptoms because of intervention by other health care providers
- Patient finances, environment, and schedule constraints

The intervention may be modified by one of the following actions:

- Increasing or decreasing the dosage of the intervention, especially in the case of therapeutic exercise intervention (see the section on "Exercise Modification" in this chapter)
- Treating different impairments
- Changing the focus to activity limitations
- Consulting or referring to a physical therapist with advanced training or certification in a content area
- Referring the patient to another health care provider specializing in a system that is beyond the PT scope of practice
- Improving physical therapy techniques, verbal cues, and teaching skills

In the current health care environment, physical therapists are faced with the challenge of practicing in an increasingly competitive marketplace. As marketplace competition continues to grow, patient satisfaction with physical therapy is emerging as an outcome variable of critical importance. The results of one study show that patient satisfaction with care is most strongly correlated with the quality of patient care–provider interactions.[53] This includes the care provider spending adequate time with the patient, demonstrating strong listening and communication skills, and offering a clear explanation of treatment and prevention strategies.

Complex reimbursement models, greater public scrutiny, and disclosure of clinical quality and patient safety performance standards are demanding a new, more equitable, and effective reimbursement model for hospitals and physician services.

The goal of APTA is to reform payment for outpatient physical therapy services to improve quality of care, recognize and promote the clinical judgment of the physical therapist, and provide policymakers and payers with an accurate payment system that ensures the integrity of medically necessary services.

The association and its collaborators developed a 3-tiered system of CPT evaluation codes to replace the previous single code that covered all physical therapist evaluations. This new system went into effect January 2017. The new CPT evaluation and reevaluation codes are a step in the right direction toward overall payment reform, and APTA continues to work with AMA and other provider groups in seeing value-based payment evolve.

DISPLAY 2-6

Patient Management Concepts

- Develop an examination or evaluation schema pertinent to the patient.
- Diagnose the patient's impairments, activity limitations, and disabilities/participation restrictions.
- Develop a prognosis based on the patient's individual disablement profile.
- Develop a plan of care designed to improve, or prevent the loss of, function (i.e., the right things).
- Apply appropriate judgment and motor treatment skills to provide the proper intervention.
- Continually use clinical reasoning to modify the intervention as needed for a positive outcome.

Now more than ever, successful patient management is vital to the growth of our profession. As discussed in detail, successful patient management entails many aspects of clinician and patient–client interaction. **Display 2-6** succinctly summarizes patient management concepts.

CLINICAL DECISION-MAKING

At each juncture in the patient management model, clinical decisions are made. Appropriate decisions are crucial for a successful outcome. However, the clinical decision-making process involved in patient management presents the greatest challenge to the physical therapist. The following aspects are found to be most difficult in the clinical decision-making process:

- Organization of evaluation findings into a diagnosis
- Development of a prognosis based on the patient's activity limitations and participation restrictions
- Development of realistic patient-based goals
- Development and implementation of an intervention that is effective and efficient

Display 2-7 summarizes clinical decision-making tips in relation to patient management to assist the physical therapist when addressing these challenges. The effectiveness of clinical decision-making is based on obtaining pertinent data. The physical therapist must possess

- Knowledge about what is pertinent
- The skill to obtain the data
- The ability to store, record, evaluate, relate, and interpret the data

These actions require knowledge of the function/disability process; clinical experience and skill in treating impairments and activity limitations; and a disciplined, systematic thought process. Common to those who strive to excel in clinical decision-making are the following characteristics:

- Wide range of knowledge
- Ongoing acquisition of knowledge
- Need for order or a plan of action
- Questioning unproven conventional solutions
- Self-discipline and persistence in work

DISPLAY 2-7

Clinical Decision-Making Tips for Patient Management

Examination: Prioritize the problems to be assessed and the tests and measures to be implemented.

Evaluation: Consider and analyze all examination findings for relationships, including the progression and stages of the symptoms, diagnostic findings by other health care professionals, comorbidities, medical history, and treatment or medications received.

Diagnosis: Segregate findings into clusters of symptoms and signs by common causes, mechanisms, and effects.

Prognosis and Plan of Care: Develop long-term and short-term goals based on patient safety, needs, and goals and on information regarding the natural history and expected clinical courses of the pathology, impairment, or diagnosis.

Intervention: Determine whether impairments correlate with an activity limitation or disability and are amenable to physical therapy treatment. Select and justify a method of intervention. The most credible source of justification is based on relevant research literature.

Outcome: Measure the success of the intervention plan according to functional gain and make appropriate modifications when necessary.

Information regarding the clinical decision-making process warrants its own text. However, this text strives to include theoretic information and pertinent issues related to clinical decision-making. This information empowers the physical therapist with some of the necessary tools to make appropriate clinical decisions regarding the design and application of treatment plans.

THERAPEUTIC EXERCISE INTERVENTION

The revised Vision Statement for APTA is as follows: "The physical therapy profession will define and promote the movement system as the foundation for optimizing movement to improve the health of society. Recognition and validation of the movement system is essential to understand the structure, function, and potential of the human body. The physical therapist will be responsible for evaluating and managing an individual's movement system across the life span to promote optimal development; diagnose impairments, activity limitations, and participation restrictions; and provide interventions targeted at preventing or ameliorating activity limitations and participation restrictions. The movement system is the core of physical therapist practice, education, and research" (available at: http://www.apta.org/Vision/. Accessed February 17, 2015). It is for this reason that therapeutic exercise is the cornerstone intervention for physical therapists.

After completion of the examination and evaluation, the development of a diagnosis and prognosis, and the relationship between the pathology, impairments, activity limitations, and participation restrictions has been established, a plan of care is determined utilizing the clinical decision-making process. Therapeutic exercise may be the basis of the intervention or

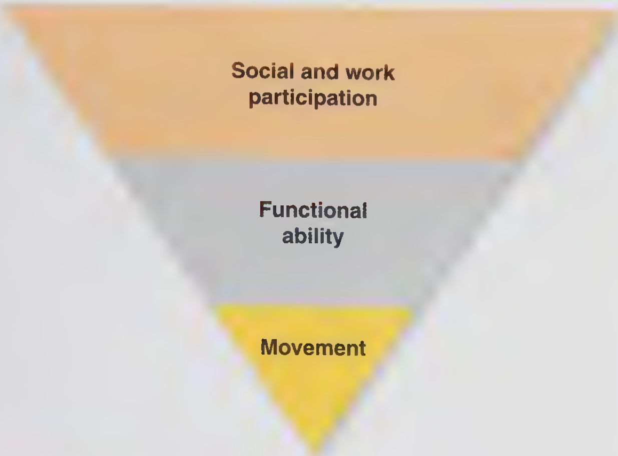


FIGURE 2-6 Movement is the foundation for functional activity and participation in social and work-related roles.

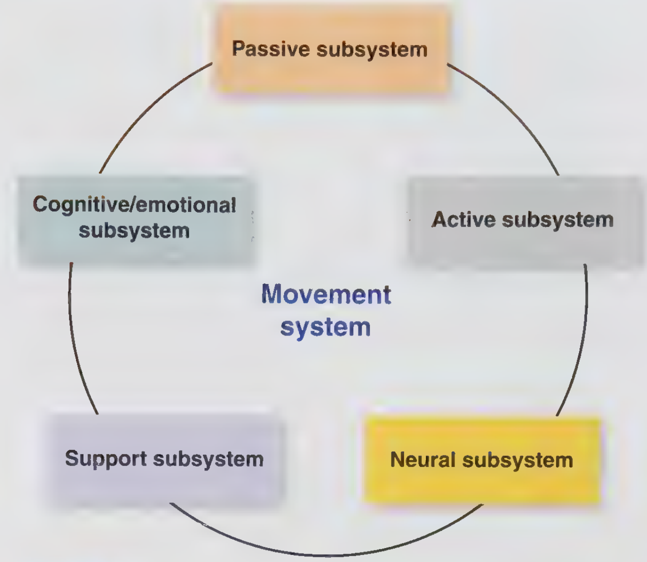


FIGURE 2-7 Model of movement system and component subsystems.

may be one component of the intervention, but it should be included to some extent in all patient care plans. Therapeutic exercise includes activities and techniques to improve physical function and health status resulting from impairments by identifying specific performance goals that allow a patient to achieve a higher functional level. It also incorporates activities to prevent loss of function in individuals where improvement is not expected, and allow well clients to improve or maintain their health or performance status and to prevent or minimize future potential functional loss or health problems.

Therapeutic Exercise Intervention Model

To prescribe the appropriate exercise, factors regarding the patient's activity limitation(s) and participation restriction(s) must be considered. Each exercise prescription has two common goals:

1. To restore functional movement as best as possible
2. To prevent or minimize functional movement loss in the future

Figure 2-6 depicts the relationship between movement, functional abilities, and participation in social and work roles. It is represented as a hierarchy in that movement is the foundation to optimal living and quality of life for all people of all ages. Movement extends beyond health to every person's ability to participate in and contribute to society. The domain of physical therapists is evaluation and treatment of the movement system. For this reason, the foundation of the intervention model is the movement system and its component subsystems.

Subsystems of the Movement System

The **movement system** is defined as:

1. A physiologic system that functions to produce motion of the whole body or of its component parts
2. The functional interaction of structures that contribute to the act of moving (http://medical-dictionary.thefreedictionary.com/movement+system. Accessed March 2015)

Figure 2-7 describes the movement system as made up of several subsystems, each of which has a unique basic function necessary for the production and regulation of movement. The optimal actions and interactions of the multiple anatomic, physiologic, and psychological systems involved in movement must be considered when prescribing therapeutic exercise. The subsystem impacts the stage of motor control, choice of activity, dosage, and specific cuing provided to the patient (see **Fig. 2-8A** and **B**).

The subsystems proposed are a hybrid of theories provided by Sahrmann, Panjabi and Lee and Lee.

The ideal movement can be thought of as the result of a complex interaction of several subsystems of the larger encompassing movement system.

- *Support subsystem:* This subsystem includes the physiologic status of the integumentary, circulatory, lymphatic, respiratory, endocrine, urinary/excretory, reproductive, and digestive systems. These systems play an indirect role in that they do not produce motion of the segments, but provide substrates and metabolic support required to maintain the viability of the other systems. Examples of components included in this element would be respiratory status (including breathing patterns) and hormonal factors.
- *Passive subsystem:* This subsystem includes the structural status of the passive properties of the neuromyofascia and capsuloligamentous, bony, and joint-related tissues (cartilage). Linking back to ICF, this includes impairments such as mobility and stability of joint function and includes tests and measures such as ROM, muscle length, and joint integrity.
- *Active subsystem:* This subsystem includes muscle contractile properties and provides the force/torque requirements for movement. ICF impairments include muscle power, tone, endurance and tests and measures such as strength, power, and endurance.
- *Neural subsystem:* This subsystem is related to motor function. ICF impairments include control over voluntary and involuntary movement functions and gait and tests and measures related to timing of muscle recruitment, muscle cessation patterns, and feed-forward and feedback systems.

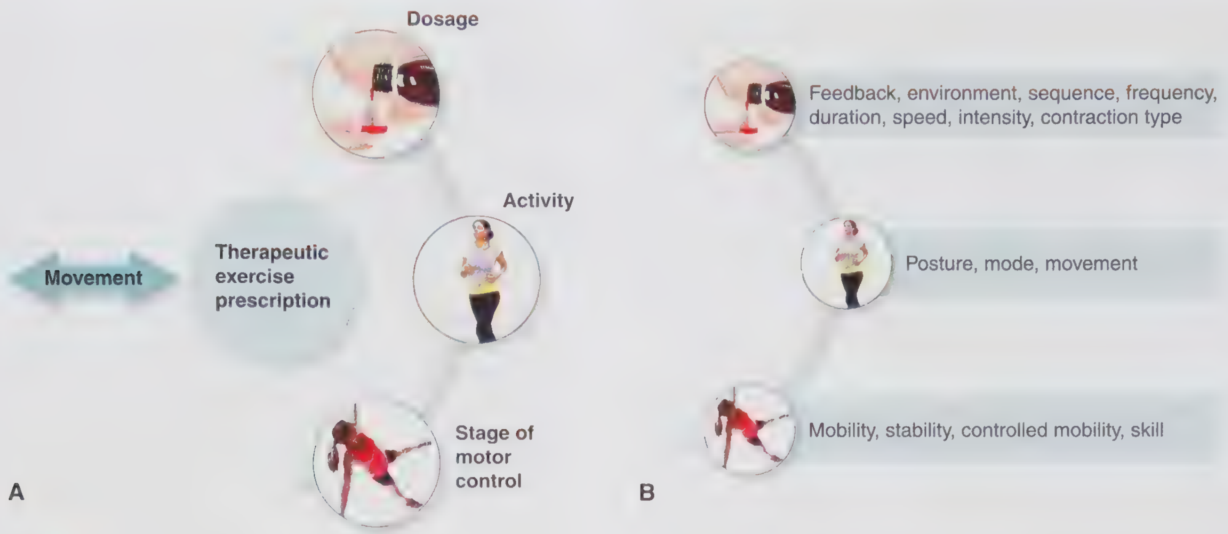


FIGURE 2-8 **(A)** and **(B)** Movement related to stage of motor control, activity, dosage.

- *Cognitive/emotional subsystem:* This subsystem includes functional status of the psychological system as it is related to movement. Components of this element include learning ability, compliance, motivation, emotional status, and processing of nociception and experience of pain.

The diagnostic process can determine the impairments that are related to the patient's activity limitations and participation restriction. To begin planning the therapeutic exercise intervention, the impairments should first be related to a subsystem of the movement system. This process not only illustrates the complex interaction of the subsystems of the movement system, but also guides the clinician toward the most appropriate stage of motor control, activities or techniques, exercise sequence, and dosage. For example, a person with knee pain with a posture impairment of genu valgum may require orthotics to influence the passive subsystem as a first priority. Changing the alignment at the knee is a prerequisite to effective active or neural subsystem training. It may then be decided that muscle performance training (active subsystem) is a prerequisite to motor control training (neural subsystem) because of the fact that the patient's strength, power, and endurance are below functional levels. Muscle performance dosage parameters are different from motor control dosage parameters (see "Dosage" in a subsequent section of this chapter).

After evaluating a patient, it may be apparent that one, a few, or all subsystems of the movement system are related to the activity limitation and participation restriction. Most often, the interaction of the subsystems is critical, but nonetheless must be prioritized. **Building Blocks 2-2** and **2-3** are provided for examples of this clinical decision-making process.

Display 2-8 lists the relationship between impairments and subsystems to the case in Building Block 2-2.

Attempts should be made to prescribe exercise that will address the complex interaction of the subsystems. For example, to restore normal shoulder girdle movement, instruction in diaphragmatic breathing (i.e., support) may be pivotal to reduce the activity (neural) of the pectoralis minor, improve thoracic spine alignment (passive), and increase thoracic spine and rib cage mobility (passive). Another example is to design an exercise that will concurrently

BUILDING BLOCK 2-2

History

A 42-year-old female graphic designer presents with a diagnosis of impingement syndrome of the shoulder. She spends a large part of her day at a monitor creating design documents. She has two children aged 1 and 3. She likes to garden and cook. Activity limitation is an inability to raise the arm to groom her hair.

Evaluation

A pivotal impairment is determined to be a thoracic kyphosis that results in the scapula resting in an excessive anterior tilt (**Fig. 1**).

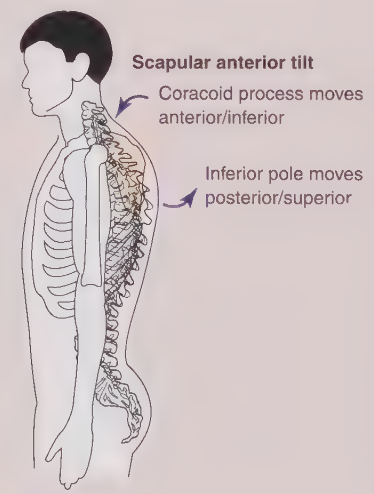


FIGURE 1 Thoracic kyphosis with excessive scapular anterior tilt. With anterior tilt of the scapula, the inferior angle moves posterior/superior and the coracoid process moves anterior/inferior.

The scapula, resting in anterior tilt, fails to adequately tilt posteriorly during upper extremity flexion (**Fig. 2**). As a result, the glenohumeral joint mechanically impinges under the acromion process, and tissues in the subacromial space (e.g., subacromial bursa, biceps tendon, and rotator cuff tendons) undergo microtrauma resulting in pain (i.e., impairment), inflammation (i.e., pathology), and the inability to raise the arm without pain (i.e., activity limitation). List examples of activity limitations and participation restrictions that result from this movement impairment.

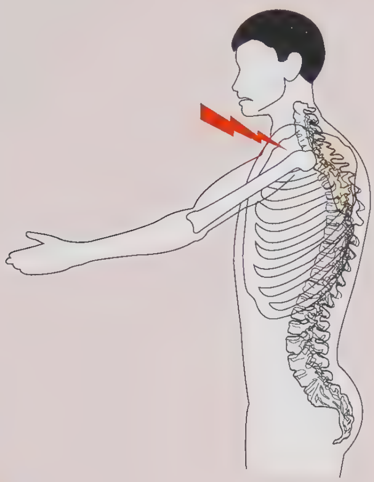


FIGURE 2 Lack of scapular posterior tilt leads to glenohumeral impingement.

BUILDING BLOCK 2-3

Wall slides (Fig. 2-7) are a good choice of exercise for the patient described in Building Block 2-2. This exercise can simultaneously address several impairments. List three impairments that this exercise addresses and indicate the correlating subsystem of the movement system.

DISPLAY 2-8
Subsystems of the Movement System Related to Impairments

- **Support subsystem impairment:** Using accessory muscles of inspiration (pectoralis minor) versus diaphragm for breathing, potentially leading to overuse and shortening of pectoralis minor
- **Passive subsystem impairment:** Short pectoralis minor and short head of biceps pulling coracoid process anterior and inferior, lengthened and weak lower trapezius not providing sufficient counterforce leading to scapular anterior tilt. Thoracic kyphosis contributing to the anterior tilt of the scapula
- **Neural subsystem impairment:** Reduced recruitment of lower trapezius and serratus anterior not counterbalancing the anterior scapular tilt
- **Active subsystem impairment:** Reduced force production from the lower trapezius and serratus anterior
- **Cognitive/emotional subsystem impairment:** Patient is clinically depressed, and the physical manifestation is a slumped posture contributing to the thoracic kyphosis. The depression also contributes to central sensitization and hyperalgesia experience of pain.

FIGURE 2-9 This exercise illustrates a patient performing a wall slide. The patient moves from the position shown here to the end position of the shoulders in full elevation. Note the arms are positioned in the scapular plane (slightly forward of the wall with thumbs touching the wall), the spine and pelvis are in neutral, and the feet are only a few inches away from the wall.

DISPLAY 2-9
Considerations in Clinical Decision-Making Relevant to the Subsystems

- Identify the activity limitations and related impairments to be treated.
- Relate activity limitations and impairments to be treated with the appropriate subsystems of the movement system.
- Prioritize subsystems of the movement system.

stretch the pectoralis minor and strengthen the lower trapezius (active) (**Fig. 2-9**). Optimizing the recruitment strategy (neural) during specific exercise and during functional movement is always necessary to achieve the best functional outcome.

Display 2-9 summarizes the factors to consider before determining the relevant and prioritized list of the subsystems of the movement system (see **Building Block 2-4**).

BUILDING BLOCK 2-4

Given the example of the women with impingement in Building Block 2-2, is there another pivotal subsystem of the movement system that might need to be addressed, prior to any other, for her to achieve a successful outcome? Explain your answer.

Stages of Motor Control

Once the impairments and the relationship to the movement system are defined, the therapist is challenged with determining the appropriate stage of motor control with which to focus. This will further define the activity and dosage parameters.

A person with musculoskeletal dysfunction may exhibit impairments in either or both parameters of mobility. For example, after total knee arthroplasty, a person may experience passive mobility restrictions caused by pain, swelling, and soft-tissue stiffness and have decreased ability to initiate active knee motion as a result of reduced muscle force/torque production or reduced recruitment capability. The cause of the mobility restriction must be determined on a case-by-case basis to determine the most appropriate exercise intervention (see Chapter 7).

A precursor to achieving the stability necessary for movement, or dynamic stability, is optimal posture (see Chapter 9). The individual must be able to maintain optimal posture without a load before optimal posture can be maintained during movement of a limb. Mobility and stability are not mutually exclusive. Achieving mobility before addressing stability is unnecessary; the two stages of motor control can occur concurrently. For example, as mobility after total knee arthroplasty is achieved passively, active motion must be prescribed. For optimal active motion, the knee requires a stable proximal base from which to move (i.e., pelvis and trunk) and distal base for weight-bearing (i.e., foot and ankle). Stability must be achieved at these regions for optimal active motion to take place (**Display 2-10**).

Controlled movement requires proper timing and recruitment of synergists that perform movement concurrent with recruitment of muscles and appropriate length of soft tissues providing a stable foundation for movement. The previous example would progress from exercises improving knee mobility, as well as pelvic-trunk and foot-ankle stability, to functional movement patterns. To walk, the knee must flex and extend at proper stages in the gait cycle. The trunk, pelvis, ankle, and foot must move into proper position at each stage of the gait cycle and provide proximal and distal stability for optimal knee function. The activity may involve the swing phase of gait, which requires a stable pelvis from which to swing the lower limb (**Fig. 2-10A**), or the stance phase of gait (Fig. 2-10B), which requires a stable foot for optimal knee loading.

The final progression in the stages of motor control is skill. Skill implies consistency in performing functional tasks with economy of effort.[54] Skill in the upper extremities most often requires freedom of movement in space in a coordinated manner within and between the hand, wrist, forearm, elbow, shoulder girdle, trunk, and pelvis (e.g., grasping a cabinet door) (**Fig. 2-11**). Occasionally, closed chain (weight-bearing) movements are required in the upper extremity (e.g., gymnast performing a handstand on the balance beam) (**Fig. 2-12**). Skill

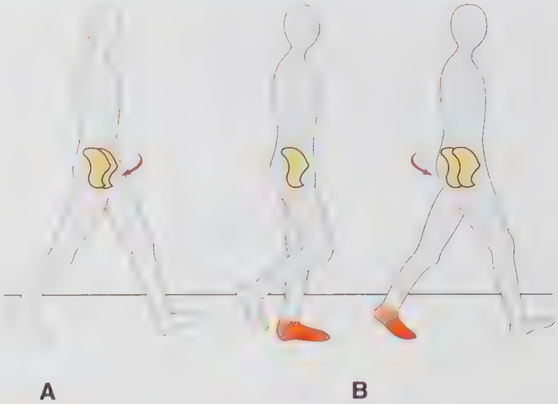


FIGURE 2-10 **(A)** Swing phase of gait requires a stable pelvis. **(B)** Stance phase of gait requires a stable foot.

FIGURE 2-11 Grasping a cabinet door requires freedom of movement in space in a coordinated manner within and between the joints of the upper extremity, trunk, and pelvis.

FIGURE 2-12 A gymnast performing handstand on the balance beam represents an upper extremity closed chain movement.

DISPLAY 2-10

Stages of Movement Control

Mobility: A functional range through which to move and the ability to sustain active movement through the range

Stability: The ability to provide a stable foundation from which to move

Controlled Mobility: The ability to move within joints and between limbs following the optimal PICR

Skill: The ability to maintain consistency in performing functional tasks with economy of effort

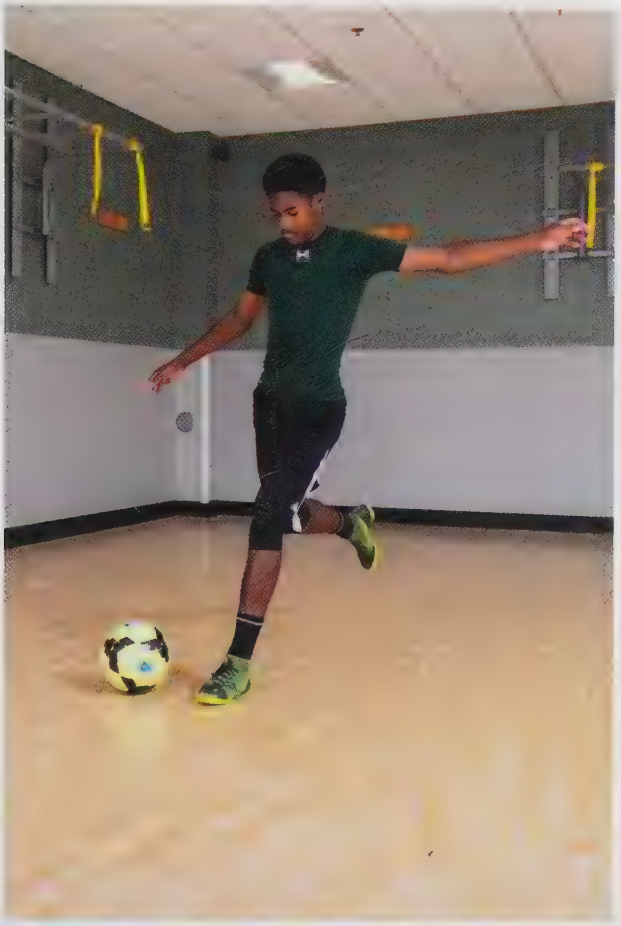


FIGURE 2-13 Skill in lower extremities requires coordination of open and closed chain movement. The swing leg performs an open chain movement as the stance leg performs a closed chain movement.

FIGURE 2-14 A tennis swing represents a total body movement, which is coordinated within and between each segment involved in the movement.

in the lower extremities requires coordination of open chain (nonweight-bearing) movements (e.g., swing leg in kicking a soccer ball) (**Fig. 2-13**) and closed chain movements (e.g., stance leg in kicking a soccer ball) within and between the foot, ankle, knee, hip, and spine for movement on varied surfaces. For total body movement to be optimal, coordinated movement must occur within and between each segment involved in the movement (e.g., tennis swing) (**Fig. 2-14**).

Commonly, patients are asked to perform skill-level activities without first developing the proper foundation for functional motor control. Conversely, patients may be prescribed exercises developing the other stages of motor control without finalizing the intervention with skill-level activities during functional movements. Skill is a necessary stage of motor control despite the prognosis of the patient (e.g., walk 10 ft with a walker versus run a marathon), which must be worked toward by achieving optimal function at each prior stage of motor control.

In summary, an activity can be as simple as performing a dynamic knee extension movement in sitting (i.e., mobility) or as difficult as an integrated movement pattern such as walking on an uneven surface (i.e., skill). An understanding of the level of involvement of the support, base, modulator, and cognitive/affective elements of the movement system helps to determine the complexity of the task and the stage of motor control in which to intervene.

Activity or Technique

To be successful in choosing the proper activity or technique, first determine the subsystem associated with the impairment or activity limitation. Each subsystem is associated with specific therapeutic exercise interventions. **Table 2-2** cross-references the subsystems with the most common therapeutic exercise activities or techniques. Though an argument can be made to prescribe a specific therapeutic activity or technique to address nearly any subsystem of the movement system, this table refers to the most common relationships.

In addition to identifying the subsystems and the stage of motor control, the physiologic status of the body function or structure must be considered. This information assists in determining the activity or technique, posture, movement, and mode parameters. For example, if muscle performance (active subsystem) is pivotal to return to an activity or participation, the chosen activity or technique may depend on the force or torque capability of the affected muscle(s). If the

TABLE 2-2

Therapeutic Activities Cross-Referenced with Subsystems of the Movement System

ACTIVITY	SUPPORT	PASSIVE	ACTIVE	NEURAL	COGNITIVE EMOTIONAL
Stretch (passive/active)		x	x		
ROM (passive, active assisted, active)		x	x		
Strengthening[a]			x	x	
Neuromuscular reeducation			x	x	
Developmental activities			x	x	
Breathing	x				
Gait training	x		x	x	
Aquatic therapy	x	x	x	x	
Balance and coordination training			x	x	
Body mechanic and ergonomic training			x	x	
Movement training			x	x	
Posture awareness training			x	x	
Aerobic or muscular endurance[b]	x		x	x	

[a] Strengthening activities include active assistive, active, and resistive exercise using manual resistance, pulleys, weights, hydraulics, elastics, robotics, mechanical, or electromechanical devices.

[b] Aerobic or muscular endurance activities include use of cycles, treadmills, steppers, pools, manual resistance, pulleys, weights, hydraulics, elastics, robotics, mechanical, or electromechanical devices.

force or torque capability is less than fair muscle strength, as determined by Kendall,[55] a gravity-minimized position active ROM activity or an against-gravity active assisted technique may be chosen. Another related impairment may be related to reduced muscle recruitment from prolonged immobilization (i.e., neural subsystem). If the ability to recruit is poor, a gravity-minimized active ROM activity may be chosen with tactile feedback or against-gravity active ROM with neuromuscular electrical stimulation as an adjunctive intervention (discussed later in this chapter), both of which are chosen to augment muscle reeducation.

Building Block 2-5 challenges you to consider the status of the tissue when determining the activity, posture, movement, and mode of exercise to address reduced muscle performance.

BUILDING BLOCK 2-5

A patient has sustained a grade 2 muscle strain to the hamstrings. It is in the intermediate stage of healing and repair (between 4 and 8 weeks poststrain). Describe two to three therapeutic activities to restore muscle strength with the mode, posture, and movement specifically described.

How would you progress each of your choices as the patient moved toward 8 to 12 weeks of healing?

Display 2-11 summarizes the factors to consider before determining the activity or technique.

DISPLAY 2-11

Considerations Involved in Clinical Decision-Making Related to Choice of Activity or Technique

- Determine the element of the movement system related to the impairment or activity limitation to be treated.
- Consider the physiologic status of the movement system.
- Determine the stage of motor control.

Mode, Posture, and Movement After choosing the activity or technique, further breakdown of the activity is necessary for precise prescription. The mode, which is the method of performing the activity or technique, must be chosen. For example, if aerobic exercise is chosen, the mode can be cycling, swimming, walking, or a similar activity. If strengthening is chosen, the mode can be weights, manual resistance, or active assisted exercise. If balance and coordination training is chosen, the mode can be a balance board, balance beam, or computerized balance device.

The initial and ending postures (e.g., standing, sitting, supine, prone, wide base of support, and narrow base of support) need to be determined. Included in this information is proper hand placement and angle of application of the force or load. When using elastics, pulleys, mechanical or electromechanical devices, proper equipment placement and angle of application of force must be determined. These descriptions must be included in the beginning and ending posture information.

Finally, the movement needs to be specifically defined (e.g., partial squat through a 30-degree arc, unilateral arm raise through full range, proprioceptive neuromuscular facilitation diagonal of the upper extremity to chest height).

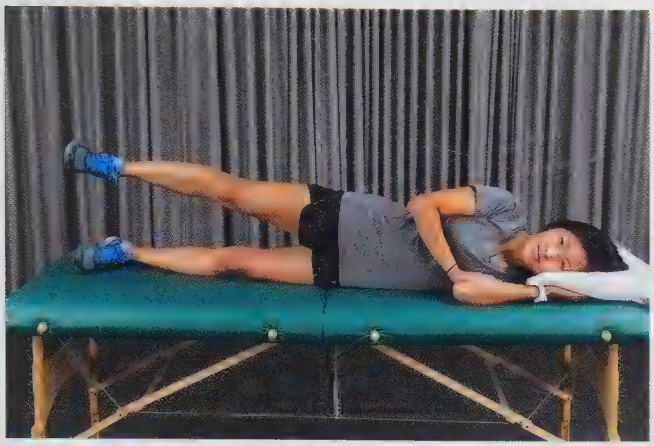


FIGURE 2-15 Hip abduction in the side-lying position. Optimal execution is with the pelvis and femur in the frontal plane and the movement of hip abduction occurring in the frontal plane with a stable pelvis. This requires recruitment of all of the hip abductors and proximal lumbopelvic muscles working in synergy.

DISPLAY 2-12

Variations in Performing Side-Lying Hip Abduction

1. Side-lying with pelvis in frontal plane and abducting the hip with all of hip abductors in synergy (see Fig. 2-11)
2. Side-lying with pelvis rotated backward and femur rotated laterally, causing the movement to move toward the sagittal plane and resulting in recruitment of hip flexors
3. Side-lying with pelvis in frontal plane with femur rotated medially and flexed, resulting in recruitment of tensor fascia lata
4. Side-lying with pelvis in frontal plane, but movement is at the pelvis (hip hike), resulting in recruitment of lateral trunk muscles
5. Side-lying with pelvis in frontal plane, but movement is abduction of opposite hip, resulting in recruitment of opposite hip abductors

The quality of performance of the exercise is critical to the outcome (i.e., neural subsystem). In relation to active or neural subsystems, an obvious but often neglected concept is that a muscle cannot be strengthened if it is not recruited. Even if the correct activity is chosen, and the mode, posture, and movement are carefully selected, proper execution of the exercise is necessary to ensure a successful outcome. For example, side-lying hip abduction can be performed with at least five different recruitment patterns (**Fig. 2-15** and **Display 2-12**).[56] Attention to precision of movement and recruitment patterns is vital and must always be promoted to the best of the individual's capability. If the intent of the exercise is not achieved, the physical therapist must modify the dosage parameters, either more or less challenging, to achieve the desired outcome.

Dosage

When determining dosage, physiologic status of the affected body functions/structures and the patient's learning capability must be considered. The anatomic site comprises the specific tissues involved (e.g., ligament, muscle, tendon, bone, cartilage, skin, and nerve). The physiologic status of the affected body functions/structures includes the severity of the tissue damage (e.g., partial versus complete tear), the irritability of the condition (e.g., easily provoked and difficult to resolve versus difficult to provoke and easy to resolve), the nature of the condition (e.g., chemical versus mechanical mediated pain), and the stage of the condition (e.g., acute, subacute, and chronic). For patients recovering from an injury, the dosage parameters are modified according to the tissues involved and the principles of tissue healing (**Table 2-3**). In the early stages of healing, tissues tolerate low-intensity passive or active activities, but in the later stages, tissues tolerate more aggressive resistive activities (see Chapter 10).

The patient's ability to learn, or learning capability, influences the schedule and the amount of reinforcement, feedback, or sensory input needed to perform the activity successfully. If a patient has difficulty learning a motor task, the dosage may be altered according to the principles of learning (see Chapter 3). For example, various forms of feedback (e.g., verbal, visual, and tactile) combined with numerous low-intensity repetitions may be required initially for optimal performance of an activity. As skill is acquired, feedback and repetitions may be reduced and more complex activities may be prescribed.

TABLE 2-3

Body Function/Structure Impairment Categories

STAGE OF RECOVERY	STAGE 1	STAGE 2	STAGE 3
Onset of injury	Recent		Remote
Symptoms	↑ Severity ↑ Irritability		↓ Severity ↓ Irritability
Activity level	Decreased use of segment/limb in function	Segment/limb used—not optimal	Near-normal use of segment/limb in function
Precautions/restrictions	Yes	Guarded	No
Outcome scores	High-participation restriction		Low-participation restriction

DISPLAY 2-13

Considerations Involved in Clinical Decision-Making Related to Choice of Dosage Parameters

- Determine the anatomic sites involved in the current condition.
- Determine the physiologic status of the tissue(s) involved.
- Consider the patient's learning capability.

After the anatomic and physiologic elements and the learning capabilities are understood, specific dosage parameters can be determined. **Display 2-13** summarizes the factors to consider before determining dosage parameters. Parameters related to dosage include:

- **Type of contraction** (i.e., eccentric, concentric, isometric, dynamic, or isokinetic)
- **Intensity** (i.e., amount of assistance or resistance required)
- **Speed** of the activity or technique
- **Duration** tolerated (i.e., number of repetitions or number of sets, particularly related to endurance and stretching activities)
- **Frequency** of exercise (i.e., number of exercise sessions in a given period)
- **Sequencing** of the exercise prescription (i.e., stretch before strengthen, low-intensity warm-up before moderate or intense aerobic activity, or single joint uniplanar movement before multijoint multiplanar movement)
- **Environment** in which the exercise is performed (i.e., quiet, controlled environment of a private room in a physical therapy clinic versus a loud, chaotic, uncontrolled, and outside environment)
- **Amount of feedback** necessary for optimal performance of the activity

SUMMARY

In summary, numerous variables in this model must be considered in prescribing an exercise, and variables often overlap. For example, learning capabilities under dosage is similar to stages of motor control, which is similar to neural and cognitive/emotional subsystems for the movement system. The task of organizing this data can be overwhelming. This model may help to visualize the relationships among the components of exercise prescription. It is the goal of this text that this model assists in organizing the data necessary to develop an effective, efficient therapeutic exercise intervention.

Exercise Modification

When the desired patient outcome is not met in a reasonable time frame, modification is based on evaluating how the following possibilities affect the lack of progress achieved with the therapeutic exercise intervention:

- The physical therapist may choose the **wrong activity**, dosage of exercise, or both.
- The physical therapist may be **ineffective in teaching** the exercise.
- The patient **may not be able to learn** the exercise well enough or misunderstand or forget the instructions or dosage.
- The patient **may not follow through** with the prescription.

To be most effective and efficient with exercise prescription, constant reexamination and reevaluation of changes in impairments, activity levels, and participations are required. The exercises must be continually modified to increase or decrease the difficulty to ensure continual progress is being made with minimal setbacks. Numerous parameters can be modified to render an exercise more or less difficult. Four general parameters can be varied in an exercise prescription: biomechanical, physiologic, neuromuscular, and cognitive/emotional. **Display 2-14** outlines parameters that can be varied and provides examples for various types of exercise.

If you've paid careful attention to these basic methods and principles, but the patient is not responding to the intervention, you must realize that all has been done within the scope of your therapeutic knowledge, expertise, and experience and that the patient should be discharged if you feel maximum improvement has been attained. If not, the patient should be referred to another practitioner for further treatment.

DISPLAY 2-14

Exercise Modification Parameters

Biomechanical

Stability

- Size of base of support
  Example: It is more difficult to balance with feet close together or in tandem than feet wide apart, and in side-lying rather than supine.
- Height of center of mass
  Example: Sit-ups may be done first with hands at the sides, progressed to forearms folded across the chest, progressed to hands clasped behind the neck. This upward shift of arm weight moves the center of mass toward the head by stages, progressively increasing the difficulty of the exercise.
- Support surface
  Example: The stability of the support surface can be progressed from a static or stable surface to a mobile base, such as foam, a balance board, or a trampoline.

External Load

- Magnitude
  Example: Increased magnitude of resistance alters the weight of the segment and thereby increases the difficulty

DISPLAY 2-14

Exercise Modification Parameters (*continued*)

of movement; however, it may also increase feedback from muscle and joint receptors and enhance the response.

- Gravitational forces
  Example: The force of gravity on a segment is maximal when the part is horizontal and diminishes as it moves toward the vertical. Knee flexion in prone is more difficult at the beginning of the movement and becomes easier as the motion progresses. Hip abduction is gravity reduced in prone and against gravity in side-lying.
- Speed (see Chapter 5)
  Example: A medium rate is usually easier than very rapid or very slow rate.
- Length of lever arm
  Example: In prone exercises for scapular adductors (middle and lower trapezius), raising the arms with the elbows flexed gives less resistance than if the elbows are nearly or completely straight.
- Point and angle of application of manual or mechanical resistance
  Example: A muscle pulling at or near a right angle to the long axis of the segment exerts its force more effectively than when its angle of pull is very small.

Number of Segments Involved

- Fewer segments may not always be easier than more segments, especially as in fine motor control.

Length of Muscle

- A muscle is better able to exert active tension when it is in a lengthened state than after it has undergone considerable shortening. When it is desirable to limit the participation of a given muscle in a movement, it is placed in a shortened position, or "put on slack." The active tension exerted by a muscle spanning more than one joint at a given joint depends on the position of the second joint over which it passes, because this determines the length of the muscle. For instance, the hamstrings are more effective as knee flexors when the hip is flexed and less effective when the hip is extended. Similarly, if the goal is to isolate the gluteus maximus during hip extension, the participation of the hamstrings is reduced if hip extension is done with the knee flexed compared with the knee extended.

Passive Tension of Two-Joint Muscles

- The hip can be flexed to only 70 to 90 degrees with the knee extended but considerably more if the knee is flexed. Similarly, the ankle can dorsiflex more when the knee is flexed than when the knee is extended. These considerations are particularly important in planning effective stretching activities and in analyzing stabilization of body segments in all types of exercise. Altering joint positions or the use of external supports such as pillows can reduce or increase the tension of two-joint muscles based on the goal of the exercise.

Open versus Closed Kinetic Chain

- The kinetic chain is related mostly to specificity of exercise. If the desired activity is in the closed kinetic chain, this position should be used for training whenever possible. However, the closed kinetic chain often cannot isolate muscle function as well as a specific open kinetic chain exercise.

Stabilization (External or Within)

- If stability is required for a movement, use of external support or prepositioning a limb may assist stabilization if the patient is unable to stabilize with proper patterns internally. For example, in supine, the trunk can stabilize with greater ease if the hip and knee are flexed and held in place by the hands while the other limb slides down and back during an abdominal strengthening exercise (Fig. 1). This is an example of prepositioning to offer external stability.

Physiologic

Duration

- Duration of activity in seconds, minutes, or hours
- Number of repetitions or sets performed

Frequency

- Number of exercise sessions in a given time period

Speed

- Slower is not necessarily easier (see earlier)

Intensity of Contraction or External Load

- Percentage of maximum voluntary contraction

Type of Muscle Contraction

- Eccentric, isometric, concentric

Sequence of Exercise

- May require beginning with less complex tasks or less strenuous activity in the early stages of learning or healing and progressing to less need for "warm-up" activities as skill is achieved and tissues are in more advanced stages of healing

Rest Between Repetitions and Sets

- As strength or endurance improves, less rest is necessary between repetitions and sets. But, as intensity of exercise increases, rest between sessions for tissue recovery becomes more important. Be cautious of overtraining, especially in the presence of neuromuscular disease or injury.

Neuromuscular

Sensory input

- Visual, vestibular, and proprioceptive inputs can be manipulated. If the eyes are closed, visual input is eliminated, leaving the vestibular and proprioceptive receptors to detect any disturbance. The proprioceptive input can be varied by standing on soft foam. The vestibular input can be varied with head movement.

Sensory Facilitation or Inhibition

- Techniques such as cutaneous and pressure input, approximation, and traction can alter muscle responses. Prolonged pressure on the long tendons such as the quadriceps, biceps, hamstrings, or finger flexors seems to

(*continued*)

DISPLAY 2-14

Exercise Modification Parameters (*continued*)

A B

FIGURE 1 Leg slide movement for strengthening lumbopelvic stabilizing muscles. The hip and knee are flexed and held close to the chest as the other limb slides down and back. This modification reduces the stabilizing force needed by the trunk muscles because of the amount of hip flexion in the stationary limb. The more proximal the stationary limb is relative to the center of mass, the less difficult the exercise becomes; the more distal the stationary limb is relative to the center of mass, the more difficult the exercise becomes. This photograph illustrates the mid position of the exercise **(A)**. The patient should end with the extremity as close to full extension as the length of the hip flexors will allow **(B)**.

inhibit responses. The placement of manual contacts is critical to facilitate the desired response. Contacts are placed in the direction toward which the segment is to move. Approximation or compression into or through a joint stimulates the joint receptors and may facilitate muscles and stability around a joint. Traction separates the joint surface and is incorporated if increasing ROM around a joint is desired.

Number of Segments Involved

- In weight-bearing postures, joint involvement usually refers to the weight-bearing segments; for example, prone on elbows does not require participation of the forearm and hand or the lower body compared with the quadruped position. The placement of manual contacts or other external forces also influences the number of segments involved. For example, contacts placed on the scapula and pelvis in side-lying involve the entire trunk, whereas contacts positioned on the lumbar spine and pelvis result in more isolated activity of the lower trunk.

Stage of Motor Control

- Mobility, stability, controlled mobility, skill (see Display 2-9 for the definitions of stages of motor control)

Cognitive/Emotional

Frequency and Duration of the Activity

- Increased frequency and duration of the activity increases the practice schedule to enhance learning.

Initial Information Provided

- Care should be taken to provide enough information to perform the activity with the correct strategy, but not to give too much information, which may overwhelm the learner.

Accuracy Provided

- As skill is acquired, increased accuracy of cues is provided to "fine-tune" a movement.

Variability of Environmental Conditions

- Initially reduced number of external distractions is provided with increasing external distractions toward a functional environment as skill is acquired.

Complexity of Activity

- Number of steps involved, as in breaking down components of gait into single tasks and then uniting them into the integrated complex motor task of gait with numerous steps

Anxiety Level

- Initially, greater focus on the activity is combined with the least emotional distractions to enhance early learning.

ADJUNCTIVE INTERVENTIONS

To complete this chapter on patient management, adjunctive interventions were chosen to be included in this section to provide insight into the complementary role they play in therapeutic exercise prescription. The interventions presented in this section are considered adjunctive to therapeutic exercise in that they are not regarded as essential to achieving a functional outcome.

When choosing to use an adjunctive intervention, a decision must be made regarding the benefit of its use in conjunction with therapeutic exercise. The clinician should be reasonably sure that combining the adjunctive intervention with the therapeutic exercise would produce more rapid or optimal functional recovery. Make it clear to the patient that the adjunctive intervention is being used in the short term to augment the exercise and that the exercise and posture and movement habits will ultimately change the impairments and activity limitations for long-term improvement. There are conditions for which physical agents, mechanical and electrotherapeutic modalities, and orthotics are imperative to achieve improved physical function and health status, in which case these interventions are not considered adjunctive (e.g., significant soft tissue inflammation, severe pain disorders, skin conditions, nerve injury, impaired motor function, and structural abnormalities).

Physical agents, mechanical modalities, and electrotherapeutic modalities can play a vital role in the total plan of care for a patient and serve as important adjuncts to therapeutic exercise. Elaboration of the role of each of these therapies can be found on thePoint.lww.com/BrodyHall4e. Additional adjunctive interventions such as taping and orthotic prescription are presented in Units 5 and 6.

KEY POINTS

- The physical therapist integrates five elements of care—examination, evaluation, diagnosis, prognosis, and intervention—in a manner designed to maximize the patient's outcome.
- An understanding of each component of the patient management model assists the clinician in maximizing patient satisfaction and in delivering the most effective and efficient services possible.
- The clinician's knowledge, expertise, experience, and ongoing acquisition of knowledge and experience are the determinants for successful patient management.
- Critical clinical decisions are those involved in determining which impairments from the list generated from the examination are most closely related to activity limitation and participation restriction and therefore warrant intervention.
- Patient-related instruction must be an integral part of any physical therapy intervention.
- The three-dimensional therapeutic exercise intervention model is designed to help organize the data necessary to make clinical decisions regarding therapeutic exercise intervention.
- Exercises must be continually monitored to determine the need for modification to increase or decrease difficulty to ensure continual progress is being made with minimal setbacks. To be most effective with exercise modification, the clinician must possess thorough understanding of the parameters that can be modified.
- Therapeutic exercise can be complemented with adjunctive interventions if the additional intervention can lead to a higher level of functional outcome in a shorter period.

CRITICAL THINKING QUESTIONS

1. Read Case Study No. 2 in Unit 7.
   a. List the physiologic, anatomic, and psychological impairments.
   b. List the activity limitations.
   c. Correlate the impairments to the activity limitations.
   d. Choose the impairments and activity limitations you feel warrant treatment.
   e. Correlate the impairments and activity limitations you have chosen to treat with the subsystems of the movement system.
   f. Prioritize the subsystems of the movement system.
2. Still using Case Study No. 2, you have decided to prescribe exercises to improve knee mobility, because you know the patient requires 70 degrees of knee flexion to perform simple ADLs. You would like to use a sit-to-stand movement to work on knee mobility. Recall that she requires moderate assistance with sit-to-stand transfers.
   a. Describe the posture (beginning and end position), mode, and movement of the activity.
   b. Describe all pertinent parameters of dosage.
3. The patient has progressed to 70 degrees of flexion and no longer requires assistance with sit-to-stand transfers. How would you modify the mobility exercises to make them more difficult? Use the principles of exercise modification listed in Display 2-12.
4. The patient is having difficulty with recruitment of her quadriceps.
   a. What adjunctive intervention would you use?
   b. Describe the posture, mode, and movement of the activity.
   c. Describe all pertinent parameters of dosage.

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CHAPTER

3

Strategies for Improving Therapeutic Exercise Outcomes

LORI THEIN BRODY

The best intended therapeutic exercise program will be unsuccessful if the exercises are done incorrectly or not done at all. Teaching patients how to self-manage their condition between appointments is a critical component of patient care. Changes in the structure of the medical system, reimbursement issues, and an increase in the prevalence of chronic problems require educating patients about their conditions and teaching them effective self-management strategies. Teaching in the clinic is an ongoing and ever-changing process. Many clinicians find that they are no longer full-time, hands-on providers of rehabilitation services but rather part-time educators, administrators, and clinicians.[1] Teaching self-management strategies extends the provider's impact beyond the face-to-face visit and arms the patient with tools to recover from their current problem and to prevent a recurrence.

PATIENT EDUCATION: DEFINITION AND SCOPE

Patient-related instruction is the "process of informing, educating, or training patients/clients, families, significant others, and caregivers with the intent to promote and optimize physical therapy services."[2] Instruction includes information on:

- Current condition
- Diagnosis
- Prognosis
- Plan of care
- Health and wellness
- Risk factors

Teaching in the clinic is an ongoing process throughout the evaluation and treatment sessions (**Evidence and Research 3-1**). Therapists typically educate patients about their condition, the prognosis and plan of care, and teach specific activities (i.e., stretching exercises, gait training, postural interventions, etc.). Clinicians also educate their patients on important issues such as the relationship between symptoms and their patients' daily routines and the expected response to the exercise program. Patients' satisfaction with treatment and willingness to adhere are often based on the fulfillment of their expectations. More time spent educating the patient on prognosis and expectations from the rehabilitation program may increase adherence to and satisfaction with the treatment program. However, "educating" and "teaching" are carried out by the provider, whereas "learning" is associated with the patient. Understanding issues related to effective communication skills, teaching, learning, and performance is essential to optimizing outcomes.

Patient learning is categorized as **cognitive**, **affective**, and **psychomotor**.[4] In therapeutic exercise, all three domains are part of the instruction process. The cognitive domain includes information and facts about the patient's condition and the rehabilitation program. This might include descriptions of the anatomy, biomechanics, or pathomechanics of the condition. Educating patients about therapeutic exercise theory and the rationale behind the exercise choices also falls into the cognitive domain (**Evidence and Research 3-2**). Affective domain education addresses the patient's attitude and motivation. Possessing the cognitive information and the psychomotor skill to execute the exercise program is of little use when the patient is unmotivated to participate. The patients' attitudes toward their condition and their attitudes and beliefs about the likelihood of the therapeutic exercise program remediating their symptoms are essential for program adherence. This topic is explored further in the section on "Adherence and Motivation."

Finally, the psychomotor domain is critical for learning the proper motor programs and performing the therapeutic

EVIDENCE and RESEARCH 3-1

A study of the perceptions of physical therapists regarding their involvement in patient education showed that therapists educate 80% to 100% of their patients.[3] Gahimer and Domholdt[1] found that therapists educated their patients primarily in the areas of information about illness, home exercises, and advice and information. Moreover, the patients reported attitudinal or behavioral changes ranging from 83.8% to 86.5% as a result of this education. Health education and stress counseling were addressed less frequently during the treatment session.

EVIDENCE and RESEARCH 3-2

A study of patients with a mean 10-year history of low back pain found that 51% of these patients had noticeable improvement in their pain 1 week after being provided with an individualized biomechanical treatment booklet. At both the 9- and the 18-month follow-up assessments, statistically and clinically significant improvements were reported in pain management, number of episodes of care, and perceived benefit.[5]

exercises correctly. The nuances of muscle activation and control during therapeutic exercise distinguish this type of rehabilitative exercise from recreational exercise. The psychomotor domain is explored in further detail in the "Motor Learning" section.

KEY COMPONENTS OF PATIENT-RELATED INSTRUCTION

Effective patient-related instruction for successful patient outcomes is a complex process with many interrelated components. For example, how the diagnosis, prognosis, and plan of care are communicated to the patient will impact the patient's confidence in the provider and adherence to the plan of care. Poor instruction in the psychomotor aspects of an exercise can cause symptom exacerbation rather than remediation. Some of the key components of patient-related instruction include communication skills, cognitive aspects of instruction, affective domain considerations, and psychomotor factors.

Patient–Clinician Communication

Communication is a two-way conversation, not a one-way provision of factual information. Good communication requires understanding both the verbal and the nonverbal components of communication. Communication has many nuances and components, each requiring appropriate interpretation and responses. Body language and posture, eye contact, physical contact, tone of voice, type of questioning, and listening ability all impact rapport and trust. Clinicians must recognize their own verbal and nonverbal communication and also similar cues from the patient. They must then respond appropriately from these patient cues, reflecting back the patient's concerns and providing support.[4]

Communication is most effectively accomplished when the clinician has established rapport with the patient. **Rapport** is a quality of interaction that is difficult to define but is comprised of an ability to make patients feel cared for and respected.[4] The patient must trust the care provider, and the care provider must be able to accept and empathize with the patient's situation. This does not mean that the provider should support poor health behavior choices but that he or she should acknowledge the challenges the patient may be facing. This acknowledgment is followed by active problem solving to eliminate barriers to good choices and to design a support system that will facilitate and reward positive choices.

Individual differences significantly affect the patient–clinician relationship. Fundamental personality differences, values, and teaching and learning styles influence communication and may ultimately affect adherence and outcome. Possessing important skills to assess the patient's willingness and style of communication and learning can enhance the rehabilitation program. These skills include the ability to actively listen to and reflect on the patient's reports and to provide appropriate feedback[6,7] (**Evidence and Research 3-3**).

EVIDENCE and RESEARCH 3-3

Sluijs et al.[8] found lack of positive feedback to be one of the primary factors related to lack of adherence to a rehabilitation exercise program. Cameron[9] suggests improving the quality of the interaction by showing sensitivity to the patient's verbal and nonverbal communications and understanding of and empathy with the patient's feelings.

Patient communication implies a willingness to participate by the patient and the clinician. The patient's readiness to learn depends on many factors, including the relationship with the health care provider. The relationship is affected by how the patient is coping with the particular situation. Schwenk and Whitman[7] describe a control scale in which the control level of the patient and that of the clinician are inversely related. As the clinician uses less controlling or assertive behaviors, the patient's control of the situation increases. The converse is also true: the active and assertive clinician is likely to push the patient into a more passive role. If the patient is unwilling to be in such a role, conflict will ensue or the clinician will become more passive, relinquishing some control to the patient.

The clinician's attention to the patient's needs can guide the appropriate communication style. In the initial visits, a more active listener role gives the patient an opportunity to explain his or her needs. The clinician can then hear the patient's concerns, expectations, and goals. Fundamental skills necessary for active listening include close observation of the patient's words, intonation, and body language. Judicious use of eye contact, along with affirmation and reflection of the patient report, can clarify what the clinician heard and validate the patient report (**Fig. 3-1**). This gives the clinician an opportunity to discuss the

An effective communicator:
- Observes body language
- Listens for intonation
- Establishes rapport
- Establishes trust
- Actively listens
- Reflects and rephrases
- Affirms and restates
- Provides realistic expectations
- Understands and integrates cultural factors

FIGURE 3-1 Key factors in effective communication.

recovery prognosis given the adherence to the treatment program, which, along with discussion of the clinician's expectations of the patient, can enhance communication and the rehabilitation process. Several studies have shown the "Pygmalion effect" in a variety of settings in which the instructors' expectations were matched by students' achievements.[10–13]

Although communicating the expectations of all involved participants is important, it is equally important to provide realistic expectations in the form of short-term and long-term goals. Setting reasonable and achievable goals that address the patient's impairments and that are linked to activity limitations and participation restrictions can provide one form of positive feedback for the patient. Occasionally, the patient's motivation can be improved by education about reasonable goals. The ability to perform the same level of exercise or activity at a lower level of pain is a reasonable short-term goal. The patient may only see that he or she is performing at the same level and perceive this as a lack of progress. Clarification on how progress is defined and reasonable expectations regarding progress can improve patient adherence and satisfaction (see **Building Block 3-1**). Some advocate a contract approach in which the specific obligations of each party in the attainment of the therapy goals are set forth and a timeline is determined.[9]

BUILDING BLOCK 3-1

Kathy is a 53-year-old high-level recreational tennis player. She sustained an acute rotator cuff tear during a fall 8 months ago, and 2 months later underwent rotator cuff repair. Physical therapy was initiated 2 weeks post-op, and Kathy has been making steady progress on her ROM and strength. However, at 3 months post-op, she is frustrated at the rate of her progress and feels as though she should be farther along in her recovery than she currently is. She is worried that she will not be able to play tennis again. She has been performing her land-based rehabilitation program faithfully.

Her physician performed an ultrasound to assess healing and felt that her rate of healing was as expected given her age and tissue quality. She remains frustrated at what she perceives to be a lack of progress despite improvement in impairments and increased functional use of the arm. How would you counsel the patient?

Patient-Related Instruction in Home Exercise Prescription

The home exercise program is an increasing component of the overall treatment program for most patients. In some cases, patients perform the exercises independently, whereas in other cases, a family member or other health care provider assists in the exercise program. In either situation, clarity in goals and exercise procedures is essential to ensure an optimal outcome.

One of the fundamental steps in ensuring a positive outcome is the therapist's ability to communicate instructions effectively. The best-designed rehabilitation program may fail because it has not been carried out well. Variables such as language or cultural barriers, reading or comprehension levels, hearing or visual impairment, and clarity of instructions can affect understanding. Do everything possible to ensure that your instructions are clear and easy to understand. Although affective domain issues may be relevant here, many of the learning issues are related to the cognitive domain.

Cultural Barriers

Identify any cultural barriers to understanding early in the rehabilitation course. Language differences may hinder the use of even the simplest terminology. Although an individual may appear to understand many words in English, communicating thoughts about medically related issues is often difficult. Use of an interpreter can minimize communication difficulties in this area.

Other cultural barriers to adherence may exist and should be identified to the best of your ability. Religious or other cultural customs may prevent individuals from exercising on certain days or from wearing clothing that allows a body part to be visualized or palpated during exercise. In major metropolitan areas, a multitude of cultures exist, making it difficult to know the intricacies of all cultures and customs. Culturally competent providers will:

- Do their best to know the times and meanings of the patient's ethnic or religious holidays
- Seek information on cultural or religious customs related to:
  - Eye contact (avoiding eye contact is a sign of respect in some cultures)
  - Physical contact
  - How the patient is addressed
  - Appropriate type of greeting[14]
- Ask for permission to perform examination procedures in advance
- Explain what needs to be done and ensure patient comfort with procedures

Although these specific instances are difficult to know ahead of time, be alert to signs during the appointment that the patient is unwilling or hesitant to participate. In many cases, the patient feels most comfortable being examined by a therapist of the same sex. To the best of your ability, these issues should be addressed when scheduling the patient.

Clarity of Instruction

Simple aspects of the exercise program such as clear descriptions and legible writing are also important for adherence. Although written exercise programs may provide a personalized touch to the program, it may have detrimental results if the patient is unable to read the writing. Some key issues are:

- Specific exercise descriptions may make perfect sense to the clinician but confuse the patient.
- Baseline knowledge assumed by the therapist may be too much for the patient and may result in incorrect exercise performance.
- Clarity about which direction is "forward" or "up" is necessary.

Providers may find it useful to ask patients what they would name the exercise or how they would describe a certain movement. Using the key words identified by the patient helps to personalize the home program and increases the patient's understanding of it. This is in contrast to an authoritarian position where the provider gives the patient a routine exercise handout that seems highly impersonal. Directions should be lengthy enough to be comprehensive without overburdening the patient with details. Full sentences are unnecessary, but key phrases or bulleted points can improve clarity.

Include pictures of the exercises and show the exercise in the start and finish positions. Communicating a three-dimensional movement on a single sheet of paper at a stationary point in time is difficult. Show starting and ending positions or show pictures from different angles to clarify the three-dimensional nature of the movement. Arrows showing the direction of movement with marks clearly indicating the start and end positions are helpful. Often, exercise pictures show positions midway through the exercise, and the patient is unclear as to the full excursion of the movement. Throughout this book, Self-Management boxes present examples of exercise instructions.

Many clinics provide picture files or computer-generated exercises with pictures, descriptions, and exercise prescriptions included. These are helpful for the clinician, but use caution and be alert to these considerations:

- The therapist frequently needs to modify the exercise in some way to adapt it to the specific patient needs.
- These modifications should be made on the patient's exercise record, not just verbalized.
- Do not assume that because an exercise is provided in one of these formats, it is the best or the only way to perform the exercise.
- The exercise prescription should be individualized based on the patient's needs and ability to self-manage the problem, not necessarily prescribed as a certain number of sets and repetitions per day.

This type of prescription may conflict with the goal of teaching the patient self-management skills. Exercises that appear to be "canned" or the standard sheet of exercises that is given to every patient with a certain diagnosis minimizes the individuality of the exercise program. Lack of individualization minimizes the skills of the therapist and may affect adherence if the patient feels his or her needs are not being met.

Communication with the patient regarding the exercise program should be written, verbal, and, with increasing frequency, visual using video. Using the patient's own phone to video exercises can provide easy access to correct performance at their fingertips. Research has shown similar performance in patients receiving written handouts compared with video programs.[15,16] However, simply handing a patient the exercise program without demonstrating or having the patient perform each of the exercises increases the likelihood of nonadherence and incorrect performance[17] (**Evidence and Research 3-4**). Although patients may say they can remember their exercises, it is best to document the exercises with a written description that is reinforced with verbal cueing as the exercises are performed.

Organize the exercises in a logical sequence. An exercise program requiring frequent position changes is time consuming and burdensome for the patient. Cluster exercises of a similar nature for ease of understanding and ease of performance. For example, when possible, cluster all exercises performed in a supine position to minimize position changes, and group together shoulder rotation exercises because of their similar nature. Be sure to organize the exercises to simplify their performance and minimize the impact on the patient's lifestyle.

> **EVIDENCE and RESEARCH 3-4**
>
> A study by Friedrich et al.[18] found that patients who received a brochure of exercises rather than a supervised instruction had a lower rating of "correctness" of exercise performance. A strong correlation between the quality of exercise performance and a decrease in pain was found.

Cognitive Domain: Informing and Educating

Patient education is critical for a number of reasons including understanding the diagnosis, prognosis, plan of care, intervention techniques/dosage, and expected outcomes; improving program adherence; and teaching self-management. Clinical teaching, particularly teaching home exercise programs, is very important, because in-house supervised physical therapy services are often inadequate to achieve the patient's goals. Frequently, rehabilitation services are limited to a few visits. In this situation, the patient may be carrying out the rehabilitation program at home or at a local health club with intermittent rechecks for reexamination and program progression. To ensure safety during exercise and improvement in the patient's symptoms, the exercise program must be executed properly. Poor technique can slow or stop improvement and potentially worsen the symptoms. Therapists also teach patients which signs and symptoms predict an exacerbation so that they can modify the exercise program appropriately. This education can prevent a setback or potential reinjury (**Building Block 3-2**).

> **BUILDING BLOCK 3-2**
>
> Kathy returned to physical therapy for a follow-up visit. Review of Kathy's land-based program reveals that she has been performing exercises correctly and she has added aquatic rehabilitation exercises as well. However, in her zest to hasten her progress, she was overexercising, performing her exercises more frequently than prescribed, which resulted in an increase in pain and a slowing in her progress. Given this information, what are key aspects of education for this patient?

When prescribing a rehabilitation program, therapists must educate patients about the expected effects of the therapeutic exercise program on specific symptoms. This will provide patients with the necessary information to self-manage the situation. The more clearly patients understand the relationships among various activities (including the exercise program) and their symptoms, the better able they will be to regulate their activity levels. This makes the patient a partner in the rehabilitation program (**Evidence and Research 3-5**). The patient

> **EVIDENCE and RESEARCH 3-5**
>
> A recent study examined the impact of patient education and counseling regarding pain management, physical activity, and exercise in patients with low back pain and high levels of fear avoidance behavior.[19] While both groups improved with standard physical therapy intervention, those who received additional education and counseling had significantly fewer days off work than those without this education. This finding reinforces the importance of educating patients about their condition and strategies to effectively manage their symptoms.

still looks to the clinician for guidance and education regarding the physical problem, but the clinician gives the patient some responsibility in decision-making. This approach gently guides the patient in the self-management process.

Self-management has become increasingly important as people are living longer with chronic health conditions such as arthritis, heart disease, stroke, and diabetes. Patients must learn how to manage their symptoms, prevent a decline in their health status, maintain their overall level of health and well-being, and prevent complications of the disease process. In summary, patient must learn to self-manage conditions to avoid activity limitations and participation restrictions. An individual seeing a physical therapist for knee osteoarthritis may need education to understand the role of therapeutic exercise in maintaining knee function and total body health. Extensive patient education may be necessary to help that patient achieve optimal function. Additionally, patients who are hospitalized for various conditions are being discharged earlier. This results in a greater demand for outpatient services and the need for patient and family/caregiver education to manage impairments to avoid activity limitations and participation restrictions (**Evidence and Research 3-6**).

EVIDENCE and RESEARCH 3-6

Holmes et al.[20] successfully used a self-management approach in the treatment of a woman with impingement syndrome and adhesive capsulitis. She was seen for 6 visits over 10 weeks and followed up for 1 year. The authors felt that the intensive patient education allowed the patient to develop an internal sense of control and prevented the development of an external focus in which the patient depends on the therapist for the management of the condition. Motivation exhibited by patients may be a manifestation of their locus of control beliefs.[8]

Affective Domain: Adherence and Motivation

Patient compliance with a treatment regimen is a subject of a great deal of research. The terms *compliance*, *adherence*, and *therapeutic alliance* are often used to discuss the extent to which a patient's behavior coincides with medical advice.[9] Some feel that the term compliance is too dictatorial on the part of the caregiver and seems to neglect the philosophy of "patient as partner" in determining the plan of care. The term adherence is used throughout this chapter. The best-designed rehabilitation program achieves little if the patient is not compelled to participate (**Evidence and Research 3-7**). Strategies to improve adherence follow from an understanding of health behaviors.

EVIDENCE and RESEARCH 3-7

A study by Sluijs et al.[8] demonstrated a complete adherence rate of only 35%, with 76% of the patients "partly" compliant with their rehabilitation program. The factors related to nonadherence were patient-perceived barriers, a lack of positive feedback, and the degree of helplessness.

Health Behavior Models

Clinicians spend a great deal of time designing what they believe to be the best plan of care for their patients. However, even the best intervention plans will fail in the absence of patient participation. The factors associated with adherence to medical professional recommendations have been well studied. Some studies focus on eliminating unhealthy behaviors (smoking, excessive alcohol use), whereas others focus on initiating healthy behaviors (good eating habits, exercise, compliance with medication schedules).[8,9,21] A number of behavior change models have been put forth. For example, the Health Belief model stresses a reduction of environmental barriers to healthy behaviors including perceived barriers, benefits, self-efficacy, and severity.[22,23] Other models include the Health Locus of Control, Self-Efficacy, and Transtheoretical, or Stages of Change model.[22,24] Of these models, the Transtheoretical model has been applied to many aspects of exercise behaviors.

The Transtheoretical model emphasizes the temporal aspect of a behavior change, underscoring the ability to change a behavior over a variable length of time. Individuals may spend varying lengths of time in different stages as they slowly make changes, or they may get stuck in one stage. Additionally, the patient may move through some of the stages several times before completing the behavior change.[24] The stages identified in this model include *precontemplation*, *contemplation*, *preparation*, *action*, and *maintenance* (**Table 3-1**).

In the precontemplation stage, the individual states that he or she has no intention of changing in the next 6 months.[25] A person in this stage will be reluctant to begin any rehabilitation program and generally does not see the need or benefit of it. The individual may feel forced to come for rehabilitation by an outside party (physician, family member, employer), and no amount of explanation or information will improve adherence.

Individuals in the contemplation phase state that they are planning to make a change within the next 6 months. Those in the preparation stage indicate that they are planning to change in the next month or had made some changes but had not fully achieved the change. Individuals in the action stage have reached some criterion level of change (such as quitting smoking or exercising three times per week) within the past 6 months. Those in the maintenance stage had reached the criterion level of behavioral change more than 6 months earlier.[25]

Improving Adherence

Improve adherence by giving attention to the patient's readiness to begin such a program.[21,24,26] The first step is active listening to identify clues as to the patient's state of readiness for change. This can be done by using open-ended questions to explore issues related to adherence and to facilitate the patient's personal involvement. Help the patient identify potential barriers to participation and request input as to how these barriers can be removed or minimized. Patients need to believe that the pros of participation outweigh the cons and that they are capable of achieving the expected outcomes if they participate.[25,27,28] Build rapport through regular appointments and reflective conversation.[28] Purposefully link the exercise to the patient's impairments, activity limitations, and participation restrictions. For example, a patient may be more likely to perform a quadriceps strengthening exercise when they understand this intervention directly affects their reduced function of the lower extremity for activities of daily living (ADL) (i.e., activity limitation) and their inability to play tennis (i.e., participation restriction). Activity limitations and participation restrictions are often the primary reasons the patient sought medical attention initially. Friedrich et al.[18] found

TABLE 3-1

Transtheoretical Model of Behavior Change

STAGE	DESCRIPTION OF STAGE	PHYSICAL THERAPIST ROLE
Precontemplation	No intention of changing Does not see the need to change	Help identify goals that might be achieved by participation in the rehabilitation program
Contemplation	Seriously considering change but have not initiated it	Build motivation by providing information and encouragement
Preparation	Have plans to change in the next month Started to make changes but not complete	Educate the patient on the relationship between his or her own goals, the treatment program, and expected outcomes
Action	Have reached some level of change in the past 6 months	Actively engage in the plan of care development and provide support for the plan
Maintenance	Have reached the behavior goal more than 6 months ago	Provide positive reinforcement to continue participation

that compliance with exercise was increased through patient education in a group of patients with rheumatoid arthritis. The therapist must identify and address barriers to implementation in the treatment plan while encouraging ongoing participation and relapse prevention.

Use caution when using standardized "exercise files." Patients may have difficulty adhering to an exercise program that seems nonspecific or unrelated to the patient's functional needs. In the early rehabilitation phases, some exercises may not appear "functional" to the patient, but are important foundational components of the treatment program, as they oftentimes address impairments. Explaining the importance of the exercise educates the patient about the condition, assures the patient of the clinician's understanding of the problem and the potential solution, and treats the patient as an educated participant in the rehabilitation process. Further explanation of how the exercises will progress to more functional activities that address activity limitations and participation restrictions validates the importance of that activity and verifies that this is important to the patient.

Exercise program progressions should more closely reflect the identified activity limitations and participation restrictions. For example, for the individual recovering from shoulder surgery who is unable to reach a top shelf repeatedly (activity limitation), transferring dishes or groceries of increasing weight from the counter to the shelf for progressively longer periods is more motivating and interesting than lifting a 1-lb weight (**Fig. 3-2**). This type of activity has the added benefit of requiring distal muscle function that more closely replicates the actual functional activity. Weights and tubing are useful adjuncts to the rehabilitation program and, when possible, should be used in a way that duplicates the functional activity. Rather than performing a series of cardinal plane shoulder exercises, mimicking activities such as a tennis swing, raking, sawing, or throwing a ball (participation restriction) can increase strength and reinforce important motor programs (see **Building Block 3-3**).

A therapeutic exercise program requiring the fewest lifestyle changes increases the patient's adherence to it. Rather than trying to add more activities to the patient's day (often asking that exercise be performed several times per day), choose exercises that can be incorporated into his or her day. If an exercise program requires 15- or 30-minute time blocks carved out of a person's busy day, adherence is difficult despite the patient's desire to participate. If the exercises can be blended into activities that the patient already does during the day, adherence becomes much easier (**Evidence and Research 3-8**). An example of an exercise program for a patient with adhesive capsulitis can be found in **Display 3-1**.

FIGURE 3-2 Choose home exercises reflective of the patient's usual activities such as lifting cans up onto a shelf.

BUILDING BLOCK 3-3

Kathy returns to physical therapy and is pleased with the progress but is anxious to return to tennis. She can see how she is getting stronger and her ROM is nearly full. She is concerned that she will not be able to make the arm movements necessary to play tennis. Her exercise program has focused on cardinal plane strengthening from 0 to 90 degrees on land and on overhead swimming strokes and diagonal patterns in the pool. How might you modify her exercise program to address her concerns?

Fitting exercise into the patient's daily routine establishes a conditioned response that may carry over after therapy is concluded. For example, if a patient needs to increase the length of the gastrocnemius-soleus complex by stretching several times each day, instructing that person to stretch for 20 to 30 seconds each time he or she ascends the stairs is less burdensome than doing this as part of an exercise routine at

EVIDENCE and RESEARCH 3-8

A study by Fields et al.[29] examined the relationships among self-motivation or apathy, perceived exertion, social support, scheduling concerns, clinical environment, and pain tolerance to adherence to sport injury rehabilitation in college-age recreational athletes. Of the variables under consideration, significant differences were seen between adherers and nonadherers in self-motivation, scheduling concerns, and pain tolerance; of these factors, scheduling concerns contributed most to the overall group difference. In another study, Sluijs et al.[8] found that the strongest factor in nonadherence was that the exercises did not fit into the patient's daily routine.

the day's end. For the individual needing to increase shoulder flexion ROM, leaning ahead with his or her arm forward and flexed on the desk or kitchen counter before making a phone call is a productive use of time. This may become a conditioned response, and whenever the phone rings, the individual associates that activity with stretching his or her shoulder, or whenever the patient climbs the stairs, he or she thinks of calf stretching. This technique works particularly well with postural reeducation exercises (**Fig. 3-3**).

DISPLAY 3-1

Home Exercise Program for an Office Worker with Adhesive Capsulitis

Impairments

1. Decreased ROM in all directions in a capsular pattern
2. Decreased strength tested by manual muscle tests in all major shoulder muscle groups
3. Resting pain at 4 on 0 to 10 (0 = least; 10 = most pain); activity pain at 8 and 0 to 10.

Activity Limitations

1. Unable to use the arm for activities of daily living
2. Unable to lift weight with the arm held away from the body
3. Unable to get the arm over the head for work and daily activities

Participation Restrictions

1. Unable to fulfill all roles at work, such as filing heavy documents
2. Unable to participate in leisure activities, such as bowling

Home Exercises

1. Stretching for shoulder elevation while in warm shower
2. Active use of the arm for personal hygiene, including showering, combing hair, dressing, eating, and pendulum exercises during dressing
3. Scapular retraction exercise with abduction in front of the mirror during grooming three times per day, looking in the mirror each time
4. Shoulder flexion or abduction stretch on the desk when talking on the phone
5. Passive shoulder external rotation stretch at the file cabinet every time
6. Isometric exercise while reading morning mail
7. Walk with large arm swings during lunch hour
8. Supine overhead stretches on the couch during the evening news
9. Use the arm as much as possible for cooking, dishwashing, housework, and yard work
10. Resistive tubing exercises sometime during the day—patient's choice

FIGURE 3-3 Prescribe exercises that can be performed during other home or work activities.

Psychomotor Domain: Motor Learning

Patient education and instruction in a clinic or home exercise program require more than the simple transfer of information from the provider to the client. While some aspects are clearly cognitive, many are psychomotor. Exercise program design and exercise execution can impact the client's participation and eventual success. A successful program is designed to maximize learning a skill and to facilitate carryover of that skill to other environments, contexts, or situations. Factors for success extend beyond cognitive and affective to include psychomotor. How the exercises are ordered and how feedback is provided affects the motor learning process. Thus, another important focus of exercise program design and patient education is motor learning.

Models of Motor Learning

- Opportunities to enhance motor learning exist within the exercise program design. **Motor learning** is defined as the acquisition and/or modification of movement.[30] Some issues affecting the acquisition and learning of motor skills include the organization of practice conditions, the type and frequency of feedback, and the use of observational practice.

These factors influence the patient's ability to learn, apply, and retain motor programs. Learning is different from performance:

TABLE 3-2

Two Major Models of Motor Programming

	FITTS AND POSNER		SYSTEMS MODEL		EXAMPLE
	STAGE NAME	CHARACTERISTICS	STAGE NAME	CHARACTERISTICS	LUMBAR STABILIZATION
First stage	Cognitive	Gross motor strategies developed	Novice	Cocontraction restrains degrees of freedom	Learner overconstrains, tightening all pelvic muscles in order to control movement
Second stage	Associative	Motor strategies further refined	Advanced	Constraint reduced and degrees of freedom increased	Muscle activation and cocontraction are decreased as appropriate pelvic control is learned
Third stage	Autonomous	Motor tasks performed with little cognitive input	Expert	All degrees of freedom are released	Learner activates core muscles in the right sequence and right level for task at hand in a variety of situations

learning is more permanent, reflecting a true change in a person's ability to perform a skill whereas *performance* can be temporary, affected by the immediate testing conditions.[31]

Researchers and clinicians have attempted to characterize the process of learning a new motor skill. Visualize the last time you learned or watched someone else learn a new motor skill such as snowboarding, skating, or playing a musical instrument. Various theories related to the stages of motor learning exist; two three-stage theories will be summarized (**Table 3-2**).

The **Fitts and Posner[32] model** labels the first stage as *cognitive*. In the cognitive stage, attention to the task is necessary to master the fundamental components of the skill. During this phase, gross motor strategies are developed. Overcorrection and exaggerated movements are typical in this phase. The second phase, or *associative* phase, is characterized by further refinement of these gross strategies. Movements are becoming more efficient with less overcorrection and more refined muscle activation. The third and final phase is the *autonomous* phase where the motor program is activated and implemented with little cognitive input.

Another model, the **systems three-stage model**, is based on controlling the movement and degrees of freedom as the central tenet of motor learning.[30] In the first, or *novice* phase, the learner uses muscle agonist–antagonist cocontraction to restrain movement and control the degrees of freedom.[33] Here, the learner simplifies movement by constraining or coupling some joints, thereby stabilizing or fixating these joints, decreasing the degrees of freedom to be managed. This is a relatively inflexible and inefficient movement pattern. The second phase, or *advanced stage*, is characterized by reducing constraint and increasing the degrees of freedom to be managed. This allows more coordinated movement without the constraint of agonist–antagonist cocontraction. Movement becomes more efficient and less rigid. The final phase, called the *expert phase,* sees the individual now releasing all degrees of freedom, and movement is allowed to proceed in the most efficient and coordinated manner. Movement is adaptable to multiple environments.

Varying Practice Conditions: Contextual Interference

Theories of motor learning have been tested using a variety of practice conditions. Therapists strive to teach patients effective and efficient motor programs that they hope will transfer to a variety of situations. When a motor learning does not generalize to other environments or situations, it is termed *interference*.[34] Contextual interference is the process of using various forms of interference during a practice session in order to improve retention and carryover.[35,36] Contextual interference[35,36] and its ability to enhance motor skill acquisition appear to be affected by many variables including practice schedule (random, blocked, serial, combined), focus of attention, previous experience, feedback, age, and the task difficulty[37–41] (**Evidence and Research 3-9**).

EVIDENCE and RESEARCH 3-9

In an example of a motor programming trial, Herbert et al.[42] examined the effectiveness of different feedback schedules on the performance and learning of a lumbar multifidus muscle activity. Those subjects who had a variable practice schedule performed better 3 to 4 months later than did those with a constant practice schedule.

Practice Schedule

In general, it appears as though random practice conditions (where the patient practices several different tasks in random order) result in superior transfer skill performance compared with blocked practice conditions (practicing one task and then moving on to the next) or serial practice conditions (the practice schedule is ordered and predictable).[43] However, blocked practice seems to be more effective when learning a new skill[44] (**Evidence and Research 3-10**). Thus, the stage of motor learning as well as the individual's capacity for learning must be considered when choosing random, blocked, serial, or combination

EVIDENCE and RESEARCH 3-10

Bertollo et al.[46] taught a group of adolescent girls a rhythmic dance sequence in either blocked or random sequence, testing after 6 training sessions and testing retention 21 days later. The blocked group performed better than the random group immediately after the training sessions. The random group showed fewer performance decrements over the 21-day interval, resulting in similar performance to the blocked group in the retention trial.

practice conditions. Porter et al.[45] found that increasing contextual interference (starting with blocked, then serial, and finally random schedules) showed superior performance, retention, and transfer to other generalized motor programs compared with either blocked or random only schedules. It may be more appropriate to use a blocked practice schedule during the acquisition phase or with lower-skilled individuals, progressing to random practice conditions once the skill is acquired.

The application of practice schedules also varies by other population variables. It appears that children, perhaps because of less life experience and practice at many tasks, respond more robustly to a varied practice schedule than do adults.[47,48] Subjects with Parkinson disease performed better with a blocked order practice schedule.[49] However, while varying practice conditions may intuitively seem superior, most importantly, the training should mimic functional activity and trend toward a constant practice schedule.[50–52] At this point, varying other components of the practice situation, such as focus of attention, may be more appropriate.

Feedback: Focus of Attention

Attentional focus, or the act of directing attention to information sources or objects, is another variable impacting motor learning.[39] Attentional focus has been divided into *external focus of attention*, where the learner focuses on the action results, and *internal focus of attention*, where the learner attends to the body movements. For example, when learning to kick a ball, cues for an external focus ask the learner to attend to the movement of the ball and its position relative to the target. An internal focus would ask the learner to attend to the movements of the hip, knee, and foot while kicking.

Although numerous studies have found that groups trained with an external focus performed better on both immediate and transfer trials, other studies suggest that preference for an external or an internal focus may be skill and/or age dependent[53–56] (**Evidence and Research 3-11**). In adults, it has been hypothesized that an internal focus constrains the motor system, altering the usual automatic control processes.[53,54] A large body of research suggests that instructions that promote an internal focus or draw attention to the patient's bodily movements disrupt the automatic processes that produce efficient movement patterns.[57–61] The internal focus also requires more cognitive input, potentially limiting available space for additional information processing, such as other players, ball movement, environmental conditions.[62] Therefore, in adults, particularly those of some skill level, an external focus of control will likely produce optimal results. These findings have been reproduced in a number of populations and conditions including elderly women,[63] low-skilled sprinters,[64] patients post ankle sprain,[65] patients following a stroke,[66] in patients with Parkinson disease,[67,68] and in agility[69] and plyometric training. Moreover, increasing the distance of the external focus of attention led to further improvements in activities such as the standing long jump.[70,71] Focus preferences in children are less clear, and whereas some research supports a preference for an internal focus of control, others have found external or combined attentional focus producing better outcomes, suggesting a need for further study.[39,47,72]

EVIDENCE and RESEARCH 3-11

A study of highly skilled and lesser skilled golfers found that the highly skilled golfers performed better with an external focus of control, while the lesser skilled golfers performed better with an internal focus.[53]

Feedback Frequency

The type and schedule of feedback impacts motor program development. The timing of performance feedback can vary from during performance to immediately after or can be delayed. Feedback frequency can vary, with feedback given randomly, scheduled, or with every trial; importantly, the feedback schedule can be self-controlled. Research on optimal feedback schedule is often confounded by the type of feedback given. For example, a high frequency of feedback that has an internal focus can compromise motor learning[73] (**Evidence and Research 3-12**).

EVIDENCE and RESEARCH 3-12

Wulf et al.[73] studied the effects of feedback frequency (100% vs. 33%) and type of feedback (internal vs. external) in a group of experienced soccer players. Accuracy was increased in the external focus group, and frequency of feedback did not affect accuracy in this group. However, the internal focus group performed better under conditions of reduced feedback, suggesting that frequent internal focus feedback may have negative effects on performance.

Research into the motivational aspects of feedback has suggested that feedback provided after "good" trials results in more effective learning than feedback provided after "poor" trials.[31,74] Many individuals have a relatively accurate sense of their own performance, rendering corrections after a poor trial redundant. This can increase the self-focus, constraining the body's automatic processes and further compromising motor learning.[58]

Self-control over the practice session and feedback schedule has emerged as an important motor learning factor.[75–78] In most clinics, the therapist determines the patient training schedule including the activity choices and their frequency, intensity, duration, and sequence. However, subjects who were allowed to choose when they received feedback showed greater improvements in motor learning (measured by a delayed transfer task) than those who received scheduled feedback. Both groups preferred receiving feedback after "good" trials.[76] Additionally, subjects who were allowed to choose whether or not to receive feedback after their trial showed greater motor learning effects than those who had to choose before their trial.[77]

Visual Feedback: Observation and Mental Practice

Feedback extends beyond verbal feedback to include an ever expanding variety of feedback techniques to enhance motor learning. Movement observation, either alone or combined with physical practice, has been shown to improve motor learning.[79–81]

Brain imaging has identified a network of several regions of the brain that are activated when observing a physical activity.[82–84] These networks are activated similarly when an individual performs as well as observes a task.[85] Additionally, the model

EVIDENCE and RESEARCH 3-13

Research suggests that observing either a correct model or a peer model (someone also in the process of learning the skill) is equally effective in learning a motor skill.[86,87] Peer observation may allow the observer to observe movement deficits and devise motor strategies to correct these deficits without the dual demand of the cognitive load and physical performance.

observed does not have to be an expert at the task in order for learning to take place (**Evidence and Research 3-13**). Observing a peer provides the observer with an opportunity to problem solve deficits without the simultaneous physical demand (**Fig. 3-4**).

Many high-level athletes use mental practice to augment their physical training. Research has shown improved performance when mental practice was combined with physical practice.[88] In general, mental rehearsal and imagery can be a useful adjunct to physical practice.[89–92] However, mental practice alone is not a sufficient substitute for physical practice.

Combined observational and physical practice can be easily achieved using dyad training. Dyad training uses pairs of individuals alternately performing and observing a task. Dyad training research has shown that this type of training provides efficient use of resources, possible competitive motivation, and improved performance and learning.[57,62,93–95] Dyad training using alternate practicing with a partner can be more effective than individual training even when retention trials are performed individually.[93] However, dyad training outcomes can be specific to the environment and task at hand[96,97] (**Fig. 3-5**).

An alternate form of observational training is the use of video feedback or video overlay of a movement pattern. A video overlay uses a video model of the approximate same size and proportions as the individual performing the task correctly. This provides a target for the individual who can see a video overlay of his or her own movement pattern to observe how closely it matches the correct model's pattern.[62] The goal is to achieve full overlap of the individual and the correct model during the movement being trained. This type of training provides real time external attentional focus feedback of motor performance.

APPLICATIONS: HOME EXERCISE PRESCRIPTION

Prescribing exercises for a home program is challenging. These exercises are performed without supervision, and patient education is critical for success. Frequently, limited patient visit time further challenges the clinician to teach the patient all the necessary components of the self-management program. Providing a short, safe home exercise program is better than being too broad and overwhelming the patient with information on the first visit.

Considerations in Exercise Prescription

Exercise prescription can be difficult for several reasons. We know less about exercise prescription in those with impairment, injury, or disease, making proper exercise dosage determination challenging. Too little exercise may not produce the desired result, whereas too much exercise may overwork the patient, resulting in a decline in progress. Many factors influence choices regarding the exercise prescription:

- Stage of healing
- Tissue irritability and symptom stability
- Daily activities
- Time between physical therapy visits
- Ensuring proper exercise execution
- Equipment and environment
- Patient's time and willingness to participate

A B

FIGURE 3-4 Athlete watching another athlete jump off **(A)** and **(B)** land from a box. Observation of another person performing an activity can improve learning.

FIGURE 3-5 Athletes watching each other **(A)** jump, and **(B)** land in dyad training. Dyad training is another effective strategy for motor learning and works well in partner activities.

Stages of Healing

The acuity or chronicity of the injury affects the exercise prescription, including the regularity of supervised physical therapy and the time between visits. In the early stages, give the patient a few things to do at home between closely scheduled supervised visits. In this phase, appointments may be more frequent because of the rapidity with which the patient's symptoms and impairments are changing. The exercise program changes more frequently as goals are met and new goals established. In the early stage, the symptoms may be new to the patient, making determination of the appropriate exercise level difficult. Closely following the response to treatment is necessary to ensure forward progress. Conversely, in the intermediate to later stages, changes in the patient's symptoms and function occur more slowly, and the exercise program may be more extensive. At that point, the patient is often instructed in self-progression of activities.

Tissue Irritability and Symptom Stability

Tissue irritability has a significant effect on intervention choices. This factor is somewhat subjective and is determined through a complete subjective examination. Questions regarding the patient's symptoms provide the clinician with the best information on this issue (**Display 3-2**).

Before deciding on the content of the home program, understand what kinds of activities or positions worsen the patient's symptoms. These activities or positions may or may not need to be avoided. If the patient can tolerate the activity or position for some time, is able to detect the prodromal signs that the symptoms are going to worsen, and understands that stopping the activity or changing position can alleviate the symptoms, use these activities or positions therapeutically. For example, if a patient with carpal tunnel syndrome enjoys knitting but knitting is currently compromised (participation restriction), knitting may be used as part of the rehabilitation program. The patient must be able to recognize the onset of symptoms and be able to alleviate them by taking a rest period or discontinuing the knitting. Similarly, if a patient with back pain enjoys and is able to tolerate some walking, this activity can be a component of the exercise program. The patient must be able to detect the onset of symptoms and relieve them by discontinuation, stretching, icing, or some other self-management intervention. Conversely, if the patient reports an unmanageable, inevitable worsening of symptoms once irritated, the exercise program should expressly avoid any position or activity that may exacerbate symptoms.

DISPLAY 3-2

Questions Assessing Tissue Irritability

1. What activities or positions increase your symptoms?
2. How much time can you spend in that activity or position before your symptoms begin?
3. When you start feeling these symptoms, will they continue to progress despite discontinuing the activity or changing positions? Will changing the activity or position alleviate the symptoms?
4. After you begin experiencing your symptoms, how long do they last? How long until you return to "baseline?"
5. Is there anything you can do to relieve your symptoms?

Be sure to consider the *stability* of the patient's symptoms as a component of tissue irritability. Individuals may have significant unpredictable fluctuations in their symptoms over the course of the day or week. If symptom changes cannot be associated with the time of day, position, or any specific activity, the exercise prescription can be difficult. If the patient is unable to determine what kinds of things make him or her better or worse, assessing the effects of the exercise program becomes yet another variable in the symptomatology. Deciding whether a specific exercise prescription is beneficial or deleterious is challenging if the patient's symptoms fluctuate randomly. When possible, it is best to proceed with fewer exercise interventions until a stable baseline of symptoms is achieved. This baseline then serves as a gauge of the effect of the exercise program.

Daily Activities

The patient's other daily activities affect the exercise prescription. Understanding the behavior of a patient's symptoms over a 24-hour period and how his or her normal daily routine affects the symptoms helps the clinician to gauge appropriate exercise levels. The patient may be unaware of the impact of certain routine activities on his or her problem, or the patient must perform some activities that worsen his or her symptoms (such as sitting or walking). For example, counsel the individual with patellofemoral pain about the importance of good shoes, particularly if standing for a large portion of the day. Despite the fact that standing behind a cash register for 8 hours may exacerbate the patient's symptoms, this work may be financially necessary. The individual with back pain may need to lift a child out of a crib several times each day, despite the fact that this activity is painful. Educate the patient about the impact of these activities on symptoms and provide suggestions to minimize their negative effects. Educate the patient regarding modification of the exercise program based on the symptoms related to participation in these activities. On days when the patient's symptoms may be increased because of excessive standing, working, or lifting, he or she may need to decrease the rehabilitation exercise level. Failure to recognize the impact of daily activities on symptoms may cause the clinician to erroneously assume that a change in the patient's symptoms was caused by the exercise program alone.

Time Between Physical Therapy Visits

The time between follow-up visits affects the exercise prescription. For the patient attending supervised physical therapy one or more times per week, the clinician may give the patient more challenging home exercises, knowing that the patient will be monitored more closely in the clinic. For those patients who live some distance away or who have longer intervals between supervised visits for other reasons, provide exercises that are less likely to overwork the patient. Supplement this program with instructions on how to progress exercises if they become too easy (e.g., increase time, repetitions, intensity), or schedule an intermediate phone follow-up. In many cases, interim contact with the patient via a phone call or electronic communication can assess the patient's progress. The therapist can make suggestions on how to modify the home program until the patient's next clinic appointment, thereby avoiding any plateaus in the rehabilitation process.

Proper Exercise Execution

Although patients may appear to follow the exercise instructions, they may still perform the exercise incorrectly. Patients may understand the instructions, but:

- The instructions may be incomplete or unclear
- Patients may read things into the instructions
- Patients may simply be unaware that they are doing the exercises incorrectly

For example, the patient may think he or she is performing a trunk curl but is actually doing a full sit-up or performing a straight leg raise without the necessary quadriceps set first.

Ensure proper performance by:

- Having the patient perform each of the exercises under your direction and guidance
- Providing verbal and tactile cueing for proper performance
- Encouraging the patient to take notes during these sessions
- Incorporating evidence on the psychomotor aspects of motor learning

Although written and verbal instructions help ensure proper performance, more instruction is occasionally necessary. Other options include having a family member observe the clinician instructing the patient, so that this individual may guide the patient's home exercise performance. Videoing the exercise session allows the patient to see him or herself performing the exercise, along with hearing the clinician's verbal cues and observing tactile cues for proper performance. The patient can replay this video at home if a question regarding the exercise program exists.

When the patient returns for follow-up, ask him or her to demonstrate the home exercise program. In most cases, if the patient has been performing the exercises on a daily basis, the exercises should nearly be committed to memory. The ability of the patient to quickly recall the exercises with or without the assistance of the handout may provide insight into adherence. Moreover, this shows precisely how the patient has been executing the exercise. Frequently, the exercise has been changed somewhat from the clinician's original intended performance, and this may affect the patient's progress since the last visit. Occasionally, the incorrect exercise performance can have negative consequences, such as increasing the patient's symptoms or hindering progress (**Fig. 3-6A** and **B**).

A B

FIGURE 3-6 Review the exercise program at follow-up visits to ensure correct performance. **(A)** Incorrect position—straight leg raise without appropriate quadriceps set. **(B)** Correct performance—clinician cues the patient for correct exercise performance.

Equipment and Environment

Along with determining what motivates the patient, determine the motivation derived from the use of exercise equipment. Performing exercises using body weight, objects in the home or office, or work tools may be more functional; however, the patient may feel like this is not really exercise if it does not involve weights or resistive bands. Patient education is necessary to ensure the patient knows the importance of these activities. However, preconceived ideas about exercise are frequently difficult to overcome, and adherence may be improved by use of some equipment. The financial cost of purchasing some equipment for home use may increase or decrease adherence. If money must be spent to carry out the exercise program, the patient may decline participation. However, some patients feel obligated to use equipment that they have purchased. Assess the patient's position on this issue before issuing or recommending purchase of equipment.

When designing an exercise program with some specific equipment, ensure that the patient has a place to use the equipment (**Fig. 3-7**). For example, the patient's home may or may not have stairs. Accommodations may be necessary if exercises require the use of a step. When prescribing exercises to be performed in a supine or prone position, a surface of the appropriate height and firmness must be available. Exercises often are easy to perform on the plinth in the clinic, but the quality or the ability to perform the exercise is negated at home because of the patient's environment. The patient must be able to comfortably transition positions to and from that surface. If the only available firm surface to carry out the exercise program is the floor, the patient must be able to easily get up and down from the floor. If not, the exercise program should be modified to increase the ease of participation in the program.

FIGURE 3-7 Choose equipment that can be easily used by the patient at home.

A final aspect of the environment that the clinician has little control over but should consider is the presence of a supportive family. Social support is an important factor in patient adherence to a treatment regimen. Social support includes both the medical community and the patient's family and immediate community. Social isolation has been determined to be a major factor in nonadherence to a medication regimen. Lack of social support has contributed to dropping out of treatment in a number of studies.[98] Social support is particularly important when managing chronic disease, owing to the ongoing nature of the problem.

Be sure to evaluate the role of the family and other support systems in the patient's immediate community. The family or work community can either provide support or potentially have a negative effect. A supportive family can maximize the patient's opportunity to participate in medical care by being physically and emotionally supportive. Family members who take over duties normally carried out by the patient and advocate participation in the exercise program can enhance the patient's opportunity for improvement. Nonsupportive family members who criticize the patient for being injured or unable to carry out expected roles can create barriers to improvement.

If possible, involve the family members in the patient's care to ensure an understanding of the plan of care and prognosis. This will help them understand how the impairments, activity limitations, and participation restrictions are relative to the patient's goals and the plan to achieve the goals. If family members are nonsupportive, do your best to minimize their negative impact by providing additional support to your patient. Always be alert to signs of this situation and make referrals as necessary to ensure optimal participation in the rehabilitation program.

Patient's Time and Willingness

The amount of time the patient has available to exercise is an important factor affecting exercise prescription. If the patient claims to have little time available for the home exercise program, be sure to respect the patient's position on this issue. Educate the patient about the importance of the program in a nonjudgmental fashion, followed by conscious choices about priority exercises. Make an effort to select exercises considered to be the most important for the exercise program. More is not always better, and giving thoughtful consideration to the core exercises is beneficial for the clinician and the patient. Choosing exercises that have the greatest impact for the least time commitment can minimize the time requirement and maximize the benefits. The patient will probably appreciate your concern and attention to his or her needs. Couple this approach with education regarding the importance of the home exercise program to address activity limitations and participation restrictions in as expedient and efficient a time frame as possible. Emphasize

TABLE 3-3

Curwin and Stanish Classification for Determining the Appropriate Level of Discomfort Associated with Home Exercise Prescription

LEVEL	DESCRIPTION OF PAIN	LEVEL OF SPORTS PERFORMANCE OR ACTIVITY
1	No pain	Normal
2	Pain only with extreme exertion	Normal
3	Pain with extreme exertion and 1–2 hr afterward	Normal or slightly decreased
4	Pain during and after any vigorous activities	Somewhat decreased
5	Pain during activity and forcing termination	Markedly decreased
6	Pain during daily activities	Unable to perform

From Curwin S, Stanish WD. Tendinitis: Its Etiology and Treatment. Lexington, MA: DC Heath, 1984:64

your own and the patient's responsibilities in achieving those mutually defined goals.

Determining Exercise Levels

Determining the appropriate level of exercise can be difficult, particularly when the patient has had little or no experience with the specific problem or with exercise. Although many individuals exercise regularly, many others have little experience with exercise. Knowing how to respond to different sensations felt during the rehabilitation exercises can prove frustrating to the patient. Many patients ask whether to continue exercising if the exercise produces pain. Despite the fact that pain is a subjective symptom, acknowledge this sensation. Consider pain in the context of change from the patient's baseline symptom level and how the symptoms behave over the subsequent 24-hour period.

Curwin and Stanish[99] provide guidelines originally designed to help determine readiness to return to a sport. However, these same guidelines are nicely adapted to evaluate the patient's exercise program (**Table 3-3**). The column in Table 3-3 entitled "Description of Pain" refers to the level of pain during performance of the rehabilitation program, and the category "Level of Sports Performance or Activity" could be retitled "Level of Exercise Program Performance." Activity levels that keep the patient within his or her optimal loading zone are generally levels 1 through 3. Occasionally, some patients may be able to tolerate exercise at level 4 without any residual effects. For example, patients with adhesive capsulitis often experience pain at level 4, but this level of pain does not interfere with their overall function or progress. These guidelines provide the patient and the clinician with common criteria by which the exercise program prescription is evaluated.

Despite the clinician's best efforts, some patients experience an exacerbation of their symptoms, which may or may not be related to the exercise program. Although the first response of the clinician and the patient may be some level of distress, an exacerbation is not always a negative experience. An exacerbation can be a "teachable moment" with valuable lessons learned. At some point, whether days, weeks, months, or years later, most patients experience some type of symptoms related to the current problem. The patient with patellofemoral pain may experience a milder level of pain after a hiking vacation, or the individual with low back pain may notice some back discomfort after a long plane flight. Some patients experience a complete exacerbation of their symptoms at some future point, and patients must learn how to manage exacerbation of symptoms.

Therapist-guided self-management instruction can teach the patient how to intervene immediately in future cases of an exacerbation. Too often the patient experiencing a recurrence of symptoms delays obtaining medical attention or has difficulty obtaining a timely appointment. The optimal time for intervention has passed, and the patient may be struggling with secondary problems resulting from compensation, movement changes, or other impairments. One of the best services the clinician can offer the patient is instruction on how to manage the acute return of symptoms. Instruction may include the use of modalities such as ice, activity modifications including relative rest, changes in the maintenance exercise program, and education regarding when to seek medical attention.

In addition to possibly preventing reentry to the medical system through immediate, appropriate symptom management, self-management has the added benefit of enhancing patients' confidence in their ability to resolve the symptoms. The exacerbation experience coupled with instruction in appropriate management under the clinician's guidance can greatly decrease the patient's anxiety. Patients are often fearful about participating in activities that may provoke their symptoms, afraid that they will be "back where they started" in the early stages of their injury. Learning that an exacerbation does not necessarily send them back to the initial phase and that they can successfully manage the problem independently empowers patients to make appropriate activity choices. Eventually, patients may choose to participate in activities they enjoy at the expense of getting a little sore, knowing that they can successfully manage the symptoms independently (see **Building Block 3-4**).

BUILDING BLOCK 3-4

Kathy had been performing racquet swings without a ball for 15 minutes per day as part of her rehabilitation program. On a warm sunny day, she decided that she wanted to start hitting a ball, so she joined her usual tennis partner for 40 minutes of light hitting on the court. She returned to physical therapy 3 days later with increased pain throughout the shoulder girdle. She reported that the pain was different from the pain she experienced when she injured her rotator cuff. She is again highly concerned that she will not be able to return to tennis. What are some possible educational strategies and recommendations?

Formulating the Program

When possible, **formulate the exercise program after the patient's baseline level of symptoms has stabilized** and the previously mentioned factors (e.g., tissue irritability) have been determined. Ensuring the patient's understanding of what the "baseline" feels like allows better communication between the clinician and the patient regarding the behavior of his or her symptoms and the effects of the exercise program. Symptoms that are unstable or fluctuating without determinable cause make assessing the effects of intervention difficult. Ask the patient to articulate his or her "normal" level of symptoms to assist in determining the stability of symptoms. If patients have difficulty determining the stability of their symptoms, slow progression is necessary. When the patient is able to perform the same exercise program for three consecutive sessions without an increase in symptoms, progression is appropriate.

If intervention needs to be implemented before establishing a stable baseline, **give the patient as few exercises as possible**. This minimizes the impact of the exercise program, thereby lowering the possibility of exacerbating the symptoms. If the patient's symptoms do worsen, you will have an easier time determining the cause, and changes can be made more appropriately. As symptoms resolve and the baseline stabilizes, increase activities systematically and gradually. Do this by increasing the time and repetitions or by adding new exercises slowly.

Vary the exercise program progression based upon each person's stage of injury, specific goals, and stability of symptoms. For the individual who is in the intermediate to late healing stages and has demonstrated stable symptoms, several exercises can be progressed simultaneously. For those with unstable symptoms and frequent exacerbations, keep rehabilitation program changes to a minimum. In this way, any positive or negative response to the change can be more easily identified and remedied.

Teach patients how to modify their exercise program based on their activity level on any given day. Put exercises in the context of their daily routine. On days when the patient is more active (e.g., working overtime, child care, shopping, yard work), modify the home exercise program to prevent overload. On days when the patient is more sedentary (e.g., bad weather, day off from work), increase the exercise program. In this way, the patient begins to understand the impact of his or her overall activity level on his or her symptoms. This assists the patient in the self-management of symptoms in the future.

Choose exercises that can be incorporated into activities already performed during the day. This type of exercise prescription results in short bouts of exercise performed several times throughout the day, thus improving adherence. In this case, the patient is unlikely to overwork in any single session, resulting in a lower chance of an exacerbation of symptoms. Moreover, the likelihood of exacerbation is decreased despite a greater volume of exercise that can be performed in any single session. For example, the individual with Achilles tendinitis may tolerate only two repetitions of 30 seconds of calf stretching at a time. If that individual performs those two repetitions six times spread out over the course of his or her day, the stretch has been performed 12 times. By contrast, if the patient tried to carry out the home exercise program in the evening, chances are that only two repetitions would be performed that day.

Finally, teach the patient that some exercise is better than none, and if time limitations exist, a couple of key exercises identified by the therapist should be performed. Occasionally, other life events prevent completion of the full home exercise program despite the patient's willingness to adhere. Prioritize the exercises, highlighting those that are most important to complete if time does not permit completion of the entire program. Emphasize the importance of finishing all of the exercises when time permits, while suggesting that some exercise is better than none.

KEY POINTS

- Patient education and self-management have become increasingly important with greater life expectancy.
- Patient safety is the first consideration when designing a home exercise prescription.
- Exercises requiring the fewest lifestyle changes can increase adherence.
- Patient–clinician communication is enhanced by determining the patient's willingness to learn and listening actively to the patient's needs.
- Written and verbal instructions should be included in a home exercise program. Written exercises should include beginning and ending positions and any precautions. Use video when possible.

Incorporate evidence regarding the psychomotor aspects of exercise performance in order to facilitate motor learning.

- At follow-up visits, have the patient demonstrate the home exercise program to ensure correct performance of all exercises.
- Home exercise choices are affected by the acuity of the injury, tissue irritability, stability of symptoms, patient's daily activity level, time available for exercise, and factors affecting the length of time between follow-ups.
- A symptom exacerbation can be a learning experience for the patient if the patient is educated properly on symptom management.
- Patients must be encouraged to take control of their exercise program and taught how to modify their home exercise program based on other daily activities and symptoms.
- Understanding the typical behavior of their symptoms allows patients to more easily recognize an exacerbation and be able to guide activity choice and intensity.
- Any cultural, language, education, visual, or hearing barriers should be identified early and appropriate accommodations made.
- Prioritize exercises so that the patient may perform at least some of his or her exercises on busy days.

CRITICAL THINKING QUESTIONS

1. How would your home exercise instruction differ for patients who are
   a. Visual learners
   b. Auditory learners
   c. Kinesthetic learners

2. Consider the patient in Lab Activities. How would you provide this patient with a home exercise program if he or she were blind?
3. A patient returns to see you and reports that the home exercise was not done because of a lack of time. How would you respond? What would be your strategy and rationale?
4. A patient returns to see you and reports that the home exercise program was not done because the exercises hurt. How would you respond? What would be your strategy and rationale?

LAB ACTIVITIES

1. Refer to Case Study No. 6 in Unit 7. Design a home program for this patient. Include written instructions and diagrams for all exercises. Teach your patient this home program while relaying the following emotions:
   a. Empathy
   b. Disinterest
   c. Hurry
   d. Insecurity
2. Using the exercises developed for the first question, modify each exercise to be performed throughout the day, incorporating the exercises into the patient's daily routine.
3. Using the exercises developed for the first question, prioritize the exercises for the patient and explain your rationale for the prioritization to the patient. Use language the patient can understand.
4. Your patient desires to return to several sporting activities. Choose two of the exercises you have given the patient, and modify them to mimic a sporting activity to which the patient would like to return.
5. Teach someone else in the class who does not know how to tie a necktie how to do this without looking at each other and without using the words yes or no.
6. Pick several physical activities such as squats, lunges, side lunges, jumps, etc. Pair up in dyads and have one student perform an activity while the second attempts to match the movement pattern. Make corrections using an external focus of control.

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CHAPTER 4

Prevention and the Promotion of Health, Wellness, and Fitness

JANET R. BEZNER

The function of protecting and developing health must rank even above that of restoring it when it is impaired.
—*Hippocrates*

Interventions aimed at preventing injury and illness are among the many tools physical therapists use on a daily basis to address the health needs of patients and clients they serve. Indeed, prevention, health promotion, fitness, and wellness efforts have recently garnered increased attention as the nation struggles to control escalating health care costs and to stop the progression of chronic diseases that have reached epidemic proportions.[1,2] It has been estimated that 50% of premature deaths in the United States are related to modifiable lifestyle factors,[3] so there is clearly a need for effective prevention programs and efforts aimed at reducing risk factors and improving health and wellness.

Traditionally, the physical therapist's role in prevention and wellness has been narrowly focused on preventing a recurrence of the injury or illness a patient already has experienced or identifying risk factors and preventing escalation into disease. For example, when treating a patient recovering from an ankle sprain, some rehabilitation activities are directed toward preventing a recurrence of that injury. The approach may include direct interventions such as balance exercises or indirect interventions such as patient education. Physical therapists may perform biomechanical analyses such as running gait analysis or ergonomic workstation analysis to identify risk factors predisposing clients to injury. Although appropriate and worthwhile, these efforts do not produce the significant outcomes that primary prevention programs might, because they are applied after the onset of risk, illness, or injury. Contemporary physical therapist practice is consistent with the American Physical Therapy Association's (APTA) Vision Statement for the Profession—transforming society by optimizing movement to improve human experience.[4] There is a role for the physical therapist in addressing all barriers and limitations to movement—that is, interacting with patients and clients to promote health and improve wellness, thereby minimizing participation restriction.

Physical therapists' efforts in health and wellness promotion require an expanded view of health beyond the biomedical or disablement models. Additionally, it is important to recognize that clients may not be motivated to participate in health-causing behaviors until they become symptomatic or ill. In addition, patients may not be motivated to address health behaviors that may seem unrelated to the primary diagnosis for which they are seeking physical therapy. The purpose of this chapter is to explore the concepts of prevention, health promotion, fitness, and wellness. Because the remainder of this book discusses interventions aimed at injured or ill patients, this chapter focuses on primary prevention and the services that physical therapists can provide to clients before they become patients and to current patients to address health behaviors.

THE CONTEXT FOR PRIMARY PREVENTION

Numerous physical therapy professional references support a role for the physical therapist in health promotion and wellness. *The Guide to Physical Therapist Practice*, which defines the physical therapist's scope of practice, discusses the physical therapist's role in prevention and the promotion of health, wellness, and fitness.[5] The APTA vision statement, goals, and objectives and several policy statements reference the role of the physical therapist in the provision of health and wellness services.[4,6] Numerous state licensing acts include language permitting licensees to promote and maintain fitness, health, or wellness in all age groups.[6] The accreditation criteria for physical therapist educational programs state that graduates of accredited programs are prepared to provide physical therapy services that address primary, secondary, and tertiary prevention; health promotion; and wellness to individuals, groups, and communities.[7]

Thus, the expectation that physical therapists participate actively in health and wellness practice exists in many professional documents. To provide such services, the physical therapist must first understand and differentiate the many terms used to describe these concepts.

DEFINITIONS

Prevention, Health Promotion, and Health Education

There are many terms used within the context of "prevention" within the US health care system. Differentiating these terms

FIGURE 4-1 Differentiation of primary, secondary, and tertiary prevention.

Prepathogenesis Period			Period of Pathogenesis		
Health promotion	Health protection	Preventive health services	Early diagnosis and prompt treatment	Disability limitation	Rehabilitation
Primary prevention			Secondary prevention		Tertiary

provides a valuable perspective for the delivery of appropriate services by physical therapists. **Figure 4-1** illustrates the prevention to intervention continuum, ranging from health promotion services to rehabilitation. The associated pathologic state of the patient/client at each stage of prevention is shown across the top of the diagram. Definitions and examples for terms in the figure are provided in **Table 4-1**. Prevention is divided into primary and secondary prevention services. Also referred to as public health, primary prevention includes health promotion, health protection, and preventive health services. Primary prevention takes place in the "prepathogenesis" period before the onset of disease. Secondary prevention services take place after the onset of illness or injury, in the presence of pathology, and include screening for the purpose of early diagnosis and treatment of disease, as well as disability limitation. Secondary prevention includes efforts to identify disease early by recognizing either the physiologic changes that precede illness or signs of subclinical illness. Examples include breast and prostate cancer screening, osteoporosis screening, medical preplacement evaluations, and accident reporting.[8] Also included within secondary prevention are efforts to limit disability for those with chronic diseases such as diabetes (i.e., a foot care educational program) or spinal cord injury (i.e., a program to prevent skin breakdown). Tertiary care, or rehabilitation, is the category that encompasses most traditional physical therapist services. Although the physical therapist may use health education methods to provide information in the case of a secondary prevention effort, the health status of the patient/client determines whether this information falls under primary, secondary, or tertiary care. For example, providing information about how to be physically active for a

TABLE 4-1

Definitions and Examples of Prevention, Health Promotion, and Related Terms

TERM	DEFINITION	EXAMPLE
Prevention[5]	The avoidance, minimization, or delay of the onset of impairment, activity limitations, and/or participation restrictions. Includes primary, secondary, and tertiary prevention initiatives for individuals as well as selective intervention initiatives for subsets of the population at risk for impairments, activity limitations, and/or participation restrictions	
Primary prevention[5]	Efforts that prevent a target condition in a susceptible or potentially susceptible population through specific measures such as a general health promotion effort	Messages to the general population to be physically active; messages to teenagers to not smoke
Secondary prevention[5]	Efforts that decrease duration of illness, severity of disease, and number of sequelae through early diagnosis and prompt intervention	Breast cancer screening (early diagnosis and prompt treatment) Education for patients with diabetes to perform regular foot inspection (disability limitation)
Tertiary prevention[5]	Efforts that limit the degree of disability and promote rehabilitation and restoration of function in patients with chronic and irreversible diseases	Traditional rehabilitation services
Health promotion[62]	The process of enabling people to increase control over, and to improve, their health	Messages to eat 5–7 fruits and vegetables per day; walking trails in communities; no smoking laws
Health education[63]	Any combination of learning experiences designed to help individuals and communities improve their health, by increasing their knowledge or influencing their attitudes	Educational classes on nutrition, diabetes prevention, prenatal care
Health protection	Strategies related to engineering the physical environment	Water fluoridation
Preventive health services	Traditional medical system efforts to prevent injury and illness	Immunizations

client without injury or illness might be classified as primary prevention, whereas providing the same information to a client with diabetes would be considered secondary prevention, and including physical activity in an intervention plan for a diabetic client who is receiving rehabilitation for an amputation would be considered tertiary care.

In terms of primary prevention, health promotion is the most significant component for the physical therapist to understand (see Table 4-1).

It is critical to recognize that health promotion is broad and includes both individual and social/regulatory activities. For example, a physical therapist working for a large manufacturing company may want to begin a smoking cessation program to improve overall worker health. However, if the employer does not have a nonsmoking policy, efforts to stop smoking at the individual level will most likely be ineffective. Other illustrations of the broad net of health promotion include programs to increase the activity levels of adolescents or the elderly, corporate policies that provide release time to exercise, and funding to support or build public parks and trails. In addition to supporting individual patients/clients to improve their health, physical therapists can and should play a role in societal efforts to remove barriers to physical activity and thus to health.[9,10] For example, physical therapists can advocate for sidewalks, public transportation, and lit walkways in communities and serve on local health boards, city councils, and other community groups where decisions that impact the health of members of the community are made.

Based on these definitions, it is apparent that the term health education falls under the umbrella of health promotion, and often the activities that would define each are overlapping.[11]

Health education activities are planned out (e.g., designed), rather than incidental experiences, and facilitate behavioral changes without coercion (e.g., voluntary). Examples of health education initiatives include counseling a patient on the risks of smoking, providing an osteoporosis prevention class for a corporate wellness program, and teaching children how to carry and load their backpacks safely.

Both health promotion and health education refer to the "broad and varied set of strategies to influence both individuals and their social environments, in order to improve health behavior and enhance health and quality of life."[11(p.11)]

Physical Fitness, Exercise, and Physical Activity

Within the context of therapeutic exercise as discussed in this book, the physical therapist has a primary and important role in all types of prevention to keep people active. Several terms are used to describe what laypersons commonly refer to as "exercise." Physical activity has been defined as any bodily movement produced by skeletal muscles that results in energy expenditure.[12] Examples of physical activity include walking, performing yard or housework, and playing catch. Similarly, exercise is a type of physical activity that is planned, structured, repetitive, and is purposely aimed at improving physical fitness. Consistent with this definition, exercise is typically prescribed in terms of frequency, intensity, and duration in a dose adequate to improve physical fitness (discussed in greater detail in Chapter 6). Physical fitness is a set of attributes that people have or achieve and includes components of health-related (cardiorespiratory endurance, body composition, muscular

CASE STUDY 4-1

A 36-year-old male (Derek Prager) has come to your practice following a left ACL reconstruction performed 3 days ago. He tore his ACL 1 week ago sliding into second base during a company softball game. He had arthroscopic surgery to reconstruct the ACL. He arrives to your office with his knee wrapped in an elastic bandage and using crutches. During your subjective history you obtain the following information from Derek:

- He is married and has two children; a 12-year-old daughter and a 10-year-old son. His wife works full-time outside of the home.
- He works approximately 60 hours per week as a construction foreman. He spends about 2 hours per day in his office and the rest of the day he is traveling between residential construction sites supervising his crew. He tells you that his job has become much more stressful the past couple of years because of conflicts with his supervisor.
- Derek smokes a pack of cigarettes per day and has smoked for 16 years.
- He tells you that he was diagnosed with high cholesterol about a year ago. He is currently taking Lipitor (cholesterol-lowering medication) once a day.
- His father died of a massive heart attack at age 60. He has an older brother who he describes as "a health nut." His brother participates in triathlons and eats "rabbit food."
- Derek's hobbies include watching sports on television, watching his children's sporting activities, and playing on the company softball team one night per week.
- Derek tells you that he has gained weight over the past 5 years but doesn't weigh himself and because his wife buys his clothes he doesn't pay much attention to changes in his clothing sizes.

In addition to the physical findings that you obtained regarding Mr. Prager's left ACL reconstruction, you also obtain the following information:

- Height = 5′11″
- Weight = 208 lb
- Body mass index (BMI) = 29
- Relationship of BMI to weight status according to the Centers for Disease Control and Prevention
  - Below 18.5 = Underweight
  - 18.5 to 24.9 = Normal weight
  - 25.0 to 29.9 = Overweight
  - 30.0 and above = Obese
- Resting HR = 70 bpm
- Resting BP = 128/84

endurance, muscular strength, flexibility) and athletic-related skills. Assessment of physical fitness is used to measure the impact of exercise or physical activity on the components of fitness, such as a 12-minute walk test to assess cardiorespiratory endurance. Based on decades of research on a wide variety of age groups, inclusive of both sexes and individuals with all types of chronic and acute disease, physical activity has been shown to be an extremely powerful resource to keep people healthy and to improve impairments, activity level, and participation level in those with health conditions.[13]

Wellness, Lifestyle, and Quality of Life

Wellness is defined in the *Guide to Physical Therapist Practice*, 3.0, as "A state of being that incorporates all facets and dimensions of human existence, including physical health, emotional health, spirituality, and social connectivity."[5] Because Dunn[14] conceptualized wellness in 1961 and offered the first formal definition of the term ("an integrated method of functioning which is oriented toward maximizing the potential of which the individual is capable"), wellness has been explained by various models and approaches.[15–22] Although the literature is full of definitions of, references to, and information about wellness, a universally accepted definition has failed to emerge. Several conclusions can be drawn, however, from the abundance of literature about wellness (see **Building Block 4-1**).

BUILDING BLOCK 4-1

Consider the Patient in Case Study 4-1

1. Given the patient's history and examination findings, what health education and/or health promotion interventions might be indicated during the patient care episode?
2. Does Mr. Prager perform regular exercise?

For many people, including the public, health and wellness are synonymous with physical health or well-being, and commonly consists of physical activity, efforts to eat nutritiously, and adequate sleep. Research has indicated that when the public is asked to rate their general health, they narrowly focus on their physical health status, and do not consider their emotional, social, or spiritual health.[23] Referring back to the definitions introduced earlier, it is obvious that wellness includes more than just physical parameters. Wellness and fitness are not synonyms; as indicated in Chapter 1, well-being or wellness is a broad term, like quality of life, that the ICF defines as encompassing the total universe of human life.

The common themes that emerge from the various models and definitions of wellness suggest that wellness is multidimensi onal,[14,16–22,24,25] salutogenic or health causing,[14,16,19,20,22,26,27] and consistent with a systems view of persons and their environments.[14,28–30] Each of these characteristics will be explored.

First, as a multidimensional concept, wellness is more than simply physical health. Among the dimensions included in wellness are physical, spiritual, intellectual, psychological, social, emotional, occupational, and community or environmental.[31] Adams et al.[31] proposed six dimensions of wellness based on the strength and quality of the theoretical support in the literature.

TABLE 4-2

Definitions of the Dimensions of Wellness

Physical	Positive perceptions and expectancies of physical health
Psychological	A general perception that one will experience positive outcomes to the events and circumstances of life
Social	The perception that family or friends are available in times of need, and the perception that one is a valued support provider
Emotional	The possession of a secure sense of self-identity and a positive sense of self-regard
Spiritual	A positive sense of meaning and purpose in life
Intellectual	The perception that one is internally energized by the appropriate amount of intellectually stimulating activity

Adams T, Bezner J, Steinhardt M. The conceptualization and measurement of perceived wellness: integrating balance across and within dimensions. Am J Health Promot 1997;11:208–218.

The six dimensions and their corresponding definitions are shown in **Table 4-2**.

The second characteristic of wellness is that it has a salutogenic (e.g., health-causing) focus in contrast to a pathogenic focus in an illness model.[27] Emphasizing that which causes health is consistent with Dunn's original definition.[14] It suggests that wellness involves maximizing an individual's potential, not just preventing an injury or maintaining the status quo. Wellness involves choices and behaviors that emphasize optimal health and well-being beyond the status quo.

Third, wellness approaches use a systems perspective. In systems theory, each element of a system is independent and contains its own subelements, in addition to being a subelement of a larger system.[24,28,29] Further, the elements in a system are reciprocally interrelated, indicating that a disruption of homeostasis at any level of the system affects the entire system and all of its subelements.[28,29] Therefore, overall wellness is a reflection of the state of being within each dimension and a result of the interaction among and between the dimensions of wellness. **Figure 4-2** illustrates a model of wellness reflecting this concept. Vertical movement in the model occurs between the wellness and illness poles as the magnitude of wellness in each dimension changes (see "black arrow" in Fig. 4-2). The top of the model represents wellness because it is expanded maximally, whereas the bottom of the model represents illness.

The size of each dimension (a subelement in systems theory) represents how much wellness an individual possesses in that dimension. As wellness fluctuates in each dimension, an effect is generated on all of the other dimensions, resulting in the reciprocal interrelation (Fig. 4-2). According to systems theory, movement in every dimension influences and is influenced by movement in the other dimensions.[31] As an example, an individual who experiences a shoulder injury and undergoes surgery to repair the rotator cuff will probably experience at least short-term decreased physical wellness (the size of the physical dimension on the diagram will decrease). Applying systems theory and

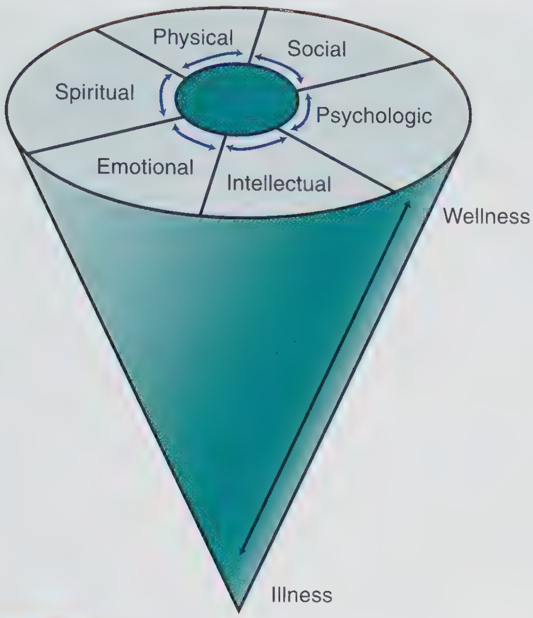

FIGURE 4-2 The wellness model.

according to the model, this individual may also experience a decrease in other dimensions, such as emotional, social, or psychological wellness, in the postoperative period resulting from the interrelatedness of all of the dimensions. The overall effect of the changes in these dimensions will be a decrease in overall wellness, which has anecdotally been shown to occur in patients when they experience a physical illness or injury. In other words, the individual also experiences a change in his or her emotional, social, or psychological states as a result of an unexpected injury; this may significantly impact body image, self-confidence, energy level, comfort, personal finances, work, etc. Further applying the model in terms of an intervention plan, focus on a nonphysical state, such as the emotional or social dimension, can positively affect the physical dimension and result in improved wellness during recovery from a health condition.

The term health-related quality of life has already been defined in the context of the ICF model in Chapter 1. A similar term, quality of life, is "an individual's perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards and concerns. It is a broad concept affected in a complex way by the person's physical health, psychological state, level of independence, social relationships, personal beliefs and their relationship to salient features of their environment."[32]

The word lifestyle differs from wellness and thus is also important to consider, because many significant causes of disease, such as obesity and diabetes, involve lifestyle choices.[33] The term "lifestyle" is defined as "the habits and customs influenced by the lifelong process of socialization, including social use of alcohol and tobacco, dietary habits, and exercise, all of which have important implications for health."[34] The complex notion of lifestyle recognizes that personal behaviors are significantly influenced by social and cultural circumstances, indicating that behavioral choices may not be entirely under volitional control. For example, there is a great deal of controversy over obesity and how much responsibility for obesity is the individual's versus a response to an obesogenic environment.[35] Consideration, therefore, of an individual's behaviors related to health and wellness is most appropriately done within the context of social and cultural influences, and, more importantly, interventions designed to change behaviors should recognize the important influence of the environment in which the patient loves, works, and plays. This understanding of lifestyle is congruent with definitions of wellness, because it acknowledges that there are multiple influences on behavior.

In summary, the terms wellness and well-being can be used interchangeably and refer to an individual's perception of self in a broad sense. Quality of life is also a broad term that refers to an individual's perception of life in a broad sense. Finally, lifestyle is a term that describes personal behaviors that impact health.

MEASUREMENT OF WELLNESS

As a result of the varied way that wellness has been defined and understood, a variety of wellness measures exist. A good wellness measure should reflect the multidimensionality and systems orientation of the concept and have a salutogenic focus. In the literature and in daily practice, clinical, physiologic, behavioral, and perceptual indicators are all touted as wellness measures.

- Clinical measure: blood lipid levels and blood pressure
- Physiologic indicators: include skinfold measurements and maximum oxygen uptake
- Behavioral measures: smoking status and physical activity frequency
- Perceptual measures: patient/client self-assessment tools such as global indicators of health status ("compared to other people of your age, would you say your health is excellent, good, fair, or poor?")[36] and the SF-36 Health Status Questionnaire[37]

Although clinical, physiologic, and behavioral variables are useful indicators of bodily wellness and are commonly used to plan individual and community interventions, they are incomplete measures of wellness.[38] Clinical and physiologic measures assess the status of a single system, most commonly within the physical domain of wellness. Overall, behavioral measures are a better reflection of multiple systems because of the influence of motivation and self-efficacy on the adoption of behaviors, but they do not describe the wellness of the mind. On the other hand, perceptual measures are capable of assessing all systems and have been shown to predict effectively a variety of health outcomes.[31,36,39–41] Perceptual measures can complement the information provided by body-centered measures.[38]

Although some perceptual measures assess only single-system status (e.g., psychological well-being, mental well-being), numerous multidimensional perceptual measures exist and can serve as wellness measures. Perceptual constructs that have been used as wellness measures include general health status,[37] subjective well-being,[42,43] general well-being,[44,45] morale,[46,47] happiness,[48,49] life satisfaction,[50–52] hardiness,[53,54] and perceived wellness.[31,55,56] Example questions from a few of these perceptual tools are listed in **Table 4-3**.

The influence of perceptions on health and wellness has been demonstrated repeatedly in a variety of patient/client populations and a variety of settings. Mossey and Shapiro[36]

TABLE 4-3

Sample Items from Perceptual Measurement Tools

INSTRUMENT	PERCEPTUAL CONSTRUCT	SAMPLE ITEMS (RESPONSES)
Short-Form 36 (SF-36)[37]	General health perceptions	"In general, would you say your health is" (excellent, very good, good, fair, or poor) "Compared to 1 y ago, how would you rate your health in general now?" (much better than 1 y ago, somewhat better, about the same, somewhat worse, much worse)
Satisfaction with Life Scale[64]	Life satisfaction	"In most ways my life is close to my ideal" "I am satisfied with my life" (7-point Likert scale from strongly disagree [1] to strongly agree [7])
Perceived Wellness Survey[31]	Perceived wellness	"I am always optimistic about my future" "I avoid activities that require me to concentrate" (6-point Likert scale from very strongly disagree [1] to very strongly agree [6])
NCHS[a] General Well-Being Schedule[42]	General well-being	"How have you been feeling in general?" (During the past month) (In excellent spirits, In very good spirits, In good spirits mostly, I have been up and down in spirits a lot, In low spirits mostly, In very low spirits) "Has your daily life been full of things that were interesting to you?" (During the past month) (All the time, Most of the time, A good bit of the time, Some of the time, A little of the time, None of the time)
Philadelphia Geriatric Center Morale Scale[65]	Morale	"Things keep getting worse as I get older" "I am as happy now as when I was younger" (yes, no)
Memorial University of Newfoundland Scale of Happiness[49]	Happiness	"In the past months have you been feeling on top of the world?" "As I look back on my life, I am fairly well satisfied" (yes, no, don't know)

demonstrated more than 25 years ago that self-rated health was the second strongest predictor of mortality in the elderly, with age being the strongest predictor. Numerous other researchers have replicated these findings in other populations, lending support to the value of perceptions in understanding health and wellness and indicating that how well you *think* you are may be more important than how well you *actually* are. Patient's perceptions are critical in understanding and explaining quality of life.[38] Health perceptions provide an important link between the biomedical model with its focus on "etiological agents, pathological processes, and biological, physiologic, and clinical outcomes" and the quality of life model, with its focus on "dimensions of functioning and overall well-being"[38] (**Fig. 4-3**). Health perceptions "are among the best predictors of general medical and mental health services as well as strong predictors of mortality, even after controlling clinical factors."[36,38]

Physical therapists assess perceptions as a part of the patient/client history, as recommended in the *Guide to Physical Therapist Practice*.[5] Some of the kinds of perceptions that can be assessed include perceptions of general health status, social support systems, role and social functioning, functional status in self-care and home management activities, and work, community,

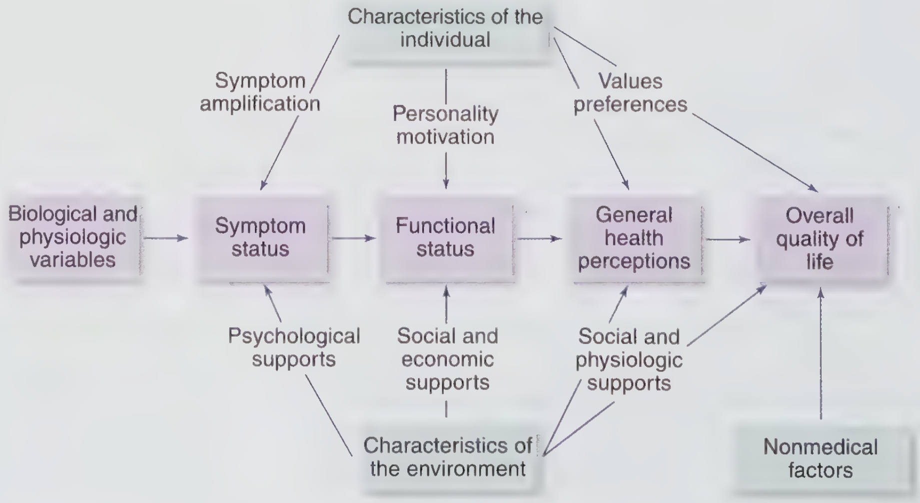

FIGURE 4-3 Health-related quality of life conceptual model. (Reprinted with permission from Mokdad AH, Ford ES, Bowman BA, et al. Prevalence of obesity, diabetes, and obesity-related health risk factors, 2001. JAMA 2003;289:76–79.)

and leisure activities. Although a few of these categories are included in overall wellness, such as general health status and social and role functioning, measuring wellness perceptions specifically can provide additional and more complete information about the patient that the physical therapist can use to formulate a plan of care unique to the patient/client. Therefore, perceptual tools should be included when measuring wellness within a primary prevention context and when examining patients/clients within a secondary or tertiary prevention context (see **Building Block 4-2**).

BUILDING BLOCK 4-2

Consider the Patient in Case Study 4-1

1. How do you think Mr. Prager's perceived wellness will be impacted by his knee injury?
2. How would you describe Mr. Prager's lifestyle?
3. What assessment tool would you use to measure perceptions?
4. Why use one of these perceptual instruments?

HEALTH PROMOTION AND WELLNESS-BASED PRACTICES

Establishing a wellness-based practice or offering health promotion and wellness services requires that the physical therapist modify the traditional approach used to treat patients. Creating a successful wellness-based practice has many unique features:

- Changing the focus from illness to wellness
- Being a role model of wellness
- Incorporating wellness measures into the examination
- Considering the client within his or her lifestyle or "system"
- Offering services beyond the traditional patient–provider relationship

From Illness to Wellness

The types of services provided in a physical therapist wellness-based practice can be varied and are influenced by the population served, the skills and expertise of the physical therapist, and the setting in which the services are provided. Based on the definition and characteristics of wellness provided earlier in this chapter, wellness services can be provided in any setting and to any population—it simply requires changing the approach to consider patients as clients who have the potential and opportunity to be more well.

The most common wellness-based practices are integrated within a traditional physical therapist practice in which patients convert to "members" after discharge for a specific diagnosis.[57] These patients/clients use the clinic or fitness facility to continue their exercise program. In this case, the client would have access to the facility to perform an individually or group prescribed exercise program and to the physical therapist who would be available to answer questions and progress the client's program. Additionally, to truly address "wellness," the provider must consider offering services beyond the physical domain. In other words, providing the "nonpatient" with the opportunity to continue an exercise program under the supervision of the physical therapist addresses the physical component of wellness, and although exercise can impact the other dimensions of wellness as described earlier, specific interventions aimed at the other dimensions of wellness would provide a holistic approach to wellness, as described below.

Establishing a wellness-based practice within an existing physical therapist practice requires several features. The facility should be available and staffed at convenient hours for clients; the staff should have expertise in exercise prescription as well as awareness and knowledge of wellness. For example, opportunities can be created to acknowledge the influence of social connections on wellness by offering group classes and group interaction among clients. The intellectual aspect of wellness can be tapped by providing educational resources and challenges for clients. For example, offering an educational class on topics such as progressing an exercise program or nutrition, followed by a test of understanding of the class topic are activities that would use and challenge the intellectual dimension. Additional staff with expertise in mental and spiritual health can be retained as consultants to provide services in these dimensions when indicated or requested by clients. Some facilities provide an integrated experience, with mental and spiritual health as a component of the wellness program.

Establishing a wellness-based practice also requires that the provider assume the role of a facilitator or partner rather than that of an authority figure.[58] When a patient is ill, it is often appropriate for the health care provider to act as the expert when the patient has limited ability to provide self-care and is relying on the provider for information and skills to recover and improve. In a wellness setting, the best approach is to believe that the client knows best in terms of maximizing his or her potential, therefore assuming a partner or facilitator role is more appropriate and will create a relationship in which the client feels empowered to take control. Rather than "making" the client well, the provider can view the client as a whole person within a biopsychosocial context and consider teaching the client how to achieve wellness. Being a role model and fulfilling the role of facilitator will establish a relationship and environment in which clients can attain greater wellness.

The Use of Screening as an Examination Tool Within a Wellness-Based Practice

Screening, or determining the need for further examination or consultation by a physical therapist or for referral to another health professional, is important and applicable in a health promotion context because it enables identification of the health status, personal goals, and available resources of the client. Within a physical therapist's scope of practice and a health promotion/wellness context, clients can be screened in numerous ways. Physical therapists routinely screen for osteoporosis, physical activity level, balance/risk for falls, muscle strength and endurance, and flexibility. Physical therapists can also screen perceptions, including perceived wellness and quality of life, and motivation to change health-related behaviors or adopt new behaviors. A number of tools have been developed and are available in the literature for use in screening clients. Example perceptual screening tools that can be used in a wellness or primary prevention context and their uses are listed in **Table 4-4**.

Screening tools can be used to identify whether or not a client has risks that should be investigated before participating in an

TABLE 4-4

Perceptual Screening Tools

PERCEPTUAL SCREENING TOOL	USE	RESOURCE/REFERENCE	PHYSICAL THERAPY APPLICATION
Physical Activity Readiness Questionnaire	General activity screen for ages 15–69	Canadian Society for Exercise Physiology http://www.csep.ca/en/publications	Indicates whether or not an individual should seek further medical consultation before beginning an aerobic exercise program
Self-efficacy for Exercise Questionnaire	Assesses the beliefs one has regarding success with physical activity	Marcus et al.[66]	Provides the physical therapist with information about perceptions of success with physical activity, which can be a barrier to adopting an activity habit if not addressed
Physical Activity Enjoyment Scale	Assesses how enjoyable a client finds exercise	Kendzierski and DeCarlo[67]	Provides information about how enjoyable a client finds exercise. Researchers have found that enjoyment is related to adherence to physical activity, so when enjoyment is low it should be addressed in the exercise prescription
Motivational Readiness for Change Scale (Transtheoretical Model)	Assesses a client's readiness to change for any behavior (exercise, smoking, etc.)	Marcus and Simkim[68]; Prochaska and DiClemente[69]	Provides information from which the physical therapist can tailor the intervention for a specific behavior. For example, if a client is not ready to change, the intervention will be very different compared to a client who is ready to make a change
Short Form 36 (SF-36)	General perceptual health status and outcomes questionnaire	Medical Outcomes Trust www.outcomes-trust.org	Provides information about perceptions in eight health concepts, including physical functioning, role limitations resulting from physical health problems, bodily pain, social functioning, general mental health, role limitations resulting from emotional problems, vitality (energy/fatigue), and general health perceptions. Can be used to determine the relative burden of an injury or illness and to document the relative benefits/outcomes of an intervention or interventions
Perceived Wellness Survey	General perceptual wellness survey	Adams et al.[31]	Provides information about general wellness perceptions in six dimensions, including physical, emotional, social, psychological, spiritual, and intellectual. Can be used to determine the relative burden of an injury or illness and to document the effect of an intervention on overall wellness
Risk for Falls	Assesses a client's risk for falling	Balance Self-Test www.balanceandmobility.com/patient_info/printout.aspx	Indicates an individual's risk for falling and thus the need for further examination and intervention
Computer Workstation Checklist	Identifies clients at risk for injury as a result of computer use	www.osha.gov/SLTC/etools/computerworkstations/checklist.html	Identifies specific areas within a computer workstation where problems may exist that would benefit the worker to be addressed. Includes the areas of posture, seating, keyboard/input device, monitor, work area, accessories, and general issues

intervention program. The physical therapist can also use the screening information to identify who should perform further examination and intervention, and the conditions under which the intervention should be performed (e.g., with or without supervision, the need for a medical diagnostic test). Screening tools can also identify a baseline from which progress can be assessed and documented. Depending on specific state law, screens may be performed on existing clients or can be used to identify those who would benefit from services.

Starting a Wellness-Based Practice

The mechanics of starting a specific wellness-based practice do not differ from starting or expanding any type of practice.

The first step should include verifying that "wellness" or "health promotion" is included within the definition and description of physical therapy in the state practice act.[59] Second, the liability policy should be checked to ensure coverage for wellness-type activities. As with any new endeavor, physical therapists should spend time identifying and understanding the potential risks involved in the provision of wellness services.

Although great strides have been made in the area of insurance coverage for health promotion and wellness services, most insurers do not reimburse health care providers for these services. However, the public understands the value of these services and is becoming more and more willing to pay directly for them.[60] Although there isn't a specific formula for determining the mechanics of charging for health promotion services and integrating these services into a physical therapist practice, following the same practice management and business principles used in creating any physical therapist practice, as well as knowing what other providers charge for health promoting services, will result in a service that will be competitive in the market as well as provide a valuable service for clients. A rich section of resources can be found on the APTA website (www.apta.org/PatientCare) in the Prevention, Wellness, and Disease Management section of the Patient Care page. In the case of populations that are unable to afford these types of services, consider providing more affordable group and community programs, applying for state and federal grants to support programs, or providing pro bono services that offer recognition through positive public relations.

Other activities that should be well thought out and planned include marketing and advertising the program and evaluating the program's success. Although specifics of these activities are outside the scope of this chapter, they are key to overall program effectiveness. Whether you are starting a specific wellness-based practice or program or are adopting a wellness approach within an existing health care setting, shifting from a medical to a biopsychosocial focus, recognizing that, as important as they may be, there is more to wellness than physical parameters. As such, adding the assessment of perceptions to your examination toolbox is a critical approach that will provide a strong basis for a wellness program.

PHYSICAL WELL-BEING: PHYSICAL ACTIVITY PROGRAMS

Transitioning a patient within a physical therapist practice from an intervention program addressing specific impairments to a general physical activity program addressing overall physical fitness and/or quality of life, and keeping in mind the impairments the physical therapist was addressing, is an approach physical therapists can and should consider. Physical therapists are uniquely qualified to create physical activity programs that enhance overall fitness and quality of life, while concurrently addressing specific neuromusculoskeletal impairments that require the expertise of the physical therapist. The 2008 Physical Activity Guideline recommendations include that adults accumulate 150 minutes per week of moderate physical activity or 75 minutes per week of vigorous activity and perform muscle strengthening activities that are of moderate or high intensity and involve all major muscle groups twice per week.[13] Physical therapists within the context of primary prevention can assist clients to achieve this goal safely and effectively by routinely inquiring about patient/client physical activity habits, conducting physical fitness assessments, prescribing physical activity to improve general health and well-being, and encouraging clients to adopt an active lifestyle.

Conducting Health-Related Physical Fitness Assessments

Clients who desire a physical activity program for improvement of overall physical fitness and/or quality of life should receive a physical therapist examination and evaluation similar to any other patient/client seen by a physical therapist. Parts of the examination may be abbreviated or taken from the patient/client's existing medical record in the case of a patient/client who was treated by the physical therapist for a specific impairment or health condition in the recent past. Prior to engaging in a physical activity or exercise program, clients should be screened to determine their readiness and appropriateness for exercise. For individuals who do not require medical evaluation as described in Chapter 6, preparticipation screening can be performed using a self-report questionnaire, such as the Physical Activity Readiness Questionnaire or PAR-Q[60,61] (see Appendix 3). Based on the answers to the seven questions on the PAR-Q, individuals between the ages of 15 and 69 can either appropriately participate in exercise or be referred to a physician for further evaluation before beginning an exercise program. All individuals who fall outside of the boundaries described should be referred to a physician for medical evaluation before participating in exercise training.

Depending on the client's goals for an exercise program, the five elements of physical fitness should be assessed to create a baseline and from which to prescribe exercise. **Table 4-5** provides examples of the types of tests that can be used to assess each of the five elements of physical fitness. For example, for a client who desires to lose weight through physical activity and nutrition modification, body composition and cardiorespiratory endurance should be assessed at a minimum to establish a baseline of weight, body fat, and cardiorespiratory fitness and to establish goals and assess progress. If a general systems screen indicates impairments in musculoskeletal areas that might be impacted by physical activity, tests of muscular endurance, strength, and flexibility should also be performed. In general, a personalized physical activity prescription should be prescribed based on the patient/client's specific physical characteristics, which will prevent injury, enhance participation and adherence, and promote overall physical fitness.

Establishing Physical Activity Interventions

Armed with the results of a patient/client history, including goals for physical activity, systems review, and physical fitness testing, the physical therapist can establish a physical activity program for a client. Specific aspects of the history that may be useful when prescribing exercise include past experience with exercise or physical activity, dietary habits, social situation, and current medications. This information can be useful and necessary to ensure safety, enjoyment, adherence, and effectiveness when creating an exercise program for a client.

TABLE 4-5

Health-Related Physical Fitness Tests

PHYSICAL FITNESS PARAMETER	TEST NAMES	TEST DESCRIPTION	REFERENCE/RESOURCE
Body composition	1. Body mass index 2. Waist to hip ratio 3. Skin fold measurements	1. Ratio of weight to height (weight in kg/height in m) 2. Circumference of waist at smallest point/circumference of hips at largest point 3. Uses skin fold calipers to assess amount of fat using standardized equations	American College of Sports Medicine[61,70]
Cardiorespiratory endurance	1. Cooper 12-min test 2. 1.5 mile test 3. 3-min YMCA step test 4. Astrand-Rhyming cycle ergometer test	1. Participant walks or runs to cover the greatest distance in 12 min. 2. Participant runs or walks the distance in the shortest period of time. 3. Using a 12-inch-high step, the participant steps up and down at a rate of 24 steps/min for 3 min. Heart rate is measured immediately for 1 min and used to estimate VO_2. 4. Participant cycles on a stationary cycle ergometer for 6 min at a standard resistance, pedaling at a rate of 50 rpm. Heart rate is taken twice and used to estimate VO_2.	American College of Sports Medicine[70]
Flexibility	1. Sit and reach test 2. Standard flexibility tests	1. Test to assess low back and hip joint flexibility; client in long sitting, reaches with both hands between outstretched legs as far as possible and tester measures distance reached 2. Tests to determine joint range of motion specific to each joint	American College of Sports Medicine[61,70]
Muscular endurance	1. Total number of repetitions at a given amount of resistance 2. Total number of repetitions at a % of 1 repetition maximum (RM) 3. Curl up 4. Push-up	1. Participant performs as many repetitions of a specific movement as possible at a submaximal level of resistance to fatigue. 2. Same as no. 1 using a percentage of 1 RM 3. Participant is supine with knees at 90 degrees, arms at side, palms facing up. Client performs slow controlled curl ups at a rate of 25 per minute. Tester counts the number per minute. 4. Male participants use standard "down" position and females "knee push-up" position. Participant raises body by straightening elbows and returns to down position keeping back straight. Tester counts the number per minute.	American College of Sports Medicine[61,70]
Muscular strength	1. Manual muscle testing 2. 1 RM	1. Manually applied resistance to specific muscle groups based on established norms and using standard scales 2. The greatest resistance that can be moved through the full range of motion in a controlled manner with good posture	American College of Sports Medicine[70]

There are numerous ways clients can become more physically active, including but not limited to walking, cycling, climbing stairs, doing yardwork and housework, and dancing. Clients who have been appropriately screened can engage in any type of physical activity that appeals to them and that they enjoy and will perform consistently. Setting a goal of 30 minutes of physical activity, 5 days per week for an inactive client, consistent with government guidelines, provides great latitude in terms of activity, and yet is achievable for most people. To achieve health-related benefits, physical activity can be performed in smaller bouts and does not need to be continuous or performed all at one time. For example, three 10-minute walks per day satisfy the goal of 30 minutes of moderate physical activity per day and perhaps can be incorporated more easily into the busy and demanding lifestyle of an individual who struggles to find time for physical activity (see **Building Block 4-3**).

BUILDING BLOCK 4-3

Consider the Patient in Case Study 4-1

1. Near the end of his episode of care for his knee rehabilitation, Mr. Prager indicates that he is worried and has gained weight over the past 6 weeks while rehabilitating his knee. What might you suggest for Mr. Prager?
2. You administer the PAR-Q to Mr. Prager. What does the PAR-Q indicate?
3. What assessment tool would you use to assess body composition?
4. How would you address stress with Mr. Prager?
5. Create a physical activity program involving walking that incorporates physical activity into Mr. Prager's lifestyle.

Some clients may have specific goals that require more than the minimum amount of physical activity for health-related well-being, like running a marathon, playing recreational soccer, or losing weight. In these situations, specific exercise prescriptions should be established including well-defined and tailored doses of exercise in order to accomplish the specific client goal. The information in Chapter 6 is designed to assist in creating these types of exercise prescriptions.

KEY POINTS

- Prevention is classified as primary, secondary, or tertiary
- Health promotion and wellness fall into the realm of primary prevention, whereas most rehabilitation is secondary or tertiary prevention
- The terms health promotion and health education are often used interchangeably
- Physical activity is any bodily movement produced by skeletal muscles resulting in energy expenditure, whereas exercise is planned, structured, and repetitive and is a type of physical activity
- Wellness is multidimensional, salutogenic, and requires a systems perspective and can be used interchangeably with the term well-being
- Wellness extends beyond only the physical domain to include many other dimensions such as spiritual, intellectual, psychosocial, and emotional well-being
- Perceptual measures are often better predictors of general well-being than physiologic measures
- Wellness requires a vision beyond just the physical domain and the biomedical model
- Physical therapists should assess the physical activity level of their patients/clients and encourage patients/clients to become more physically active, including establishing physical activity programs to enhance health-related quality of life and well-being

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Impairments of Body Functions and Therapeutic Exercise

UNIT 2

CHAPTER

5

Impaired Muscle Performance

LORI THEIN BRODY • CARRIE M. HALL

Muscular performance is an essential component of a person's life. Every human activity from breathing to walking to the bathroom to running a marathon requires muscle activity. Physiologic, anatomic, psychological, and biomechanical factors affect muscle performance. Pathology and disease affecting the cardiovascular, endocrine, integumentary, musculoskeletal, neuromuscular, or pulmonary systems can also affect muscle performance; strength training can improve the function of these systems. Muscle performance impairments can be considered as impairments in muscle *strength, power,* or *endurance*. These impairments must be related to an activity limitation or participation restriction, or promote prevention, health, wellness, and fitness, in order to justify therapeutic exercise intervention. For example, an individual lacking the muscular ability to carry a bag of groceries into the house requires intervention to achieve this instrumental activity of daily living. A worker lacking the muscle endurance to maintain efficient posture and safe movement patterns throughout the workday requires intervention to prevent work disability. A person with osteoarthritis of the knee and poor quadriceps muscle performance requires quadriceps muscle training to prevent further knee joint deterioration.

Although not all scientific and clinical information on strength, power, and endurance production can be covered in this text, this chapter provides a strong foundation for this element of therapeutic exercise intervention. Fundamental terms and concepts are defined, the essential morphology and physiology of skeletal muscle relative to muscle performance are reviewed, and clinical applications are presented.

DEFINITIONS

Definitions of key terms vary from one researcher, text, or profession to another. The following definitions are presented to clarify how these terms will be used throughout this text.

Strength

Impaired muscle performance is commonly treated by clinicians and is usually described as a strength deficit. However, strength is only one of the three components of muscle performance (i.e., strength, power, and endurance).

Strength is defined as the maximum force that a muscle can develop during a single contraction, and is the result of complex interactions of neurologic, muscular, biomechanical, and cognitive systems. Strength can be assessed in terms of force, torque, work, and power. If appropriate decisions are to be made regarding these impairments, operational definitions are necessary.

Force is an agent that produces or tends to produce a change in the state of rest or motion of an object.[1] For example, a ball sitting stationary on a playing field remains in that position unless it is acted upon by a force. Force, described in metric units of newtons (N) or British units of lb, is displayed algebraically in the following equation:

$$\text{Force} = \text{mass} \times \text{acceleration}$$

Kinetics is the study of forces applied to the body. Some of the factors influencing muscular force production include the neural input, mechanical arrangement of the muscle, cross-sectional area, fiber-type composition, age, and gender.[1]

Torque is the ability of a force to produce rotation. All human motion involves rotation of body segments about their joint axes. These actions are produced by the interaction of forces from external loads and muscle activity. Torque represents the rotational effect of a force with respect to an axis:

$$\text{Torque} = \text{force} \times \text{moment arm}$$

The *moment arm* is the perpendicular distance from the line of action of the force to the axis of rotation. The metric unit of torque is newton-meter (Nm); the foot-pound (ft lb) is used in the older British system of units.

Clinically, the word *strength* is often used synonymously with torque. Large amounts of torque are produced by the musculoskeletal system during everyday functional activities such as walking, lifting, and getting out of bed. Torque can be altered in biomechanics through three strategies:

1. Changing the force magnitude
2. Changing the moment arm length
3. Changing the angle between the direction of force and momentum

In the human musculoskeletal system, changing the force magnitude (i.e., tension-producing capability of muscle) can be altered by training. The moment arm can be decreased by positioning a load closer to the body, and the angle between the force and moment arm may be changed by altering joint alignment through postural education (see **Building Block 5-1**).

BUILDING BLOCK 5-1

A patient with thoracic spine and neck pain works at a research laboratory where the work stations are positioned such that it requires the patient to either (a) bend over a table top or (b) work with her arms extended well in front of his or her at shoulder height. Please apply the three principles of altering torque just discussed to minimize thoracic and cervical spine pain for this patient.

Power and Work

Power is the rate of performing work. *Work* is the magnitude of a force acting on an object multiplied by the distance through which the force acts. The unit used to describe work is the joule (J), which is equivalent to 1 Nm (the foot-pound unit is used in the British system). Work is algebraically expressed in this equation:

$$\text{Work} = \text{force} \times \text{distance}$$

The unit of power in the metric system is watt, which is equal to 1 J per second (foot-pound per second in the British system). Power can be determined for a single body movement, a series of movements, or for a large number of repetitive movements, as in the case of aerobic exercise. Power is algebraically expressed as:

$$\text{Power} = \text{work/time}$$

For the simple movement of lifting or lowering a weight, the muscle must overcome the weight of the limb and the weight (force), acting some distance from the axis of rotation (torque) through a range of motion (ROM) (work) during a specific time frame (power). This example summarizes the practical aspects of force, torque, work, and power in resistance training.

Endurance

Endurance is the ability of muscle to sustain forces repeatedly or to generate forces over a certain period of time. It is often measured as the ratio of the peak force that can be generated by a muscle at a given point in time, relative to the peak force that was possible during a single maximum contraction. Muscle endurance is the ability of a muscle group to perform repeated contractions against a load. This load can be applied externally or as a result of posture, such as when someone is working over a desk, counter, or work station all day (**Fig. 5-1**). Muscle endurance can be examined by isometric contractions, repeated dynamic contractions, or repeated contractions on an isokinetic dynamometer.

Muscle Actions

Poorly defined muscle actions can be a source of confusion and inaccuracy. Resistive exercise uses various types of muscle contraction to improve impaired muscle performance. Muscle actions can be divided into two general categories: static and dynamic. A static muscle action, traditionally referred to as *isometric*, is a contraction in which force is developed without any motion about an axis, so no work is performed. The amount of force generated by the muscle matches the external resistance applied.

All other muscle actions involve movement and are called *dynamic* or *isotonic*. An **isotonic exercise** suggests a uniform

A B

FIGURE 5-1 Individual standing at a computer workstation using **(A)** poor posture or **(B)** good posture.

force throughout a dynamic muscle action. No dynamic muscle action uses constant force because of changes in mechanical advantage and muscle length. *Isotonic* is therefore an inappropriate term to describe human exercise performance, and the term *dynamic* is preferred.

Dynamic muscle action is further described as concentric or eccentric action. The term *concentric* describes a shortening muscle contraction, and the term *eccentric* describes a lengthening muscle contraction. A concentric contraction happens when the internal force generated by the muscle exceeds the external load, whereas an eccentric contraction occurs when the external load exceeds the muscle force and the muscle lengthens while still developing tension.[2] Eccentric contractions differ from concentric and isometric contractions in several important ways. Per contractile unit, compared to concentric contractions, eccentric contractions:

- Can generate more tension and at a lower metabolic cost (i.e., less use of ATP-derived energy)[3]
- Are an important component of a functional movement pattern (e.g., required to decelerate limbs during movement)
- Are the most energy-efficient form
- Can develop the greatest tension of the various types of muscle actions

The term *isokinetic* refers to a concentric or eccentric muscle contraction in which a constant velocity is maintained throughout the muscle action. A person can exert a continuous force by using an isokinetic device, which provides a resistive surface that restricts movement to a preset, constant velocity. Some acceleration and deceleration occurs as the individual accelerates the limb from a resting position to the preset velocity and decelerates the limb to change directions. By constraining the speed of the isokinetic device, the limb moves at a constant velocity. Because the device cannot be accelerated beyond the preset speed, any unbalanced force exerted against it is resisted by an equal and opposite force. This muscular force may be measured, displayed, recorded, or used as concurrent visual feedback. Although the isokinetic device may be moving at a constant velocity, it does not guarantee that the user's muscle activation is at a constant velocity. Despite this inaccuracy, the terms *isokinetic* and *isotonic* to describe muscle action are likely to be employed for pragmatic reasons.

During functional movement patterns, combinations of static and dynamic contractions occur. Trunk muscles contract isometrically to stabilize the spine and pelvis during movements of the extremities such as reaching or walking. Lower extremity muscles are subjected to impact forces requiring combinations of concentric and eccentric contractions, sometimes within the same muscle acting at two different joints. Muscles commonly perform eccentric contractions against gravity, as in slowly lowering the arm from an overhead position.

Muscles often act eccentrically and then contract concentrically. The combination of eccentric and concentric actions forms a natural type of muscle action called a *stretch-shortening cycle* (SSC).[4,5] The SSC results in a final action (i.e., concentric phase) that is more powerful than a concentric action alone. This phenomenon is called *elastic potentiation*.[5] The SSC is discussed in more detail later in this chapter.

PHYSICAL FACTORS AFFECTING MUSCLE PERFORMANCE

The total force a muscle can produce is influenced by numerous factors. Knowledge of muscle morphology, physiology, and biomechanics is critical for successful therapeutic exercise prescription. The following section discusses the primary factors influencing force production and, hence, muscle performance. A brief review of the structure of muscle and the physiology of muscle contraction can be found on thePoint.lww.com/BrodyHall4e.

Fiber Type

Sedentary men and women and young children possess 45% to 55% slow-twitch fibers.[6] Persons who achieve high levels of sport proficiency have the fiber predominance and distributions characteristic of their sport. For example, those who train for endurance sports have a higher distribution of slow-twitch fibers in the significant muscles, and sprint athletes have a predominance of fast-twitch fibers. Other studies show that men and women who perform in middle-distance events have an approximately equal percentage of the two types of muscle fibers.[7] Any resistive rehabilitation program should be based on the probable distribution of fiber type of the individual.

Clear-cut distinctions between fiber-type composition and athletic performance are true for elite athletes. A person's fiber composition is not the sole determinant of performance. Performance capacity is the end result of many physiologic, biochemical, and neurologic components, not simply the result of a single factor such as muscle fiber type.[6]

Fiber Diameter

Although the different fiber types show clear differences in contraction speed, the force developed in a maximal static action is independent of the fiber type but is related to the fiber's cross-sectional diameter. Because type I (slow-twitch) fibers tend to have smaller diameters than type II (fast-twitch) fibers, a high percentage of type I fibers is believed to be associated with a smaller muscle diameter and therefore lower force development capabilities.[8]

Muscle Size

When adult muscles are trained at intensities that exceed 60% to 70% of their maximum force-generating capacity, the muscle increases in cross-sectional area and force production capability. The increase in muscle size may result from increases in fiber size (i.e., hypertrophy), fiber number (i.e., hyperplasia), interstitial connective tissue, or some combination of these factors.[9,10]

Although the major mechanism for increased muscle size in adults is hypertrophy, ongoing controversy surrounds evidence of hyperplasia. Mammalian skeletal muscle does possess a population of reserve or satellite cells that, when activated, can replace damaged fibers with new fibers.[11,12] The mechanisms for fiber hyperplasia probably are the result of satellite cell proliferation and longitudinal fiber splitting.[9]

Despite few investigations of the effect of strength training on interstitial connective tissue, it appears that, because interstitial connective tissue occupies a relatively small proportion of the total muscle volume, its potential to contribute substantial changes in muscle size is limited.[13]

Force–Velocity Relationship

Muscle can adjust its active force to precisely match the applied load. This property is based on the fact that active force continuously adjusts to the speed at which the contractile system moves. When the load is small, the active force can be made correspondingly small by increasing the speed of shortening appropriately. When the load is high, the muscle increases its active force to the same level by slowing the speed of shortening (**Fig. 5-2**).[14]

Slowing the speed of contraction allows a patient time to develop more tension during concentric contractions. This principle is evident during resistive exercise in water, where the water's viscosity slows limb movement, allowing more time for tension development. However, during eccentric contractions, increased speed of lengthening produces more tension. This appears to provide a safety mechanism for limbs excessively loaded. Increasing the speed of a concentric contraction significantly lowers the amount of concentric torque developed. In contrast, increasing the speed of an eccentric contraction increases the amount of torque developed until a plateau speed is reached.

Length–Tension Relationship

A muscle's capacity to produce force depends on the length at which the muscle is held with maximum force delivered near the muscle's normal resting length (**Fig. 5-3**). The relationship between strength and length is called the length–tension property of muscle. The number of sarcomeres in series determines the distance through which the muscle can shorten and the length at which the muscle produces maximum force. Sarcomere number is not fixed, and in adult muscle, this number can increase or decrease (**Fig. 5-4**).[15] Regulation of sarcomere number is an adaptation to changes in the functional length of a muscle.

Length-associated changes can be induced by postural malalignment or immobilization.[16,17] In muscles chronically maintained in a shortened range because of faulty posture or immobilization, sarcomeres are lost, and the remaining sarcomeres adapt to a length that restores homeostasis; the new length enables maximum tension development at the new immobilized, shortened position.[18] For example, people who spend most of the day sitting can develop adaptive shortening of their hip flexor muscles. These muscles need to be stretched to avoid chronic shortening. In muscles immobilized or posturally held in a lengthened position, sarcomeres are added, and maximum tension is developed at the new increased length. This may be true of people at workstations where the scapular retractor muscles are lengthened due to thoracic kyphosis and a chronically protracted scapula. When a cast is removed or posture restored, the sarcomere number returns to normal. The stimulus for sarcomere length changes may be the amount of tension along the myofibril or the myotendon junction, with high tension leading to an addition of sarcomeres and low tension to a subtraction of sarcomeres.[19]

The clinical implication of the length–tension relationship is that the evaluation of muscle "strength" must be reconsidered. Muscles that tend to be shortened (e.g., hip flexors) may test as strong as normal-length muscles, because the manual muscle test position is a shortened position.[20] Conversely, the lengthened

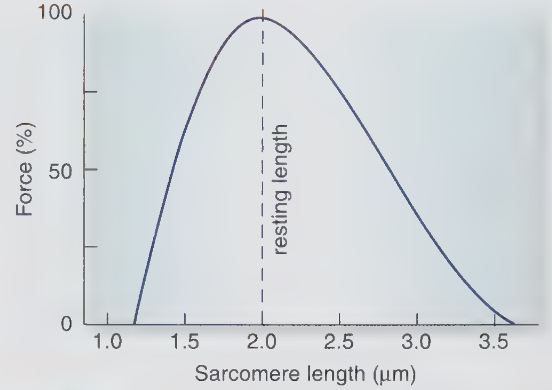


FIGURE 5-3 The length–tension curve depicts the relationship between muscle length and force development.

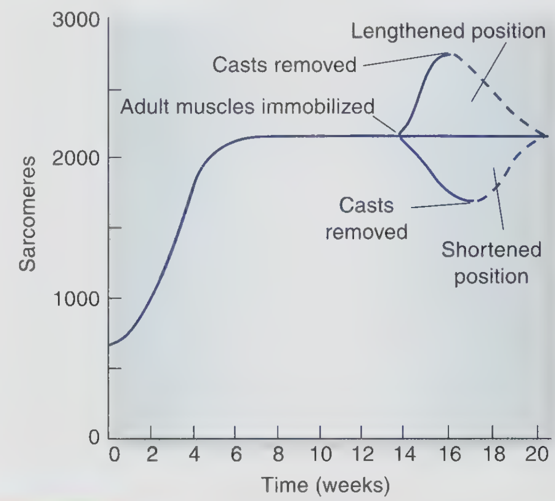


FIGURE 5-4 Changes in the number of sarcomeres in various conditions.

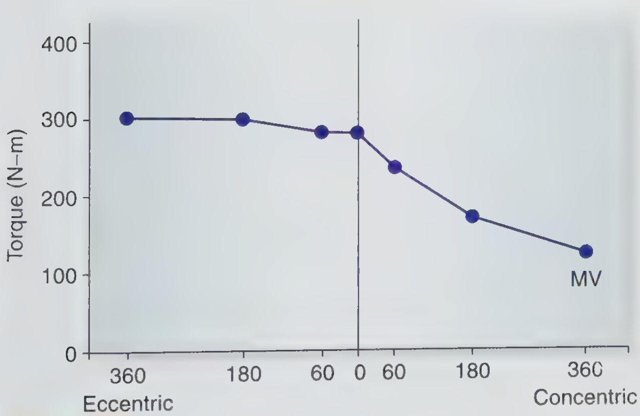


FIGURE 5-2 Relationship between the force and velocity of eccentric muscle contractions. (Adapted from Herzog W, Ait-Haddou R. Mechanical muscle models and their application for force and power production. In: Komi PV, ed. Strength and Power in Sport. 2nd Ed. Malden, MA: Blackwell Scientific Publications, 2003:176.)

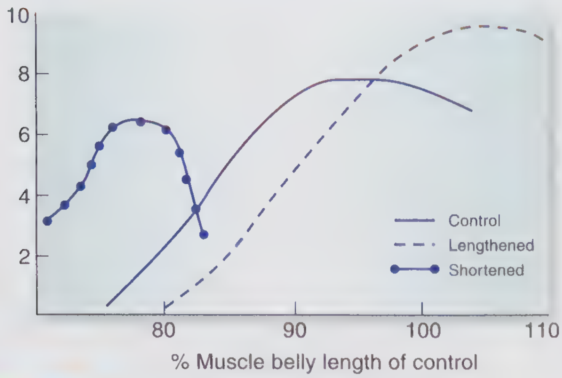


FIGURE 5-5 Changes in the length–tension relationship caused by length changes associated with immobilization. (Modified from Gossman, Sahrmann SA, Rose SJ. Review of length-associated changes in muscle. Experimental evidence and clinical implications. Phys Ther 1982;62:1799.)

muscle (e.g., the lower trapezius in the patient with protracted scapula) tests weak, because the manual muscle test occurs at a relatively shortened range, which is an insufficient position. According to animal studies,[21,22] the short muscles should develop the least peak tension, followed by the normal-length muscle and the lengthened muscle, which develops the greatest peak tension (**Fig. 5-5**). This finding directly reflects the number of sarcomeres in series. The lengthened muscle may be interpreted as weak although it is capable of producing substantial tension at the appropriate point in the range. This phenomena is called *positional strength*. Clinically, this is why a muscle should be tested at multiple points in the range. It is imperative that the physical therapist determine whether the muscle is positionally weak or weak throughout the range, as these findings will affect the selection of interventions (see **Building Block 5-2**).

BUILDING BLOCK 5-2

Think of some other muscle groups that might not test "normal" when testing at mid-range position due to positional weakness (shortening or lengthening of the muscle).

The emphasis of therapeutic exercise intervention should be on restoring normal length and tension development capability at the appropriate point in the range, rather than just strengthening the muscle. The positionally weak muscle should be strengthened in the shortened range, and the weak muscle should be strengthened dynamically throughout the range.

Muscle Architecture

The arrangement of the contractile components affects the contractile properties of the muscle dramatically. The more sarcomeres lie in series, the longer the muscle will be, the more sarcomeres lie in parallel, the larger the cross-sectional area of the muscle will be. These two basic architectural patterns affect the contractile properties of the muscles in the following ways:

- The force the muscle can produce is directly proportional to the cross-sectional area.
- The velocity and working excursion of the muscle are proportional to the length of the muscle.

Generally, muscles with shorter fibers and a larger cross-sectional area are designed to produce force, whereas muscles with long fibers are designed to produce excursion and velocity.[22] For example, the quadriceps muscle contains shorter myofibrils and appears to be specialized for force production, whereas the sartorius muscle has longer fibers and a smaller cross-sectional area and is better suited for high excursion (see **Building Block 5-3**).

BUILDING BLOCK 5-3

How might the rehabilitation of someone with a quadriceps muscle strain differ from someone with a hamstring muscle strain based upon the muscle architecture?

CLINICAL CONSIDERATIONS

Many factors impact the effectiveness of resistive exercise program. Issues such as medication use, physical health, age, and program design can impact a person's ability to participate in and successfully respond to a training stimulus.

Dosage

Exercise is described in terms of **dosage**. The components of the exercise dose include the exercise frequency, intensity, duration, volume, and rest interval. The exercise **frequency** is how often the exercise is performed, usually described as the number of days per week. The *intensity* is the amount of force necessary to achieve the activity, usually described as mass (in kilograms) or weight (in lb). The intensity is often described as a percentage of a **repetition maximum (RM),** or the maximum amount of weight that can be lifted for a certain number of repetitions. For example, a 10 RM is the maximum amount of weight that can be lifted 10 times and a 1 RM is the maximum amount of weight that can be lifted once.

The *duration* is the number of repetitions or time the exercise is performed. Often, a certain number of repetitions are performed in a **set,** and several sets of an exercise might be performed in a single session. The exercise *volume* is the total amount of exercise performed in a single session. Volume has been defined in different ways for different purposes. In weight training, volume is often defined as the product of the number of sets and repetitions and the weight. For example, the volume for 3 sets of 10 repetitions at 15 lb would be 3 × 10 × 15 lb = 450 lb. It has also been defined as the total number of repetitions performed in a training session.[23]

The *rest interval* is the amount of time between each set and/or between each exercise. The rest interval can be passive or active, where *passive rest* is simply resting before the next exercise bout, whereas *active rest* is rest where the person performs a light activity such as walking or stretching between resistive exercise bouts. In order for resistive training to improve muscle performance, the muscle must be overloaded. *Overload* means exercising or applying resistance above the loads currently or normally encountered.

The exercise dosage can be altered in a variety of ways. Some examples include:

- Increasing the intensity or amount of weight
- Changing the relationship to gravity

- Increasing the lever arm length
- Increasing sets and repetitions
- Decreasing the rest interval
- Increasing the frequency

The dosage parameters of intensity, duration, and frequency are related and together are considered the training *volume*; all must be considered when designing a resistive exercise program. Choose appropriate dosage parameters based on the needs of the patient (**Display 5-1**). Be aware of patients with fair or lower muscle grades who cannot perform resistive exercise against gravity with proper recruitment and movement patterns. In this situation, the patient may be forced to train a faulty movement pattern (see **Building Block 5-4**). Determine whether the goal is to develop muscular strength, power, endurance, or some combination of these muscle performance parameters. Subsequently, progress the resistive exercise to a functional activity to transition intervention at the impairment level to the activity limitation level (**Fig. 5-6**).

BUILDING BLOCK 5-4

A patient complains that he or she is unable to lift her arm overhead without pain. The patient is evaluated and is found to have a physiologic impairment of a muscle strength grade of fair for the lower trapezius and serratus anterior. How do these muscles function in arm elevation to an overhead position? Given her strength grade, what approach or approaches might be appropriate for initiating the rehabilitation program? Provide several options in different positions.

DISPLAY 5-1

Dosage Options for Individuals with Muscles of Various Strength Grades

Muscles Fair or Below Progressing to Muscles Above Fair:

1. Work in a gravity-lessened position or against gravity with other modification
2. Use active assistive, active, or resisted muscle contractions as available
3. Modify the working ROM, using resistance when possible, and assistance at other time
4. Progress from a shorter lever arm to a longer lever arm

Muscles Above Fair Strength Grade:

1. Vary the type of contraction (e.g., isometric, concentric, eccentric, isokinetic, plyometric)
2. Increase the amount of weight or resistance
3. Increase the number of sets or repetitions
4. Increase the frequency of training sessions (be cautious of overtraining)
5. Modify the speed of movement (slower speed increases amount of force or torque generated during concentric exercise)
6. Increase the distance (e.g., running, jumping, throwing)
7. Decrease the rest interval between sets

Dosage parameters can be manipulated for maximum gains in strength, power, and endurance through a system of training called *periodization*. Periodization systematically varies the training dosage to prevent "plateaus" in training gains, to maintain interest, and to provide a well-balanced program. Varying the training program is essential to making long-term gains in training. Periodization breaks the training program down into cycles of a specific length and goals (i.e., hypertrophy, basic strength, power, and endurance). The cycles can vary from "minicycles" of 1 week to mesocycles of several months. Often a training program comprises a variety of cycles of variable

A B

FIGURE 5-6 Progression of exercise: **(A)** Lifting free weights overhead to **(B)** placing a box up on a shelf.

lengths. Further discussion of periodization is presented later in this chapter in relation to training the advanced or elite athlete.

Intensity

Extensive strength training research has been performed on individuals without injury. Dosage parameters to increase strength began with DeLorme's classic paper in 1945.[24] He proposed a 10-RM, 10-set regimen. Later, DeLorme and Watkins[25] modified this regimen to a 10-RM, three-set regimen with loads increasing progressively for each set from one half to three fourths to a full 10-RM set. DeLorme called this regimen *progressive resistance exercise* (PRE), a term still used today (**Table 5-1**). DeLorme's three-set progressive resistance program has served as a control condition by which the effectiveness of other methods has been judged.

In 1951, an alternative to the DeLorme regimen was proposed by Zinovieff[26] at Oxford. He suggested adjusting the intensity of the load to allow for progressive fatigue. This was achieved by selecting an initial load that was just enough to permit each set to be completed. This regimen was called the Oxford technique. McMorris and Elkins[27] compared the DeLorme and Oxford techniques and found the Oxford technique to be slightly better, but the differences were not statistically significant.

The daily adjustable progressive resistive exercise (DAPRE) technique has been proposed as a more adaptable progressive exercise program than the Oxford or DeLorme approaches (see Table 5-1).[28] This program eliminates arbitrary decisions about the frequency and amount of weight increase. The DAPRE program can be used with free weights or with weight machines. A 6 RM is used to establish the initial working weight. Thereafter, weight increases are based on the performance during the previous training session.

These guidelines have been based on studies of uninjured subjects. When treating a patient with specific impairments, the resistive exercise dosage varies.[29] Exercise should be performed to substitution or form fatigue, the point at which substitution or alterations in form occur.

Duration/Volume

Duration or volume of resistive training can be considered the number of sets, repetitions, or time of a specific exercise session. Most exercises are performed for a given number of repetitions and sets that can be considered the exercise duration or volume. In rehabilitation, resistive exercises might also be prescribed for a certain time interval such as 15, 30, or 60 seconds depending on the goal of the exercise.

In weight training for fitness, *volume* is often defined as the total number of repetitions performed during a training session multiplied by the resistance used. Intensity and volume are inversely related. The greater the intensity, the fewer are

TABLE 5-1

Common Strength Training Dosages and DAPRE Program and Adjustments

TECHNIQUE	BASE REPETITION MAXIMUM (RM)	SETS	NUMBER OF REPETITIONS
DeLorme	10	1. 50% of 10 RM	10
		2. 75% of 10 RM	10
		3. 100% of 10 RM	10
Oxford	10	1. 100% of 10 RM	10
		2. 75% of 10 RM	10
		3. 50% of 10 RM	10
DAPRE	6	1. 50% of 6 RM	10
		2. 75% of 6 RM	6
		3. 100% of 6 RM	As many as possible
		4. Adjusted weight based on number of reps performed in set 3[a]	As many as possible; this number of reps is used to determine the working weight for the next day[a]

NUMBER OF REPETITIONS	ADJUSTED WORKING	ADJUSTED WORKING
Performed in set 3[a]	Weight for set 4[a]	Weight for next day[a]
0–2	Decrease 5–10 lb	Decrease 5–10 lb
3–4	Decrease 0–5 lb	Same weight
5–6	Keep weight the same	Increase 5–10 lb
7–10	Increase 5–10 lb	Increase 5–15 lb
11	Increase 10–15 lb	Increase 10–20 lb

[a]Adjustments for the DAPRE program.

the repetitions performed. When training at a low RM (near 1 RM or maximum amount of weight that can be lifted), very few repetitions are performed, and strength gains are the chief goal. When training at 10 RM or higher, many repetitions are performed, and the goals are endurance and other aspects of muscle performance.

Very little stimulus is necessary to make strength gains in the beginner. In untrained individuals, one set of 10 RM, two to four times per week, may be adequate. In advanced or elite athletes, multiple set routines, three times per week, will be necessary to achieve strength and power gains. For this group, performing one set of an exercise is less effective for increasing strength than performing two or three sets, and there is evidence that three sets are more effective than two sets.[30] However, multiple sets pose higher risk for injury; therefore, careful technique must be employed to avoid injury.

For most individuals, a moderate training volume is sufficient to achieve strength gains and these gains can be made via any resistive training mode.[31,32] A review of meta-analyses concluded that:

- In untrained subjects, a dosage of 60% of 1 RM, 3 days per week with a mean training volume of four sets per muscle group produced optimal strength gains.[33]
- For recreationally trained nonathletes, an intensity of 80% of 1 RM, 2 days per week with a mean training volume of four sets per muscle group was best.
- For athletes, a training of 85% of 1 RM, 2 days per week with a mean training volume of eight sets per muscle group was necessary for optimal strength gains.

The rest interval between sets is another important variable to consider. Much research has been performed to determine the optimal rest interval to achieve different resistive training goals. Some controversy exists regarding single versus multiple sets and the length of the rest interval between sets.[34,35] Strength results might change when training at different rest intervals. Rest intervals will vary from <1 minute to 3 to 5 minutes depending on the intensity of the lift and the purpose of the training. The higher intensity required for strength training will necessitate longer rest intervals.

- For loads near 1 RM, a rest interval of 3 to 5 minutes allows for more recovery and the ability to train at a higher intensity for more repetitions.[34]
- For power training, a minimum of 3 minutes rest between activities, such as plyometric jumps, will retain the necessary intensity.
- When training for muscle endurance, a circuit program with approximately 30 seconds between sets is sufficient.
- Muscles can be overloaded by decreasing the rest interval between sets.

Frequency

Training frequency depends on the rehabilitation goals. Isometric exercise is performed several times per day, and heavy dynamic exercise may be performed every other day. Frequency of an exercise is related to the exercise goal, intensity, duration, and other exercises in the patient's rehabilitation program. Individuals training for power lifting or body building lift daily or twice daily, whereas individuals in rehabilitation programs may perform resistive exercise 3 days per week, cardiovascular exercise on alternate days and certain exercises daily. Be sure to allow adequate time for recovery between training sessions. Shortening the recovery period between training sessions can produce persistent fatigue.[36]

Studies provide a variety of frequency recommendations, and these need to be balanced with intensity, duration, initial training status, and the goals of the training. PRE training one time weekly with 1 RM for one set increases strength significantly after the first week of training and each week up to at least the sixth week.[30] Significant increases have occurred for beginners training 1 to 5 days per week.

Sequence

The sequence of training muscles can affect the development of strength. In general, multijoint exercises are advocated for strength and power gains. However, specific isolated muscle training is often necessary when rehabilitating individuals with impaired muscle performance. In this case, the single-joint exercises should be performed first, before the patient gets fatigued. Follow these exercises with multijoint functional movement patterns. When designing the sequence of rehabilitation exercises, consider whether the exercises are **stacked** (several exercises in a row that train the same muscle group) or **unstacked** (exercises are organized to alternate between different muscle groups, allowing rest intervals). In the early rehabilitation phases, unstacking exercises to allow for an active rest interval for the muscle group being trained may prevent overwork of that muscle. As rehabilitation progresses, the exercises can be rearranged to include a sequence of two or more exercises in a row working the same muscle group. For training novice, intermediate, and advanced individuals who do not have an injury who want to increase strength, the American College of Sports Medicine (ACSM) provides the following recommendations[37]:

- Exercise large muscle groups before small and perform multijoint before single-joint activities.
- When training all major muscle groups in one training session, alternate upper body and lower body activities.
- When training upper body and lower body muscles on different days, alternate agonist and antagonist exercises.
- When training individual muscle groups, perform higher-intensity exercises before lower intensity exercises.

Program Design

Program design simply means looking at the overall training session. This includes the sequence of the exercises discussed in the previous section as well as overarching issues like interval training and circuit training. *Interval training* is a type of training that is predominantly used to build anaerobic metabolic systems; although depending on the work:relief ratio, it can be used to train aerobic systems as well. Interval training prescription includes the exercise intensity and duration as well as the duration and activity for the relief interval.[2,23]

- The relief interval can be either passive (rest-relief) or active (work-relief).
- Examples of work-relief interval activities include active movement without resistance, stretching, or another light activity.

- The relationship of work:relief can vary from 1:1 or 1:1.5 when training the aerobic system and to 1:12 to 1:20 when training the phosphagen system (the system used for all-out exercise in the first 10 seconds).
- The combination of high intensity and short duration places greater loads on the phosphagen system and requires a longer relief interval.
- A longer work interval (3 minutes or more) works the aerobic system, minimizing the necessity of a long relief interval.

Interval training methods can be applied to resistance training by using weight equipment (free weights, variable resistance machines, elastic resistance) to obtain a certain number of repetitions within a given time frame. The relief interval can again be a passive rest interval or an active work interval. Interval training will be discussed in greater depth in Chapter 6 relative to the cardiopulmonary system.

Circuit training usually includes 8 to 15 exercise stations that are completed in a sequence or circuit. The stations can be general training for the major muscle groups, serving as a general fitness routine or can be specific. For example, a swim team might perform circuit training 3 days per week with exercises focused on preventing injuries specific to swimmers. Exercises can be one mode (i.e., variable resistance machines) or they can be a combination of stations such as variable resistance machines, free weights, elastic resistance, and functional skills such as jumping. Participants complete two or three circuits at a given intensity depending on goals with a prespecified relief interval of 15 to 30 seconds between stations. When designing the circuit, keep in mind the sequence considerations discussed previously.

Training Specificity

Training specificity suggests that "you get what you train for." The SAID (**S**pecific **A**daptations to **I**mposed **D**emands) principle extends the idea first put forth in Wolff's law. Wolff's law states that bone will adapt to the loads placed upon it. The soft-tissue corollary is called Davis' law and states that soft tissues will remodel according to the loads placed upon them.[38] This specificity is particularly significant in terms of training range, mode, contraction type, posture and velocity[39–41] (**Evidence and Research 5-1**).

EVIDENCE and RESEARCH 5-1

The effects of posture on the specificity of training were assessed using squat and bench press lifts as the training tool. A variety of tests followed an 8-week training session that included skills such as vertical jump, 40-m sprint, isokinetic tests, and a 6-second bout on a power bicycle. The authors found results to support the concept of posture specificity, because the exercise postures similar to the training postures enabled the greatest improvements.[42]

The greatest training effects are evident when the same exercise type is used for testing and training, although this principle varies by muscle contraction types (**Evidence and Research 5-2**). A muscle trained isometrically will show the greatest strength improvement when tested isometrically and a muscle trained dynamically will test stronger when evaluated dynamically. However, a study of concentric and eccentric quadriceps training found that specificity was related to eccentric training but not concentric training.[44] Concentric training showed increases only in concentric and isometric strength.[43] Studies have shown bilateral transfer; training one limb resulted in strength gains in the contralateral limb.[39,45,46] Further studies of bilateral versus unilateral training have shown improved bilateral scores when training bilaterally and improved unilateral scores when training unilaterally. These findings were consistent for upper extremity and lower extremity training.[47]

EVIDENCE and RESEARCH 5-2

A group of 12 men was trained in a traditional isotonic strength program for knee flexor and extensor muscles.[43] They were tested isokinetically before and after the 12-week program. Their isotonic strength increased nearly 227%, whereas their isokinetic strength at 60 degrees per second increased only 10%.

ROM specificity also exists; strength improvements are greatest at the joint angles exercised.[40] A study of eccentric training showed isometric strength gains that were joint-angle specific; a similar study of concentric training showed improvements throughout the range.[46] The importance of training specificity is highlighted by the many variables affecting strength development. If the muscular system were the only system involved, then strength development would be predictable and linear. However, functional strength development is a complex relationship between the muscle tissue and the neural system dedicated to that tissue. This includes local and central nervous system mechanisms.

This specificity of exercise is evident to anyone who has trained for one activity (i.e., running) and subsequently discovered little transfer to another activity (i.e., tennis). Even resistive training, while providing a good strength base, does not transfer to other activities, even activities using the same muscle group. Therefore, it is important that resistive training serve as the training base upon which functional training is imposed.

Neurologic Adaptation

Muscle performance is determined by the type and size of the involved muscles and by the ability of the nervous system to appropriately activate muscles. When an unfamiliar exercise is introduced into the resistive exercise program, the early increase in strength partially results from adaptive changes in the nervous system control. Inappropriate instruction or failure to monitor the exercise and ensure appropriate nervous system control can render it ineffective or detrimental to the expected outcome. In order to achieve efficient and effective muscle performance, the following must occur:

- The agonists (muscles responsible for producing the large force in the intended direction) must be fully activated.
- The synergists (muscles that assist in coordinating the movement) must be appropriately activated to ensure precision.
- The antagonists (muscles producing force in the opposite direction of the agonists) must be appropriately activated or relaxed.

DeLorme and Watkins[25] hypothesize that the initial increase in strength after PRE occurs at a rate greater than can be accounted for by muscle morphologic changes. The initial rapid increases in strength probably result from motor learning. When a new exercise is introduced, neural adaptation predominates in the first several weeks of training as the individual masters the coordination necessary to perform the exercise efficiently. Eventually, hypertrophic factors gradually dominate over neural factors in the gain in muscle performance.[43] Although neurologic adaptations were once thought to dominate in the first few weeks of training, Staron et al.[48] found that morphologic changes begin to occur in the second week of training.

Other adaptations, such as the ability to fire motor units at very high rates to develop power, may require a longer period of training to attain and be lost more rapidly during detraining.[49] In the long term, further improvement in performance critically depends on the way the muscles are activated by the nervous system during training.[50]

Muscle Fatigue

Muscle fatigue may be defined as a reversible decrease in contractile strength that occurs after long-lasting or repeated muscular activity.[51] Human fatigue is a complex phenomenon that includes failure at more than one site along the chain of events that leads to muscle fiber stimulation. Fatigue involves a central component, which puts an upper limit to the number of command signals that are sent to the muscles, and a peripheral component. Peripheral changes in cross-bridge function associated with fatigue include a slight decrease in number of interacting cross-bridges, reduced force output of the individual cross-bridge, and reduced speed of cycling of the bridges during muscle shortening (**Table 5-2**).

When the patient is performing resistive training, be alert for signs of fatigue. Fatigue can lead to substitution or injury. The dosage for resistive exercise is often limited to *form fatigue*, the point at which the individual must discontinue the exercise or sacrifice technique. Quality of motion is necessary to ensure that the muscles of interest are being recruited. Synergists can readily dominate a movement pattern when muscle fatigue causes form fatigue. Changes in activation and optimum length for torque activation have been found following fatiguing exercise.[52,53] The patient should be instructed to stop the exercise once form is compromised (i.e., form fatigue). Continuing to exercise with poor technique compromises the outcome and may be detrimental. It is not good enough to perform the exercise; it must be performed correctly and with the appropriate recruitment pattern (**Fig. 5-7 A** and **B**). *A person cannot strengthen a muscle that is not being recruited.*

Muscle Soreness

During resistive training, especially in an untrained state, minor lesions of the muscle structure and inflammation can result in muscle soreness.[54] Most people who initiate a resistive exercise program will feel some stiffness and soreness in the exercised muscles following activity. Soreness may be caused by myofibrillar damage, membrane damage, or inflammatory processes. The serum or plasma level of creatine kinase, an enzyme found almost exclusively in muscle tissue, may be elevated, indicating muscle damage.[55–57] This muscle damage extends beyond just the local muscle environment, but it leads to systemic inflammation as well as increased arterial stiffening, negatively impacting central macrovascular function.[58,59]

TABLE 5-2

Chain of Events Leading to a Muscle Contraction

CHAIN OF EVENTS LEADING TO A MUSCLE CONTRACTION (ANATOMIC SITES OF FATIGUE)		MECHANISMS INVOLVED IN PROCESSING INFORMATION THROUGH THE CHAIN OF EVENTS (PHYSIOLOGIC PROCESSES RESPONSIBLE FOR FATIGUE)	
Central fatigue	Limbic, premotor, and association cortices ↓	Insufficient motivation or incentive	Processes involved in delivery of sufficient electrical excitation from CNS to muscle
	Sensorimotor cortex ↓	Insufficient cortical motoneuron activation	
	Spinal cord ↓	Depressed alpha motoneuron excitability	
Peripheral fatigue	Peripheral motor neurons ↓	Failure in neural transmission	
	Neuromuscular junction ↓	Failure in neuromuscular transmission	
	Sarcolema ↓	Depressed muscle membrane excitability	
	Transverse tubules ↓	Failure of muscle action potential propagation	
	Sacroplasmic reticulum ↓	Insufficient release and/or reuptake of Ca^{3+}	Metabolic and enzymatic processes involved in providing sufficient energy for contraction
	Formation of actin–myosin cross-bridges	Failure in excitation–contraction coupling, insufficient energy supplies, inadequate energy supply replenishment, metabolic accumulation	
	Muscle contraction		

From Currier DP, Nelson RM. Dynamics of Human Biologic Tissues. Philadelphia, PA: FA Davis, 1992:165.

FIGURE 5-7 Ensuring proper exercise mechanics: **(A)** Inappropriate shoulder elevation during arm raising and **(B)** appropriate scapular stabilization during arm raising.

A specific type of muscle soreness referred to as **delayed-onset muscle soreness** (DOMS) is common following eccentric exercises, especially when the exercises are performed at a high velocity.[60] DOMS usually peaks about 2 days after exertion and can last for up to 7 days. During this time, muscle function deteriorates, and muscle strength may be reduced for a week or more after intensive eccentric exercise. Additionally, there is a shift of the optimal angle of peak torque production to longer lengths.[52,53] However, an adaptive process reduces the soreness after repeated eccentric training sessions.[52] Soreness following eccentric training can also be attenuated by preconditioning the muscle groups, performing isometric muscle contractions in a lengthened position.[61,62]

The unaccustomed eccentric exercise and associated high muscle forces damage aboth the muscle contractile and noncontractile structures, and abnormal metabolite accumulation in the muscle cell produces additional damage. Because eccentric contractions utilize a smaller number of motor units than concentric contractions, the excess stress on these motor units appears to be the source of tissue damage and associated inflammation.[63,58] The inflammation initiates the healing process, resulting in an adaptive process, protecting the muscle from similar damage in subsequent exercise bouts.[52]

Even during the soreness period, moderate activity is advised, because the adaptation response occurs before full recovery and restoration of muscle function. A single session of eccentric exercise provides a protective effect against DOMS in subsequent exercise bouts for up to 6 weeks.[52] Therefore when initiating a resistive training program that includes eccentrics, it is best to begin with a light exercise session to protect against significant DOMS.[62]

Patients should be cautioned that eccentric training may lead to muscle soreness 24 to 48 hours after exercise, but that moderate exercise should continue during the recovery period. However, some research has shown attenuation of position sense and joint reaction angle following a bout of eccentric exercise (**Evidence and Research 5-3**). Therefore, use caution when treating populations who are training or working in at-risk environments (i.e., steel workers, roofers).[67,68,69]

EVIDENCE and RESEARCH 5-3

Position sense and reaction angle were tested in the upper extremity by fatiguing the elbow flexors and in the lower extremity by fatiguing knee flexors via repeated eccentric muscle contractions. Although the exercise induced greater muscle damage and loss of position sense in the elbow flexors than in the knee flexors, the elbow flexors remained faster and more accurate than the knee flexors at all measured time points post exercise.[64] Errors were biased toward a more lengthened position.[64,65] A repeated bout of exercise resulted in less muscle damage and improved position sense of the knee flexors.[66]

Life Span Considerations

Newborn Through Preadolescence

Only about 20% of a newborn child's body mass is muscle tissue. The infant is weak, and muscular strengthening in the first months takes place by spontaneous movements. These movements should not be limited by tight clothes or constant bundling of the newborn. However, the infant and toddler should not be burdened with systematic resistive training; normal developmental progression provides an appropriate stimulus for the development of an optimal amount of muscular strength.

In the preadolescent phase (up to age 11 in girls and 13 in boys; approximately Tanner stages 1 and 2), muscle mass increases parallel to body mass. Children are able to make strength gains above and beyond growth and maturation. Benefits of exercise and specifically resistive training in this age group include[70]:

- Improved muscle performance
- Increased motor performance
- Improved body composition
- Increased bone strength
- An enhanced sense of well-being
- A positive attitude toward fitness

During preadolescence, there are no differences between girls and boys with respect to the ability for strength training. Boys have a small genetic advantage, which is completely compensated by the developmental advantage of girls.[71] There is no biologic basis for a sex-dependent difference in strength performance. Most improvements in performance are the result of neurologic changes, such as increased motor unit activation, coordination, and motor learning.[70]

Moderate strength training is acceptable. Resistive training at this age should focus on the neurologic aspects of training (**Fig. 5-8**). See **Table 5-3** for recommendations for programs at the pre-adolescent level.[72,73]

Muscle performance training should always be supervised by knowledgeable staff to avoid risk of injury. Although it has been suggested that resistance training in pre-adolescent children leads to increased musculoskeletal injuries, this appears to be anecdotal. Controlled studies have not found an increase in muscle, bone or joint injuries in resistance training in this population when the program is run by experienced professionals.[74,75]

FIGURE 5-8 Child performing a squat exercise.

Adolescence

Adolescence refers to the time period between childhood and adulthood encompassing young girls aged 12 to 18 years and boys aged 14 to 18 years (Tanner stages 3 and 4).[72] The ability to improve strength increases rapidly during adolescence, particularly in boys. The increase in male sexual hormones is significant because of their anabolic (i.e., protein-incorporating) component. During maturation, the proportion of muscle in boys increases from 27% to 40% of body mass.[71] With the onset of adolescence, the strength of girls compared with boys diverges markedly. On average, the strength of girls is 90% that of boys at 11 to 12 years, 85% at 13 to 14 years, and 75% at 15 to 16 years.[71] Although this gender difference has a biologic basis, biology does not completely account for the differences seen, suggesting continued societal influences.

General strength training is recommended during this phase (**Table 5-4**). Optimal strength and muscular balance are critical for the quickly growing skeleton. Like preadolescence, evidence does not support increased musculoskeletal injuries in adolescents involved in appropriately supervised resistance training programs.[70,74] Low back or other musculoskeletal injuries in resistance training often occur in unsupervised settings where appropriate instruction may be absent.

Guidelines for resistance training in adolescents are similar to that of preadolescents with the most important factors being proper instruction, supervision, and safe progression. Additionally, participants must have the ability to listen and directions to ensure safety. As youth progress through a resistive training program, they progress with activities from isolated muscle exercises to complex multijoint activities that require more coordination. They progress with varies speeds, including higher-speed activities to develop power, and include activities that challenge balance as well (**Table 5-5**). For specific guidelines, see Behm et al.[70] and Faigenbaum et al.[72]

Early Adulthood

Strength potential is at its highest in the 18- to 30-year period.[75] The competent biologic structures show a state of good adaptability, and the joints tolerate high loads. Most individuals are actively involved in physical activity without the responsibility of working long hours. During this period, emphasis should be placed on a balanced fitness program comprised of cardiopulmonary fitness, muscle performance, and flexibility.

Middle Age

The decrement of strength during this phase of life must be differentiated according to training activities, gender, and body area. Training for as little as 2 hours or more each week is sufficient to positively influence strength. A small amount of training increases the difference between active and inactive persons as age increases. As obligations increase in middle age, exercise may become secondary to other responsibilities. Continuing a resistive exercise program can help maintain

TABLE 5-3

General Youth Resistance Training Guidelines

- Provide qualified instruction and supervision
- Ensure the exercise environment is safe and free of hazards
- Start each training session with a 5–10-min dynamic warm-up period
- Begin with relatively light loads and always focus on the correct exercise technique
- Perform 1–3 sets of 6–15 repetitions on a variety of upper- and lower-body strength exercises
- Include specific exercises that strengthen the abdominal and lower-back region
- Focus on symmetrical muscular development and appropriate muscle balance around joints
- Perform 1–3 sets of 3–6 repetitions on a variety of upper- and lower-body power exercises
- Sensibly progress the training program depending on needs, goals, and abilities
- Increase the resistance gradually (5%–10%) as strength improves
- Cool down with less-intense calisthenics and static stretching
- Listen to individual needs and concerns throughout each session
- Begin resistance training 2–3 times/week on nonconsecutive days
- Use individualized workout logs to monitor progress
- Keep the program fresh and challenging by systematically varying the training program
- Optimize performance and recovery with healthy nutrition, proper hydration, and adequate sleep
- Support and encouragement from instructors and parents will help maintain interest

From Faigenbaum AD, Kraemer WJ, Blimkie CJ, et al. Youth resistance training: updated position statement paper from the national strength and conditioning association. J Strength Cond Res 2009;23(5 Suppl):S60-S79.

TABLE 5-4

Recommendations for Strength Training in Youth

	NOVICE	INTERMEDIATE	ADVANCED
Muscle action	ECC and CON	ECC and CON	ECC and CON
Exercise choice	SJ and MJ	SJ and MJ	SJ and MJ
Intensity	50%–70% 1 RM	60%–80% 1 RM	70%–85% 1 RM
Volume	1–2 sets × 10–15 reps	2–3 sets × 8–12 reps	≥3 sets × 6–10 reps
Rest intervals (min)	1	1–2	2–3
Velocity	Moderate	Moderate	Moderate
Frequency (d/wk)	2–3	2–3	3–7

ECC, eccentric; CON, concentric; SJ, single joint; MJ, multijoint; 1 RM, 1 repetition maximum; rep, repetition.
From Faigenbaum AD, Kraemer WJ, Blimkie CJ, et al. Youth resistance training: updated position statement paper from the national strength and conditioning association. J Strength Cond Res 2009;23(5 Suppl):S60-S79.

TABLE 5-5

Recommendations for Power Training in Youth

	NOVICE	INTERMEDIATE	ADVANCED
Muscle action	ECC and CON	ECC and CON	ECC and CON
Exercise choice	MJ	MJ	MJ
Intensity	30%–60% 1RM VEL	30%–60% 1 RM VEL 60%–70% 1 RM STR	30%–60% 1 RM VEL 70% to ≥80% 1 RM STR
Volume	1–2 sets × 3–6 reps	2–3 sets × 3–6 reps	≥3 sets × 1–6 reps
Rest intervals (min)	1	1–2	2–3
Velocity	Moderate/fast	Fast	Fast
Frequency (d/wk)	2	2–3	2–3

ECC, eccentric; CON, concentric; MJ, multijoint; 1 RM, 1 repetition maximum; VEL, Velocity; STR, strength; rep, repetition.
From Faigenbaum AD, Kraemer WJ, Blimkie CJ, et al. Youth resistance training: updated position statement paper from the national strength and conditioning association. J Strength Cond Res 2009;23(5 Suppl):S60–S79.

strength and function, bone density, and appropriate body composition.

Advanced Age

The body can adapt to strengthening exercise throughout the life span. It is possible to reverse existing muscular weakness in old age.[76] Strength increases can result from relatively low stimuli in detrained elderly individuals. Like younger individuals, these strength increases result from both muscular hypertrophy and neural factors.[77,78] Cross-sectional area of trained muscles in older individuals show increases after several weeks of resistive training[79] (**Evidence and Research 5-4**). In general, fatigability increases with advancing age, and older muscles require a longer period of recovery after strenuous exertion. There is also a significant increase in the collagen content of muscle with advancing age. This is associated with thickening of the connective tissue and increased muscle stiffness.

EVIDENCE and RESEARCH 5-4

Fourteen elderly subjects were randomly assigned to a resistive training (RT) or control group. The RT trained BIW for 4 sets of 10 repetitions of a leg press at 70% to 80% of 1 RM. The leg press 1 RM increased by 42% after 10 weeks of training, whereas significant increases in vastus lateralis muscle cross-sectional area were seen only after 9 weeks.[22] Walker et al.[80] compared the changes in neuromuscular performance and muscle hypertrophy between young and older men who performed 10 weeks of a high-volume, medium load resistance training program two times per week. Although both groups improved their muscle performance, only the young men showed significantly increased lean mass, and only the older men showed increased muscle activation. This program did not result in increases in muscle power measured by concentric rapid force production.[81]

The decrease in muscle performance with advancing age affects men and women differently. The absolute decline in strength is less steep in women than in men. Parts of the body are also affected differently. The arms are more affected than the trunk and legs, probably because of less use of the upper extremities in strength-related activities. Active elderly women surpass inactive men with respect to trunk muscle strength.

Adequate muscle strength helps to prevent or moderate the symptoms of degenerative changes of the joints. Resistive exercise by the elderly should be directed toward the muscles susceptible to atrophic changes, especially the deep neck flexors, scapular stabilizers, abdominal and gluteal muscles, and quadriceps. Unjustifiably, little attention is paid to strength of the ventilatory muscles (i.e., diaphragm) and pelvic floor muscles. Training should include both multijoint and single-joint exercises.

Additionally, the elderly should consider training for power, not just strength. Leg power has been shown to significantly influence the physical performance of mobility-limited elderly people.[82,83,84] In some cases, power training has been found to be more effective at improving physical function than traditional strength training.[81,83,85,86] Ankle dorsiflexor and plantarflexor peak power is predictive of chair rise and stair climb performance.[87] Elderly with low power have a two to three times greater risk of significant mobility limitations compared with elderly with low strength.[88] Most strength programs are performed at a slow velocity, whereas power training typically occurs at a higher velocity.

High-velocity resistance training has been shown to increase muscle power more effectively than low-velocity training in older women.[89] High-velocity power training at both high resistance (70% of 1 RM) and low resistance (40% of 1 RM) yielded improvements in muscle power and performance in mobility-limited elderly[90,91] (**Evidence and Research 5-5**). High-velocity power training has also improved braking speed in the elderly, an important factor in fall prevention.[92] As such, high-velocity training may be a preferred resistance training strategy in the elderly.[93] Power training in this group should include light to moderate loads performed for 6 to 10 repetitions with high velocity. See Chapters 17 through 26 for resistive exercises for the spine, shoulder, arm, hip, knee, and pelvic floor (**Fig. 5-9**).

EVIDENCE and RESEARCH 5-5

Researchers studied the effects of power training at different velocities on functional activities such as habitual gait velocity (HGV), stair climb (SC), and chair rise (CR) and compared these to strength training in older men and women. .Power training at 70% and 40% 1 RM showed greater associations with HCV and SC than did strength training at 1 RM. Additionally, power training at 40% 1 RM accounted for more of the variability in HCV than did power training at 70% 1 RM, supporting the use of higher-velocity training in older men and women with mobility limitations.[91]

With advancing age, the social needs and individual motivation for strength demands lessen; the atrophy reflects the effects of disuse, not mere age-related changes. The voluntary and deliberate use of the motor system in daily life activities and intentional resistive training are able to counteract the

FIGURE 5-9 Power training in the elderly using a leg press machine.

loss of muscle mass with increasing age. The vigorous use of muscles, particularly among old persons, improves their health and sense of well-being.

Cognitive Aspects of Performance

The cognitive or mental aspects of strength and performance are most easily seen in elite athletes. Sport psychologists and athletes support using mental imagery techniques such as visualization and positive self-talk. Positive cognitive strategies can enhance strength and performance, and negative strategies may have a negative or negligible impact (**Evidence and Research 5-6**).

EVIDENCE and RESEARCH 5-6

A study of different mental preparation techniques (i.e., arousal, attention, imagery, self-efficacy, and control-read conditions) showed that these techniques and other self-efficacy techniques produced greater posttest strength performance than a group of controls who did not use any mental preparation techniques.[94] Jump height was improved following stating or reading specific action verbs, after specific kinesthetic imagery activities, and after performing mathematical operations, suggesting a link between cognition and performance.[95]

Different kinds of imagery and their impacts on power and endurance activities (i.e., seated shot of endurance activities put and push-ups to exhaustion) have been studied. Results show that these imagery techniques have a positive impact and that using metaphors is particularly effective in improving power and endurance measures.[96] A study of the impact of imagery, preparatory arousal, and counting backward on hand grip strength found imagery to enhance grip strength in both older and younger subjects.[97] Gould et al.[98] found that imagery and preparatory arousal improved strength performance. Verbal encouragement and head-to-head competition enhance performance of endurance activities, whereas mental fatigue has a negative impact.[99]

Effects of Alcohol

The deleterious effects of alcohol abuse on muscle have been well documented.[100] The myopathic changes seen in patients abusing alcohol have at times been attributed to malnutrition or disuse. Experiments have demonstrated that, even with nutritional support and prophylactic exercise, normal subjects can develop alcoholic myopathy if they ingest large amounts of ethanol.[101]

Alcoholic myopathy has two clinical phases:

1. An acutely painful presentation that follows "binges"
2. A chronic phase that consists of morphologic and functional alterations in muscle[102]

Acute alcoholic myopathy has morphologic features, such as fiber necrosis, intracellular edema, hemorrhage, and inflammatory changes. Binges by chronic alcoholics can result in an acute myopathy characterized by muscle cramps, muscle weakness, tenderness, myoglobinuria, reduced muscle phosphorylase activity, and decreased lactate response to ischemic exercise. Exercise is contraindicated for persons with acute myopathy and those with myoglobinuria, because it may stress an already compromised system.

Changes seen with chronic alcoholic abuse include type II fiber atrophy, suggesting that alcoholic patients may exhibit an inability to generate tension rapidly and to produce power.[103] For many patients, abstinence leads to full recovery of muscle function, but for others, the injury may be more severe and resistant to treatment, and this must be considered as a comorbidity when projecting the prognosis.

Effects of Medications

The widespread use of oral corticosteroid agents as anti-inflammatory and immunosuppressant agents has led to cases of steroid atrophy.[104,105] Corticosteroids are a potent catabolic stimuli, and the atrophy caused by prolonged corticosteroid use occurs as protein degradation exceeds protein synthesis. In patients with chronic lung disease, the adverse effects appear to be dose related with increased muscle weakness, back pain, and bruising associated with higher-corticosteroid dosages.[106] The primary biopsy finding in patients treated with prednisone-like steroids (e.g., prednisone, prednisolone, methylprednisolone) is type II fiber atrophy, specifically in type IIB fibers[105,107]; it is believed to occur more often in women than men.[108] Goldberg and Goodman[109] believe that the constant use of the type I fibers during normal voluntary movement provides these fibers with a protective mechanism. Exercises recruiting type II muscle fibers may protect them from steroid-induced atrophy. Normal function can be expected to return within 1 year or, more often, within several months after steroid use has stopped.[108]

Myositis and more severe cases of rhabdomyolysis (requiring hospitalization) have been associated with statins, one of the most commonly prescribed cholesterol-reducing medications, statin[110–113] Although the benefits of cholesterol lowering are clear, side effects such as muscle fatigue, weakness, and pain can be debilitating for patients.[114] Muscle cell apoptosis has been suggested as a potential mechanism for statin-induced myopathy.[114] Myopathy may be caused by the drug itself, by interactions with other drugs, or by capitalizing on individual genetic, immunologic, or metabolic factors.[115] A few of the risk factors include polypharmacy, age >80 years, female sex, diabetes, immunocompromised, high-activity levels, or vitamin D deficiency.[116,117]

Patients with statin-induced myopathy will complain of muscle aching, pain, cramping, stiffness, and fatigue, often symmetrical, but not always. Creatine kinase levels may or may not be elevated.[117] Significant individual variability and lack of a gold standard test have made diagnosing this condition challenging. Physical therapists are uniquely positioned to use muscle performance measures to evaluate patients for statin-induced myopathy.[118] Additionally, close monitoring of patient activity levels can detect and prevent worsening conditions such as rhabdomyolysis.[119–121] Use caution when prescribing therapeutic exercise in patients who are on statin medications, particularly those patients with additional risk factors for statin-induced myopathy. Weight-bearing exercise and eccentric muscle contractions will place patients at additional risk of myopathy.[122] Additionally, statin use can blunt the usual response to aerobic and strength training.[123]

CAUSES OF DECREASE MUSCLE PERFORMANCE

Muscle performance can be impaired for a variety of reasons. Some of these include central or peripheral neurologic pathology; injury to the muscle from a strain or contusion; injury or inflammation to the tendon or its attachment to bone (see Chapter 11); certain medications (see previous section); and disuse or deconditioning for any reason. The goal of examination/evaluation of muscle performance is to determine the *cause* of the impairment in order to develop the most efficient and comprehensive intervention plan. The following section discusses the potential factors that can cause impaired muscle performance, examination/evaluation results of each potential cause, and general intervention concepts for each specific cause.

Neurologic Pathology

Neurologic pathology can affect the contractile capacity of muscle as a result of pathology in the central or peripheral nervous system. The peripheral nervous system can be affected at the nerve root or peripheral nerve level.

Individuals with nerve root pathology may present with muscle performance impairments in the nerve root distribution. For example, nerve root compression at the L4–L5 spinal level can produce quadriceps femoris weakness, whereas nerve root compression at the C5–C6 spinal level can result in deltoid and biceps weakness. Therapeutic exercise intervention depends on the prognosis for the nerve root involvement. If the changes are relatively recent and resolution of the nerve root compression is expected through conservative or surgical management, preventive and protective measures are taken. The goal of therapeutic exercise intervention is not only to promote optimal muscle performance of the muscles innervated by the affected spinal segment (pending prognosis) but also to promote spine stability and optimal movement patterns to alleviate any mechanical cause of nerve root pathology incurred by the spinal segment(s) (see Chapters 17 and 23).

Peripherally, use resistive exercise to maintain or improve current strength levels, while training deep lumbar or deep cervical flexor muscles to provide proximal stability. Centrally, use resistive exercise to train inner core muscles (i.e., longus coli, transversus abdominis, lumbar multifidus, pelvic floor; see Chapters 18, 19, and 24 for detailed muscle performance training) to effectively stabilize the spine and relieve mechanical nerve root irritants. After the mechanical or chemical cause of nerve root injury is remediated, use specific, localized resistive exercise of the involved musculature to restore precise recruitment patterns.

Neurologic weakness may also result from a peripheral nerve injury (i.e., median nerve at the carpal tunnel, the ulnar nerve at the cubital tunnel, or the common peroneal nerve at the fibular head). The pattern of sensory loss and weakness depends on which nerve and where along the nerve's course the insult occurs. Therapeutic exercise should be focused on remediating the mechanical cause of the peripheral nerve injury. For example, a depressed shoulder girdle may contribute to traction on the long thoracic nerve, causing motor changes in the serratus anterior. Exercise and posture education to elevate the shoulder girdle may alleviate the traction on the long thoracic nerve and ultimately restore normal innervation to the serratus anterior. Exercise should try to maintain muscle balance and efficient movement patterns without developing a dominant muscle group. Splinting, bracing, taping, or other supportive measures may be necessary to maintain balance, especially in the short term.

Other neurologic conditions include neuromuscular disease such as multiple sclerosis, postpolio syndrome, Guillain–Barré syndrome, and muscular paralysis or paresis resulting from spinal cord injury or stroke. Resistive exercise programs must consider the prognosis and tailor the exercises appropriately. In situations such as Guillain–Barré syndrome, certain cases of spinal cord injury and stroke and progressive stages of multiple sclerosis, some recovery is expected. Exercise programs focus on improving muscle performance in intact musculature and gently strengthening weakened muscles as recovery and remission advances. Avoid fatiguing weakened muscles during strengthening exercises. Dosage parameters generally include several short exercise sessions of a few repetitions interspersed throughout the day.

During quiescent periods of diseases such as multiple sclerosis, a general conditioning program of balanced strengthening and mobility exercises is appropriate. When recovery is not expected, resistive exercise programs emphasize functional strength of remaining musculature. This includes strength for functional activities such as self-care, transfers, and mobility. Take care to avoid overworking these muscles. Unlike persons with full innervation who use their muscles efficiently, the individual with paralysis uses the few innervated muscles they have for nearly all their activities. The potential for overuse injuries is very high.

Muscle Strain

Muscle strain occurs along a continuum from acute macrotraumatic injury to chronic microtraumatic overuse injuries and can be caused by traumatic strain, eccentric loading, chronic overuse, muscle dominance overuse, or continuous overstretching (see Chapter 11). Resistive exercise in the treatment of muscle strain injuries depends on where along this continuum the injury occurs. Resistive exercise that neither overloads nor underloads the tissue is optimal. Determining this resistance dosage is the challenge.

Acute traumatic injuries occur when a muscle is rapidly overloaded or overstretched, and the tension generated exceeds the tensile capability of the musculotendinous unit.[124] The hamstring muscle is a common site of muscle strain injury. A combination of insufficient strength, reduced extensibility, inadequate warm-up, and fatigue has been implicated in hamstring injuries[125] (see **Patient-Related Instruction 5-1**). Strength, extensibility, and fatigue resistance protect a muscle from strain injury.

Eccentric loading is a common mechanism of muscle strain injury, but a muscle prepared for eccentric loading is less likely to sustain an injury. Eccentric loading should be an integral part of any resistance training program (see **Selected Intervention 5-1**, for an example of eccentric loading). A program to prevent muscle strain injuries should include dynamic resistive exercises with a strong eccentric component, flexibility exercises, appropriate warm-up before activity, and attention to fatigue levels. The rehabilitation program after injury should also focus on these factors.

Muscles may also be strained from chronic overuse. For example, extensor digitorum longus (EDL) strain is common in workers performing continuous repetitive elbow, wrist, and hand activities as a result of using the EDL for wrist extension and elbow flexion. Training the individual to use the biceps for elbow flexion whenever possible (i.e., keep the hand supinated vs. pronated during elbow flexion) can alleviate the overuse strain to the EDL. A thorough evaluation can determine the cause of the overuse problem. Ergonomic assessment and appropriate work site modification are also necessary to prevent a recurrence of the strain if ergonomics is at the root of undesirable posture or movement patterns. If left untreated, this impairment can quickly lead to participation restrictions.

Strain resulting from muscle dominance overuse is managed by reducing the loads imposed on the strained muscle. When the tensor fasciae latae dominates over the iliopsoas during hip flexion and over the gluteus medius during abduction, the tensor fasciae latae is at risk for an overuse strain. Improving the strength and recruitment patterns of the iliopsoas and gluteus medius can reduce the load on the tensor fasciae latae and allow it to recover. Postural habits (e.g., standing in medial rotation) and movement patterns (e.g., hip flexion or abduction with medial rotation) must also be modified to improve recruitment of the underused synergists.

A potential risk factor of muscle strain is gradual, continuous overstretching, which occurs when a muscle is continuously placed in a relatively lengthened, tension-producing position. For example, the lower trapezius in a person with protracted scapulae is subjected to continuous tension and has adapted to a lengthened state. It may not take much force to produce a strain injury in a muscle that is already overstretched. This type of strain puts the muscle at risk for two forms of muscle weakness; (1) from length–tension changes and (2) from overstretch strain.

Patient education is a key component of the rehabilitation program in the case of muscle strain associated with continuous overstretch. In the lower trapezius example, educate the patient about optimal postural habits to reduce tension on the lower trapezius. Improving postural habits and reducing tension on the lower trapezius with bracing or taping (see Chapter 25) will allow the muscle to heal more rapidly. In addition, it will promote adaptive shortening and therefore ultimately achieve a more optimal length–tension relationship and reduce the risk for future reinjury.

Patient-Related Instruction 5-1

Preventing Muscle Strain

Although some muscle strains are not preventable, precautions can reduce your risk of injury.

1. Warm up before a vigorous activity; 5 to 7 minutes of a large muscle group activity such as walking, jogging, or cycling should suffice. This should be enough activity to break a sweat.
2. Stretch stiff and short muscles after your general warm-up. Stretching can be static or dynamic depending on your activity. Stretch each muscle for 15 to 30 seconds for 4 repetitions at the conclusion of your exercise session.
3. Balance your sports or other leisure activities with strengthening exercises. Your clinician can help you focus on muscles susceptible to injury.
4. Avoid fatigue during the activity. Fatigue can increase your risk of injury.
5. Strengthen underused muscles to prevent overuse to susceptible muscles. Your clinician can help you determine which muscles these are and what specific exercises you need to perform to maintain muscle balance.

SELECTED INTERVENTION 5-1

Lateral Kicks

See Case Study No. 1

Although this patient requires comprehensive intervention as described in other chapters, only one exercise related to resistive training is described. This exercise would be used in the late phase of this patient's rehabilitation.

ACTIVITY: Resisted hip abduction and ankle eversion.

PURPOSE: To increase the muscle performance of the ankle evertor and hip abductor muscles.

STAGE OF MOTOR CONTROL: Controlled mobility.

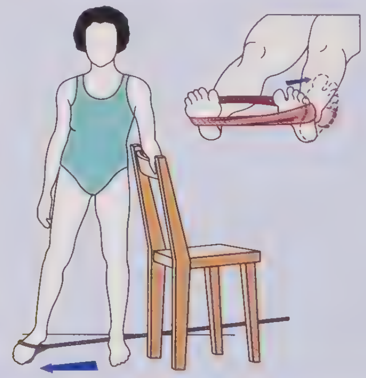
MODE: Resistive band.

POSTURE: Standing with one foot on the resistive band and the band around the other foot. A support should be readily available for balance as needed.

MOVEMENT: Standing on the uninjured leg, abduct the hip in the frontal plane, and evert (pronate) the ankle. Raise the leg to the side slowly and controlled (concentric phase) and lower to the starting position more quickly (eccentric phase), but controlled. Maintain good spinal posture throughout the exercise. Do not hike pelvis; move only at the hip joint. Maintain frontal plane movement; moving toward flexion results in the motion performed by the flexor abductor group. Repeat.

DOSAGE: Two to three sets per day to form fatigue. If patient does not fatigue by 20 repetitions, increase the resistance of the band.

EXPLANATION OF PURPOSE OF EXERCISE: This exercise increases muscle performance in the hip abductors and ankle evertors in a synergistic fashion. Abductors are strengthened in both concentric and eccentric modes. It may be progressed to a higher speed to increase the eccentric loading. Remove the support to challenge stability.



Disuse and Deconditioning

Muscle performance may be impaired because of disuse or deconditioning for a variety of reasons. Illness, surgery, specific physical conditions (e.g., pregnancy with twins), or injury may necessitate a period of decreased activity. Subtle muscle imbalances can lead to overuse of one muscle and to disuse and deconditioning of another.

Illness and injury are common causes of deconditioning. For example, illness such as pneumonia or an injury such as a herniated disk can result in a period of decreased activity and subsequent deconditioning. In these situations, total-body deconditioning occurs, and general conditioning is necessary, whereas specific exercises may be necessary to improve muscle performance and prevent secondary impairments. For example, an elderly individual may have relatively asymptomatic osteoarthritis until a bout with pneumonia produces general deconditioning. Subsequently, knee osteoarthritis becomes symptomatic because of impaired muscle performance in the lower extremity muscles involved in gait and other functional activities. Specific resistive exercises to address the impairment of muscle weakness are necessary to restore proper biomechanics and prevent activity limitations and participation restrictions.

Reduced activity levels can impair muscle performance in a similar manner. Multiparous pregnancies, exacerbation of a musculoskeletal injury, an episode of colitis, or social factors such as major life changes (e.g., job, school, divorce, family illness) can reduce activity levels and result in impaired muscle performance. For example, regular exercise may keep a woman's patellofemoral malalignment from becoming symptomatic. When her activity level decreases in the late stages of pregnancy, the combination of decreased activity, weight gain, and hormonal changes produces symptoms at the patellofemoral joint. Selective resistive exercises combined with patient education can prevent this exacerbation. Resistive exercises in the case of overall decreased activity must consider the muscles most likely to be affected, the patient's desired activity level and preference, and any underlying or residual medical conditions.

An overlooked source of deconditioning or disuse is a subtle muscle imbalance. When activating muscles for a functional movement, the body chooses the most efficient muscular and motor unit activation pattern. Certain motor units in a muscle may be preferentially recruited when a muscle is engaged in a particular task.[126] For example, motor units in the lateral portion of the long head of the biceps are preferentially activated when this muscle is engaged in elbow flexion, whereas motor units in the medial portion are preferentially activated in forearm supination.

The recruitment thresholds of motor units in a muscle are also influenced by the type of muscle actions associated with a movement. In elbow flexion, biceps motor units have a lower threshold in slow concentric and eccentric actions than isometric actions; the reverse is true for the brachialis.[127] The recruitment thresholds of motor units of a muscle active in a movement may also be affected by changes in joint angle.[128] Some muscles or portions of a muscle may be overused, whereas other muscles or portions are disused, and the resistive rehabilitation program must acknowledge this imbalance. In the previous example, instruction in general resisted elbow flexion may exacerbate the imbalance whereas specific training of the weaker recruitment pattern can restore muscle balance.

Length-Associated Changes

The principle of the length–tension curve affects muscle performance when a muscle is adaptively lengthened from prolonged posture and repetitive movement patterns with the muscle in that lengthened state. Positional weakness can result. Postural examination findings of a depressed shoulder suggest length weakness in the rhomboids and trapezius muscles, whereas findings of an adducted and medially rotated hip suggest length weakness in the gluteus medius muscle. Muscles will test weak in the short range when compared with synergists (i.e., posterior gluteus and tensor fasciae latae), paired muscle of the other extremity (i.e., right and left posterior gluteus medius), or other half of the axial skeleton (i.e., right and left external oblique muscles). Intervention should focus on strengthening the muscle in the shortened range, optimizing posture to reduce lengthening tension on the muscle, and altering movement patterns to recruit the muscle in the shortened range.

PHYSIOLOGIC ADAPTATIONS TO TRAINING

Strength and Power

The benefits of resistive exercise extend beyond the obvious improvements in muscle performance to include positive effects on the cardiovascular system, connective tissue, and bone. Moreover, these effects translate into function. Individuals perform their daily activities with more ease because they are functioning at a lower percentage of their maximum capacity. Functional activities such as gait velocity, stair climbing, and ease of transfers are all improved with resistive training.[90,129] Improved functioning also enhances the patient's sense of well-being and independence. Additionally, strength training has shown crossover effects, where training one limb translates into muscle performance improvements in the contralateral limb.[39,130]

Muscle

The most obvious benefits of resistive training are for the muscular system. Regular resistive exercise is associated with several positive adaptations, most of which are dosage dependent (**Table 5-6**). The cross-sectional area of the muscle increases as a result of an increase in the myofibril volume of individual muscle fibers, fiber splitting, and potentially an increase in the number of muscle fibers. These changes have been seen in a variety of age groups, and when using different resistance training modes and dosages.[131–135] Changes in the muscle depend on fiber type and the stimulus.[136,137] Hypertrophy of fast-twitch fibers occurs when all or most of the fibers are being recruited and is considered an adaptation for increased power output. Slow-twitch fibers hypertrophy in response to frequent recruitment. In repetitive, low-intensity activity, fast-twitch fibers are rarely recruited, and these fibers may atrophy while the slow-twitch fibers hypertrophy. Staron et al.[138] examined the differences in the proportion of muscle fiber types between distance runners, weight lifters, and sedentary controls. The weight lifters had a greater proportion of type IIA fibers than the controls or distance runners.[138] This exemplifies the need for specificity of resistive training when designing a training program.

On the cellular level, capillary density is unchanged or decreases, and the mitochondrial density decreases.[132,133] Although protein volume and cross-sectional area increase, some of the cellular or systemic factors may remain unchanged, resulting in a perceived decrease, although the decrease is only relative.

TABLE 5-6

Physiologic Adaptations to Resistance Training

VARIABLE	RESULT AFTER RESISTANCE TRAINING
Performance	
Muscle strength	Increases
Muscle endurance	Increases for high-power output
Aerobic capacity	No change or increases slightly
Maximal rate of force production	Increases
Vertical jump	Increases
Anaerobic power	Increases
Sprint speed	Improves
Muscle Fibers	
Fiber size	Increases
Capillary density	No change or decreases
Mitochondrial density	Decreases
Enzyme Activity	
Creatine phosphokinase	Increases
Myokinase	Increases
Phosphofructokinase	Increases
Lactate dehydrogenase	No change or variable
Metabolic Energy Stores	
Stored ATP	Increases
Stored creatine phosphate	Increases
Stored glycogen	Increases
Stored triglycerides	May increase
Connective Tissue	
Ligament strength	May increase
Tendon strength	May increase
Collagen content	May increase
Bone density	Increase
Body Composition	
Percentage of body fat	Decreases
Fat-free mass	Increases

Adapted from Falkel JE, Cipriani DJ. Physiological principles of resistance training and rehabilitation. In: Zachazewski JE, Magee DJ, Quillen WS, eds. Athletic Injuries and Rehabilitation. Philadelphia, PA: WB Saunders, 1996.

Energy sources that fuel muscle contraction increase after resistive training. In general, levels of creatine phosphate, ATP, myokinase, and phosphofructokinase increase in response to a resistive exercise program.[139–142] Lactate dehydrogenase is variably changed.[140]

Neural adaptations occur with resistive training. Studies have shown increases in the muscle's ability to produce torque and increased neural activation, as measured by electromyography (EMG).[49] Increased EMG values associated with greater power and maximal contraction were attributed to a combination of increased motor unit recruitment and increased firing rate of each unit.[143]

Connective Tissue

Although disuse and inactivity cause atrophy and weakening of connective tissues such as tendon and ligament, physical training can increase the maximum tensile strength and the amount of energy absorbed before failure.[144] Physical activity returns damaged tendons and ligaments to normal tensile strength values faster than complete rest.[145] Physical training, particularly resistive exercise, may alter tendon and ligament structures to make them larger, stronger, and more resistant to injury. Additionally, resistive training can increase the loading capabilities of the tendon-bone and ligament-bone interfaces.[146]

Bone

Weightlessness[147] and immobilization[148] can cause profound loss of bone density and mass. Weight-bearing activities that recruit antigravity muscles can maintain or enhance bone density and mass.[149] Individuals in sports requiring repeated high-force movements such as weight lifting and throwing events have higher-bone densities than distance runners, soccer players, or swimmers.[150] Those who play tennis regularly have higher-bone density in their dominant forearms, and professional pitchers have greater bone density in the dominant humerus.[151] A 5-month study of weight training compared with jogging found that weight training produced significantly better increases in lumbar bone density than the aerobic exercise.[152]

Resistive training to improve bone density is important for people of all ages, and particularly for women who are prone to osteoporosis[153] (**Evidence and Research 5-7**). In adolescents, resistive training and weight-bearing exercise consistently show improvements in bone density compared with sedentary peers.[157–159] Impact activities that include jumping and landing are particularly effective in building bone mass and strength, especially when combined with proper nutrition in the pre- and peri-pubertal periods.[160] Research into bone mass and exercise dosage found that daily loading regimens broken down into four sessions with recovery time in between improved bone mass significantly over a loading schedule that performed the training in a single, uninterrupted session.[161] Thus smaller exercise sessions separated by recovery periods may be a better prescription when increased bone mass is the goal.

EVIDENCE and RESEARCH 5-7

A study of adolescent female athletes found runners to have higher total body and site-specific bone mineral density than swimmers or cyclists, and that knee extension strength was an independent predictor of bone mineral density in this population.[154] Adolescent female swimmers did not show increases in bone mineral density compared with a control group, highlighting the importance of weight-bearing or impact activities for adolescent females.[155] Female athletes participating in high impact or odd impact (i.e., soccer, racket sports) demonstrated thicker cortices and denser bones than controls or swimmers.[156]

Cardiovascular System

Resistive training benefits the cardiovascular system. The idea that strength training causes hypertension is erroneous. Most reports show that highly strength-trained athletes have average or lower than average systolic and diastolic blood pressures.[162] When performed properly and heeding the proper precautions, strength training can have a positive effect on the cardiovascular system.

Increased intrathoracic or intra-abdominal pressures may affect cardiac output and blood pressure during resistive exercise. In the classic model, increased intrathoracic pressures are thought to decrease venous return, decrease cardiac output, and cause an increase in blood pressure. Performing resistive exercises with a Valsalva maneuver, which elevates intrathoracic pressure, leads to a greater blood pressure response than performance of the exercise without a Valsalva maneuver.[163] Instructing the patient to breathe properly during exercise may reduce the increase in blood pressure sometimes seen during exercise.

Increased intramuscular pressure during resistive exercise may result in increased total peripheral resistance and increased blood pressure. Mechanically induced increases in peripheral resistance probably are the cause of higher blood pressures during isometric and concentric exercise compared with pressures during eccentric exercise.[164] Isometric or concentric exercise combined with a Valsalva maneuver can produce the greatest increase in blood pressure. This combination should be avoided, especially by individuals at risk for elevated blood pressure (see Section "Precautions and Contraindications").

Resistive exercise does result in a pressor response that affects the cardiovascular system by causing hypertension through exciting the vasoconstrictor center, which leads to increased peripheral resistance. If precautions are taken to ensure proper breathing and avoid isometric contractions in persons at risk for a pressor response, resistive exercise's benefits outweigh the risks. Long-term performance of resistive exercise can result in positive adaptations of the cardiovascular system at rest and during work. Cardiovascular adaptations to resistive training are summarized in **Display 5-2**.

Endurance

As expected, the muscle's response to endurance training is different from its response to strength or power training. Muscular endurance depends on oxidative capacity, and training increases the muscle's metabolic capacity. During prolonged activities, depletion of intramuscular glycogen reserves may contribute to impaired muscular endurance.

Muscles trained for endurance demonstrate cells with increased mitochondrial size, number, and enzymatic activity,[166] allowing the muscle to better use the oxygen delivered. In addition, endurance-trained muscle demonstrates increased local fuel storage; they increase fatty acid use and decrease the use of glycogen as a fuel, allowing more exercise before fatigue. Lastly, endurance muscle training improves the oxygen delivery system by increasing the local capillary network, producing more capillaries per muscle fiber.[166] Increased perfusion slows the accumulation of lactate in the working muscles.

DISPLAY 5-2

Benefits of Strength Training on the Cardiovascular System[165]

- Decreased resting heart rate
- Decreased or unchanged systolic blood pressure
- Decreased or unchanged diastolic blood pressure
- Increased or unchanged cardiac output
- Increased or unchanged stroke volume
- Increased or unchanged maximal oxygen consumption
- Decreased or unchanged total cholesterol

EXAMINATION AND EVALUATION OF MUSCLE PERFORMANCE

Decreases in muscle performance may occur for a number of reasons. The physical therapist must perform a thorough examination to determine the cause of impaired muscle performance and the link between impaired muscle performance and activity limitations or participation restrictions. After that relationship is established, therapist must then match the intervention to the cause of impaired muscle performance. The muscle test is only one small part of the examination process and must be used with additional information (e.g., ROM, joint mobility, balance, sensory, and reflex integrity) to determine the specific cause of impaired muscle performance.

The tests and measures recommended by the *Guide to Physical Therapist Practice*[167] ensure comprehensive assessment of the patient's impairments, activity limitations, and participation restrictions. Various muscle performance tests include manual muscle tests, dynamometry, electrophysiologic testing, and an analysis of functional muscle strength, power, or endurance. Of these, manual muscle testing is the most fundamental of all strength tests. Consider length–tension relationships, muscle imbalance, and positional weakness when choosing manual muscle test positions. Minimize the chance of erroneous results by paying close attention to substitution patterns and by testing in a variety of positions. When used reliably, hand-held dynamometers can provide muscle performance information that is more reliable than that of tests using the traditional criteria of 0 through 5.

Isokinetic dynamometers are commonly used to assess muscle performance. Computerized systems provide tremendous data reduction capabilities. Tests can be performed at a variety of speeds and comparisons made with antagonists, the contralateral limb, normative standards, or previous test results. These tools provide reliable data that can be used to assess progress, as a motivator, or as criteria for progression to more advanced rehabilitation phases. A variety of muscle actions can be assessed using this equipment.

Dynamic strength can also be determined using the RM method. For example, a 10 RM is the maximum amount of weight that can be lifted 10 times, and a 1 RM is the maximum amount of weight that can be lifted once. The amount of weight that can be lifted for a given number of repetitions can be determined and compared with that for the antagonist, the opposite limb, or to a previous test result.

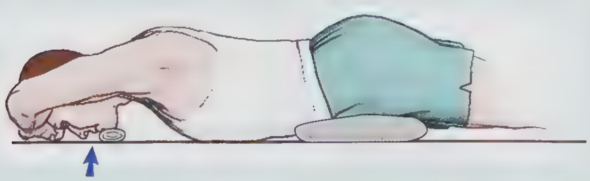
The magnitude of measured increases in force or torque depends on how similar the test is to the training exercise.[168] For example, if athletes train their legs by doing the squat exercise, the increase in strength measured as maximal squatting is much greater than the strength increase measured in isometric leg press or open kinetic chain knee extension tests. This specificity of movement pattern in strength training probably reflects the role of learning and coordination.[169] Improved coordination takes the form of the most efficient activation of all of the involved muscles and the most efficient activation of motor units within each muscle involved. Testing force production in the manner in which the muscle has been trained reflects the morphologic and neurologic adaptations.

CLASSIFICATION OF RESISTANCE EXERCISE

Resistive exercise can be broadly classified into categories comparing the force generated by a muscle or muscle group relative to an external load. This external load can be applied by numerous mechanisms such as a machine, a resistive band, hand-held equipment, a person (manual resistance), a stationary object or body weight. Exercises where the internal force generated matches the externally applied load are considered to be **isometric** exercises. In isometric exercise, no joint motion takes place, although muscle activation occurs. All other activities are **dynamic** involving joint motion. When the external load is less than the force generated by the muscle **concentric** contractions result, whereas when external loads exceed the internally generated force, **eccentric** contractions are produced. Resistance applied at a constant velocity is termed *isokinetic*.

Isometric Exercise

Isometric exercise is commonly used to increase muscle performance. Although no joint movement occurs and technically no work is performed (work = force × distance and distance = 0), isometric exercise is considered functional because it provides a strength base for dynamic exercise and because many postural muscles work primarily in an isometric fashion (see **Self-Management 5-1**, for an example of isometric exercise for postural muscles). Before an eccentric muscle contraction, a concentric or an isometric contraction must occur first, presetting tension in the muscle. For example, the quadriceps muscles isometrically preset tension to stabilize the knee in full extension before initial contact during the gait cycle; the same happens when the knee is in near full extension prior to landing from a jump. These isometric contractions allow a subsequent quadriceps eccentric contraction to decelerate the flexing knee to absorb shock. Therefore, isometric contractions are an essential component of many functional activities.

> **SELF-MANAGEMENT 5-1**
> **Isometric Cervical Spine Extensor Strengthening**
>
> **Purpose:** To strengthen cervical extensors.
>
> **Position:** Lying on your stomach with fists positioned under your forehead and a pillow under your trunk; a small towel roll under your chin may be necessary to keep your head in neutral.
>
> **Movement Technique:** Remove your hands from your forehead and hold your head in a proper neutral position.
>
> Hold for 10 seconds, breathe normally.
>
> **Dosage:**
>
> Repetitions: ________ ________________
> per set ________________________ sets
>
> Frequency: ________________________
> sessions per day, ____________ sessions per week
>
> 

Indications

Isometric exercise is a valuable rehabilitation tool in many situations. For example, isometrics are:

- A foundational exercise, an isometric training often precedes dynamic muscle training
- Used to pretension muscles before any eccentric muscle contraction
- Preferred over dynamic exercise when joint motion is uncomfortable or contraindicated, such as postoperatively or with an unstable joint
- Essential to maintain muscle strength and prevent significant declines during immobilization
- Combined with dynamic exercise to focus strengthening at a weak point in the ROM
- Frequently used for muscle reeducation purposes
- An important component of stabilization programs

One of the benefits of isometric exercise is the ability to perform repetitive submaximal contractions as "reminder" or reeducation exercises. Following lower extremity injury or surgery, recruiting and activating the quadriceps muscles can be difficult; similarly, recruiting and activating the rotator cuff musculature following shoulder surgery or injury can be equally challenging. Quadriceps setting and rotator cuff isometric exercises at a low, submaximal level can maintain connective tissue mobility (i.e., patellar mobility, ligament, tendon, and fascial mobility), and muscle mobility and function. Quadriceps and gluteal sets are also used to enhance circulation and maintain mobility and muscle performance throughout the lower extremity during periods of bed rest.

Isometric setting exercises area prerequisite for more advanced dynamic exercises, particularly those requiring eccentric muscle contractions. This is a more complex neuromuscular activity than one might think. *Neuromuscularly, isometric tension is set at an appropriate and predetermined level before commencing an eccentric muscle contraction*. For example, if one were to catch an object being tossed at them, or to jump down from a given height, the brain must first signal the necessary muscles to preset isometric tension in order to decelerate the object upon catching, or the body upon landing, *respectively*. The brain determines how much isometric tension to preset based upon previous experience and estimates of the object weight or distance to landing (**Fig. 5-10**). One of the significant challenges is teaching the patient *how* much tension to preset to accomplish a given task. In this case, isometric training at different percentages of maximal activation is useful.

Isometric exercise also functions as a component of dynamic exercise when weakness exists at a specific point in the ROM. Proprioceptive neuromuscular facilitation (PNF) techniques include isometric contractions as part of a dynamic program to enhance stability and to strengthen muscles in a weak portion of the range (see Chapter 15). For example, while performing a diagonal pattern, the therapist may stop and apply an isometric contraction at a weaker portion of the ROM.

A B

FIGURE 5-10 Landing from a jump requires presetting isometric quadriceps muscle contraction **(A)** prior to landing **(B)**.

Isometric contractions are also an important component of stabilization programs. **Stabilization** programs are a progressive series of exercises and activities designed to increase a patient's ability to dynamically control movement at a joint or series of joints. Stabilization exercises are an important component of treatment programs for shoulder, knee, and ankle instability, as well as the basis of treatment for many spinal problems (**Fig. 5-11**). For example, PNF techniques such as alternating isometrics and rhythmic stabilization use isometric contractions as the basis for stability training.

This resistive mode is easy to understand and perform correctly, requires no equipment, and can be performed in almost any setting. Isometric exercise is most effective when individuals are in a low state of training, because the benefits of isometric exercise decrease as the state of training increases. Most gains are made within the first 5 weeks of the onset of training.[170]

FIGURE 5-11 Plank on elbows and knees is a common isometric stabilization exercise.

Considerations in Isometric Training

Some factors are important in choosing isometric exercise for rehabilitation. Isometric strength is specific to the joint angle. Studies have demonstrated isometric joint angle specificity, noting that strength gained at one joint angle did not predictably carry over to other joint angles.[171] Neuromuscular changes accounted for the joint-angle–dependent effects, and obtaining generalized strength gains required multiangle training programs. Whitley[172] found significantly increased strength at all joint angles after 10 weeks of training at specific joint angles. Others have found this general transfer, although only after training was well advanced.[173] In the beginning training phase, the strength gains were transferred only when the muscle was at shorter than resting length.

Dosage

Like most resistive exercise programs, dosing the exercise is the most challenging aspect. Dosing for strength differs from dosing for muscle reeducation, and this differs from dosing for stabilization. Isometric exercise for these different therapeutic goals requires a specific approach for each.

Dosing for strength training has two important variables: intensity and ROM. Because of the angle specificity, multiangle isometric training is recommended whenever possible. Muscle contraction should be maximal or nearly maximal and should be performed to fatigue. Exercise may be performed at a low frequency. Sample dosage parameters for isometric exercise prescription for strength are as follows:

- Perform isometric contractions every 15 to 20 degrees throughout the ROM.

- Hold each contraction approximately 6 seconds, which is long enough to fully activate all motor units. The first few seconds of the first maximum contraction appears to trigger the major training effect—after the first few seconds, the ability to maintain a maximal contraction drops off dramatically.[23]
- Repeat frequently throughout the day.
- Have their greatest effect near maximal contraction, although this may not be possible in many clinical situations.

Dosing for muscle reeducation requires a different prescription. Contraction intensity is submaximal and can vary from very low intensity (<20% maximum voluntary contraction or MVC) to >50% MVC depending on the situation:

- Exercise at the lowest intensity immediately after injury or surgery serves as a reminder to contract the muscle.
- Following back surgery, perform abdominal muscle contractions at a very low level.
- Following a patellar dislocation, perform low level quadriceps contractions.
- A patient who needs improved thoracic and cervical posture might perform scapular retraction isometrics at 50% or more of MVC throughout the day.

  Because intensity and volume are inversely related, isometric contractions for muscle reeducation are performed at a high volume. Activities that are performed for postural awareness may be put "on cue" asking the patient to perform a set of isometrics on cue, such as every time the phone rings, or every time a new e-mail message arrives. Progress these exercises to dynamic strengthening, isometrics at a higher percentage of MVC, and/or isometric exercise with external resistance, such as holding a position against elastic resistance or with a free weight.

Isometric dosage for stabilization will vary depending on the patient's current strength, injury or pathology and current pain levels. Stabilization exercises are like muscle reeducation in that one of the goals is to train the muscles to dynamically maintain a joint or series of joints within a small range of optimal postures. An additional goal is to simultaneously strengthen the muscles required to do this. Thus the dosage is more flexible and is specific to each patient situation. For stabilization activities, a common pattern would be initial training for muscle reeducation, where the emphasis is on contracting the right muscle group and avoiding the "overflow" phenomenon where the patient globally activates all muscles in the region. For example, in attempting to perform a quadriceps set, the patient may "overflow" activating the hamstring and gluteal muscles in addition to the quadriceps. In the core, the patient may activate all abdominal muscles when trying to activate only the deep trunk stabilizers. Once the correct activation has been achieved, progress the program to strengthening followed again by a muscle reeducation program to teach the patient to activate just enough motor units to accomplish the functional task safely. Thus, the program might look like this:

1. Teach patient how to activate the muscle(s) of interest without overflow.
2. Once isolated, strengthen the muscle(s) of interest.
3. Reeducate to activate only to the level necessary to accomplish the task at hand.

Precautions

Use caution when prescribing isometric exercise for patients with hypertension or known cardiac disease. Isometric exercise can produce a pressor response, increasing blood pressure. Perform isometric exercise without breath holding or a Valsalva maneuver. Individuals with hypertension may benefit from simple, repeated contractions held only 1 to 2 seconds. Encourage the patient to "count aloud while exhaling" to avoid breath holding.

Dynamic Exercise

Dynamic resistive exercise can be performed in a variety of modes, postures, and dosages, as well as with a variety of contraction types (i.e., concentric, eccentric). Dynamic exercise implies joint motion and a shortening or lengthening contraction of the working muscle. Dynamic exercises have been called *isotonic exercises* in the past and the term is still in common usage today despite the technical shortcomings of the term.

Body weight, elastic bands, free weights, pulleys, manual resistance, and weight machines are a few modes of dynamic resistive exercise (see **Patient-Related Instruction 5-2**). Concentric and eccentric contractions can be used in different combinations depending on the mode of exercise chosen (i.e., most weight machines use concentric and eccentric contraction of the same muscle groups whereas manual resisted exercise can use concentric and/or eccentric contractions of opposing or same muscle groups). As with isometric exercise, each type of dynamic exercise has risks and benefits, and the training mode should match the identified activity limitations and participation restrictions. The ACSM recommends that for novice and intermediate training, both free weights and machines be used, whereas the advanced and elite athletes' emphasis should be primarily with free weights.[37]

Although isokinetic exercise is a type of dynamic exercise, it is often considered in a different category from isotonic exercise. Although isotonic exercise can be performed at a constant velocity, it is performed against a constant load. Isokinetic

Patient-Related Instruction 5-2

Purchasing Resistive Equipment

Before purchasing resistive equipment for home use, the following information should be considered:

1. Is the equipment safe? Is it approved by a reputable organization?
2. How easy is the equipment to use? How long will it take to learn how to use it?
3. Is the equipment versatile? Can it be used to train a number of different muscle groups?
4. Will the equipment suit your needs as your training progresses?

Before purchasing equipment, consider joining a health club for a month or two to see:

1. Which equipment you tend to use regularly
2. What features you like about some equipment
3. What features you dislike or seem to be lacking

exercise is performed at a constant velocity with accommodating resistance; that is, the isokinetic device "matches" the resistance applied by the subject. Specific indications and dosage for each type of dynamic exercise will be considered in the next section.

METHODS OF RESISTANCE TRAINING

The specific activities and dosage chosen to improve muscle performance depend on many factors, including the individual's age and medical condition, muscles involved, activity level, current level of training, goals (i.e., strength, power, and endurance), and cause of decreased muscle performance. The following sections describe the activities used to increase muscle performance and their relative risks and benefits. Be sure to match the appropriate training mode to the patient's impairments, activity limitations, and participation restrictions.

Manual Resistance

Manual resistance can be applied by the clinician, the patient, or a family member. It is one of the most longstanding forms of resistance training in the rehabilitation profession. This is likely due to its ease of application and its versatility. Manual resistance can be applied at a variety of intensities, speeds, ranges, and contraction types. The speed, intensity, contraction type, and movement pattern can be varied during a given exercise. Several well-known techniques such as PNF are applied predominantly with manual resistance.

Indications

Manual resistance can be performed in almost any situation where resistance for rehabilitation is required. However, it becomes challenging in situations requiring high force levels, as in training for fitness, wellness, or sports. Manual resistance is especially effective when strength varies throughout the ROM. A patient may have a portion of the ROM that is either weak or painful; the therapist can modulate the resistance more easily with manual techniques than with resistive equipment. The therapist can also apply specific tactile cues to facilitate recruitment at a weak portion of the ROM. Similarly, manual techniques work well if a patient needs assistance through a portion of the ROM, followed by resistance at other positions.

Manual techniques are quite useful when teaching proper movement patterns, as manual assistance/resistance can facilitate proper firing patterns. For example, a PNF technique called *rhythmic initiation* teaches proper movement patterns before the addition of resistance. Manual resistance is indicated when manual contacts are necessary to ensure the proper muscle activation. For example, in some situations synergists may substitute for the desired primary muscle action. Palpation, combined with manual contacts and tactile cues, can facilitate the proper muscle activation and stabilization. Manual cues with one hand can facilitate isometric stabilization contractions while the other hand facilitates and resists a dynamic contraction. PNF techniques, such as alternating isometrics or rhythmic stabilization, are very effective for enhancing specific muscle activation patterns. With these techniques, the agonist and antagonist are alternately activated within a small ROM and at progressively higher speeds until cocontraction provides stability. The alternating aspect of this activity makes manual techniques the optimal form of resistance. Finally, when a variety of speeds is necessary, manual resistance offers the flexibility to change rapidly, enhancing motor learning opportunities.

Considerations

Manual resistance has the benefit of being readily available in the clinic and does not require specific positioning against gravity to achieve resistance. Benefits include the following:

- The amount of resistance can be modified as the exercise session progresses, with decreasing resistance as the patient fatigues. The resistance can be more finely adjusted through the ROM and with every repetition to ensure maximum resistance through the exercise.
- The therapist is able to feel the change in force offered by the patient and can adjust the applied resistance appropriately. That way the patient can obtain the maximum resistance tolerated through the entire exercise set.
- The therapist's hand position is also easily modified to change the lever arm and resistance offered.
- Manual resistance also allows manual contact between the therapist and patient. For many patients, this tactile contact provides comfort and increases ease.

Although there are a number of benefits to manual resistance techniques, there are also some drawbacks including:

- The labor intensive nature of manual resistance
- Its impracticality for many home programs
- Difficulties measuring and quantifying manual resistance

Manual resistance requires the time, energy, and physical strength of a therapy provider. Depending on the body part being exercised and the relative strengths, manual resistance can be physically taxing. Performing PNF diagonal patterns for the lower extremity can be physically difficult and could potentially result in injury to the therapist using poor body mechanics. Be sure to use proper body mechanics, maximizing hand positioning, base of support, and lever arms to minimize the stress and risk of injury.

Manual resistance is not practical for many home programs. Caregiver assistance is required and may place the caregiver at risk of injury. For all but the lightest of manual resistance applications (i.e., hand, wrist, foot) the resistance is too great and the body mechanics challenging. Few homes have sufficient tables or supports at the right height and firmness to allow the caregiver to use good body mechanics.

Measuring and defining manual resistance is difficult. Therapists use terms like *minimum*, *moderate*, and *maximal* but these are poorly defined and vary from one person to another. For situations where documentation needs to be precise, verifying the dosage of manual resistance can be difficult.

Techniques

Techniques for performing manual resistance require attention to patient positioning, therapist positions, manual contact, grading of resistance, and verbal cues. Attention to these details provides the safest experience for both the patient and therapist. Consider the following points, essential to manual resistance:

- Make sure that the patient's clothing allows you to see the muscles or joints associated with the exercise.
- Position the patient so that full excursion of the movement is possible without restrictions.
- Make sure that the patient is comfortable and as stable as necessary as dictated by the exercise goal.
- Position yourself in the plane of the movement, using a wide base of support; shift your weight and step as necessary with the movement to maintain good body mechanics.
- Use as wide a contact area as possible to prevent discomfort at the point of resistance or stabilization application.
- Using a wide, gentle grip, take the patient's limb through the exercise ROM to teach them the movement pattern (PNF rhythmic initiation).
- While continuing to move through the range, tell your patient that you will be gradually applying some resistance to the movement.
- Be sure to gradually apply and slowly release the resistance to avoid sudden muscle contractions that might cause injury or pain.

Video clips of some commonly used manual resistance patterns can be found on thePoint.lww.com/BrodyHall4e.

Dosage

Dosing manual resistance can be challenging due to the inability to quantify the intensity of the exercise. The therapist is able to document sets and repetitions as well as a nominal description of the amount of resistance (i.e., minimum resistance, maximum resistance). Like all forms of resistance, manual resistance is applied with a specific goal in mind (i.e., strength, endurance, stabilization), and the sets, repetitions, and relevant rest intervals are derived from the goal. Stop the exercise when form fatigue becomes evident. Exercises can be varied by speed, muscle contraction type (concentric, eccentric, isometric) ROM, and resistance. Manually resisted exercises can be performed in an open chain or a closed chain (see **Fig. 5-12A** and **B**).

A

B

FIGURE 5-12 **(A)** Manually resisted open-chain leg press and **(B)** manually resisted rise from a chair.

Pulley System

Many pieces of exercise equipment are based on a pulley system where a weight plate is attached via a cable and pulley to a handle or lever that is controlled by the patient. In a standard pulley system, the cable attaches over a single or double round pulley. In other situations, the pulley or cam itself is elliptical, thereby providing variable resistance as they rotate through the cable's excursion. These are called *variable resistance* machines and will be considered in the next section. This section will focus on traditional pulley devices without an elliptical cam.

Most pulley systems consist of a simple cable and pulley attached to a weight stack of variable weight increments (i.e., 2.5, 5, or 10 lb). Most pulley systems are a single stack of weights that are freestanding or attached to a wall (**Fig. 5-13**). The other end of the pulley typically contains a clip or hook to which a number of different implements can be attached. These attachments may include a straight bar, cuff, handgrips, or various sizes and grips of implements designed to allow a wide range of exercises. Activities such as triceps pulls, biceps curls, latissimus pull-downs, rows, shoulder rotations, shoulder press, leg lifts, and abdominal crunches are some of the many activities that can be performed with a pulley. Thus, a pulley is a versatile piece of equipment that allows someone to perform a large variety of activities with a single piece of equipment.

A pulley system is indicated anytime resistive exercise though a ROM is necessary. Pulleys are prescribed after baseline strength is established, as most pulley systems start with a minimum of 2.5 lb of resistance. Few pulley systems provide stabilization such as chairs or benches. Therefore, most exercises require dynamic stabilization from the person performing the exercise. Chairs or benches can be set up to provide support or stabilization for specific exercises. For example, someone with

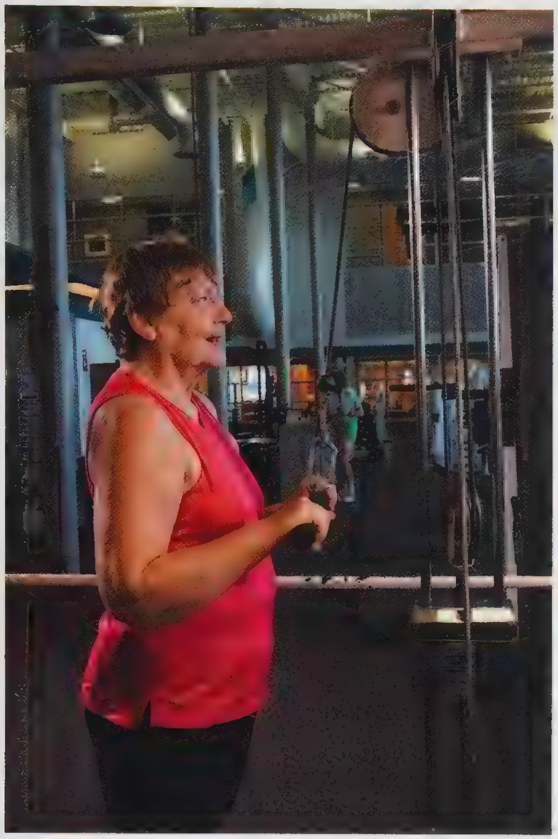


FIGURE 5-13 A standard pulley system.

FIGURE 5-14 Variable resistance machine.

limited standing tolerance or balance may be safer performing biceps curls seated rather than standing.

The most fundamental disadvantage of this type of system is the constant load provided by the equipment. When performing an exercise through a full ROM, the muscle will be maximally loaded only in the weakest portion of the range. The remaining portion of the ROM will be underloaded, failing to achieve the criteria necessary for strengthening. One technique to accommodate for this shortcoming is to train different portions of the ROM at different intensities. For example, the patient may train through the full ROM at a lower intensity, then perform an additional set at a higher intensity in the mid-portion of the ROM, where the muscle requires higher resistance to overload.

Variable Resistance Machines

Resistive exercise machines are commonly found in rehabilitation clinics and health clubs. Historically, most weight machines were designed to isolate a specific muscle group such as the quadriceps femoris or biceps brachii. Some equipment trains multiple muscle groups in combination patterns such as a leg press or pull-up machine. Those machines using weight stacks have plates weighing 5 to 20 lb each. The weight stack configuration varies with the specific muscle action trained. A pin placed in the weight stack selects the amount of weight to be lifted. The muscle contraction type is concentric during the lifting phase and eccentric during the lowering phase (**Fig. 5-14**).

The type of system—either the pulley or cam—is an important component of the weight machine. In contrast to a simple pulley system that provides a constant load through the ROM, a variable resistance machine contains an elliptical cam and pulley system that varies the resistance through the ROM. The kidney-shaped cam is an attempt to account for changes caused by varying length–tension relationships through the ROM. Variable resistance devices provide less resistance at the beginning and end of the ROM, and more resistance midrange.

Other machines use hydraulics to provide variable resistance through the range. Again, the machine is designed to provide more resistance in the mid-ROM, replicating "typical" length–tension ratios. In contrast to pulleys which provide alternating concentric–eccentric contractions of the same muscle groups, the hydraulic resistance machines typically provide reciprocal concentric contractions of opposing muscle groups (i.e., biceps–triceps). This is an important distinction to consider when designing a rehabilitation program; hydraulic machines provide only concentric resistance.

Weight machines also differ in their adjustability. Lever arms and seat positions should be adjustable for a variety of body sizes. This ensures the ability to align the joint axis with the axis of the machine and prevent injury from poor posture or exercise mechanics. Stops and range-limiting devices should be available and easily adjustable.

An **advantage** of weight machines over other types of resistance is safety. Patients are stabilized effectively by the equipment, and the risk of falls or injury resulting from instability is minimized. It takes less time to learn weight machine exercises. After the adjustments are learned, the equipment is relatively easy to use, and novice weight lifters are less intimidated by the equipment. Weight machines are also relatively time efficient because the machines are already setup. Only a few simple adjustments are necessary, and the patient is ready to begin. These machines frequently isolate a specific muscle group to be trained, and the variable resistance accommodates for changing length–tension relationships better than other types of resistance.

One of the **disadvantages** of weight machines is their expense and ability to perform only a single exercise. For example, an expensive machine may train only biceps, whereas this could be done inexpensively with a couple of free weights and a bar. Another disadvantage is that weight increases are restricted to fixed increments (i.e., weight plates) on weight machines. Smaller changes of 1 or 2 lb are not possible on most machines. Despite the many size adjustments on weight machines, they still do not fit everyone. Most also have a fixed, two-dimensional movement pattern. Because the machine guides the patient through the ROM, little proprioception, balance, or coordination is learned from the experience. The stabilization helps with isolation but limits the patient from learning self-stabilization. Most machines are designed to perform bilateral exercise. In some cases, performing unilateral exercise is difficult, if not impossible.

Elastic Resistance

Elastic resistance in a form of elastic bands or tubing, improved greatly from its origins, as "dental dam" used in dental procedures. Use of elastic resistance has increased significantly since its first appearance. It is relatively inexpensive, easy to use, small and light making it ideal for home and travel use and can be used in an infinite variety of exercises. However, the trade-off for ease of use is the difficulty in quantifying and dosing an exercise program. Research suggests that the amount of resistance varies with the band thickness, attachment technique, and the specific exercise performed.[174,175–177]

Elastic resistance is a dynamic exercise but cannot be classified as isotonic or isokinetic. The variability in load through the ROM does not allow it to be classified as isotonic and the variability in speed does not allow classification as isokinetic. It has unique characteristics that require it to be considered independent of other types of resistance. Elastic resistance is often compared with an isotonic pulley system. However, the unique characteristics of elastic do not allow a direct comparison with a pulley system.[178]

Unlike a pulley system which has a fixed load, the resistance provided by an elastic band varies with the thickness of the band and the elongation.[173,179,180] Any elastic material's resistance to stretch is proportional to its original cross-sectional area.[178] Therefore, doubling the cross-sectional area by folding (effectively doubling) the elastic doubles the resistance. Additionally, elastic resistance has unique force-elongation characteristics. The force increases as the elastic is stretched from 0% to 250% of its resting length. The force-elongation curve of Thera-Band (The Hygenic Corporation, Akron, OH, USA) elastic bands as well as the force in lb can be found in **Figure 5-15** and **Table 5-7**, *respectively*.

This force development is distinct from the torque created when functionally using elastic bands through a ROM with changing moment arms. Like all elastic materials, the force developed when pulling that material in a linear fashion will increase as the material is lengthened until failure is reached. However, the actual amount

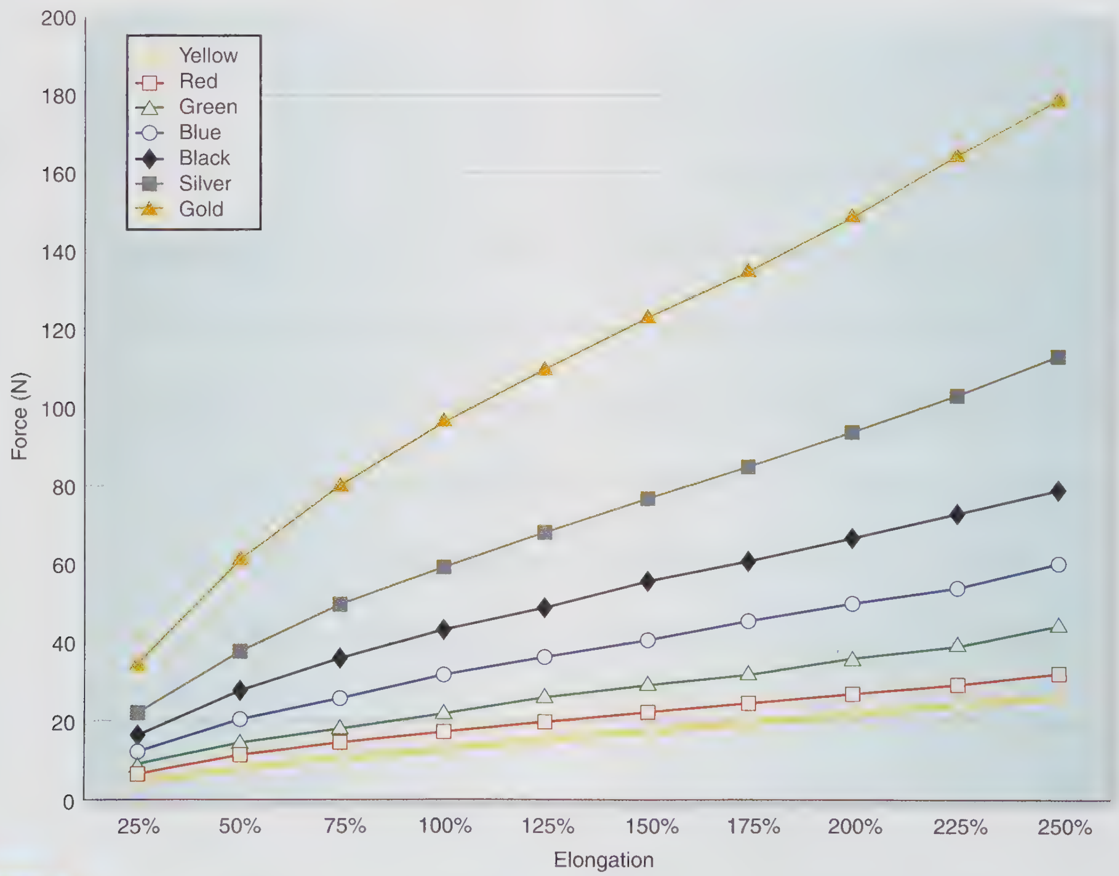


FIGURE 5-15 Force-elongation of Thera-Band elastic bands. (Used with permission of The Hygenic Corporation. Data from Page P, Labbe A, Topp R. Clinical force production of Thera-Band elastic bands [Abstract]. J Orthop Sports Phys Ther 2000; 30(1):A47–A48.)

TABLE 5-7

Force-Elongation for Thera-Band Elastic Bands (Force in lb)

ELONGATION (%)	YELLOW	RED	GREEN	BLUE	BLACK	SILVER	GOLD
25	1.1	1.5	2	2.8	3.6	5	7.9
50	1.8	2.6	3.2	4.6	6.3	8.5	13.9
75	2.4	3.3	4.2	5.9	8.1	11.1	18.1
100	2.9	3.9	5	7.1	9.7	13.2	21.6
125	3.4	4.4	5.7	8.1	11	15.2	24.6
150	3.9	4.9	6.5	9.1	12.3	17.1	27.5
175	4.3	5.4	7.2	10.1	13.5	18.9	30.3
200	4.8	5.9	7.9	11.1	14.8	21	33.4
225	5.3	6.4	8.8	12.1	16.2	23	36.6
250	5.8	7	9.6	13.3	17.6	25.3	40.1

Used with permission of the Hygenic Corporation. Data from Page P, Labbe A, Topp R. Clinical force production of Thera-Band elastic bands [Abstract]. J Orthop Sports Phys Ther 2000;30(1):A47–A48.

of torque developed when using elastic bands through a ROM (such as shoulder abduction) follows an ascending–descending pattern. That is, the torque increases from 0 to 90 degrees abduction as the moment arm increases, then decreases again as the moment arm decreases as the shoulder approaches 180 degrees. An example of strength curves can be found in **Figure 5-16**.

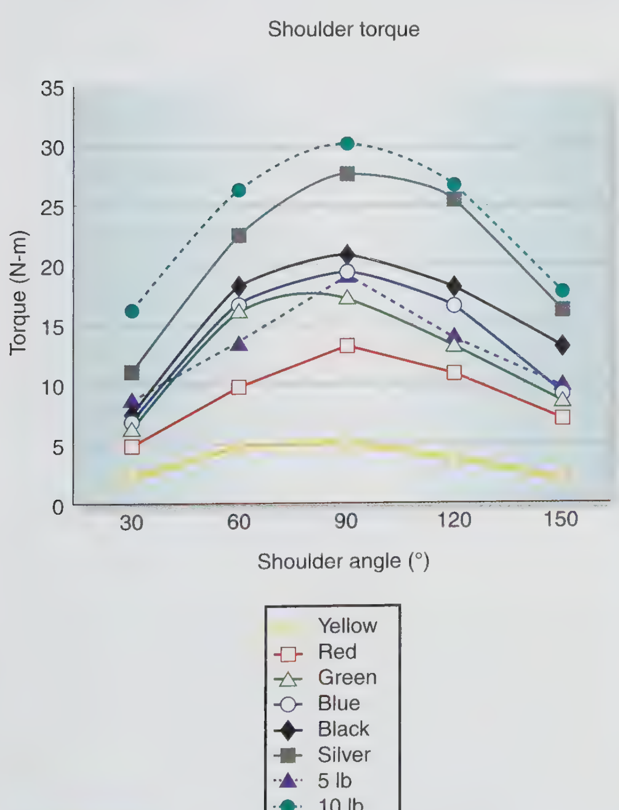


FIGURE 5-16 Strength curves of Thera-Band elastic tubing compared to free weights. (Used with permission of The Hygenic Corporation. Data from Page P, Labbe A, Topp R. Clinical force production of Thera-Band elastic bands [Abstract]. J Orthop Sports Phys Ther 2000;30(1):A47–A48.)

Indications

Elastic bands are indicated anytime strengthening but an external resistance is required. Elastic resistance can be used in the clinic under a therapist's supervision. It also works well for home programs utilized in conjunction with in-house rehabilitation. Because it is lightweight and easily transported, elastic resistance works well for those needing to perform exercise while at work or traveling. Resistive bands can be used for fitness or wellness training, providing challenges to muscle strength, power, endurance, as well as plyometric training, balance, and stabilization (**Evidence and Research 5-8**). Bands can be integrated into a practice or training session to provide additional activity-specific, open, or closed chain training. Resistive bands work well for individuals who have limited mobility, as the resistance can be applied in a variety of positions or postures. The resistance variation provides people with low physical capacity the opportunity to train and improve strength and function.[189–192]

EVIDENCE and RESEARCH 5-8

The effects and outcomes of elastic band training compared with other forms of strength training have supported the use of elastic bands in a variety of situations. Plasma creatine kinase levels, muscle soreness, and magnetic resonance imaging demonstrated equivalent responses when comparing elastic band resistance to Nautilus machine training.[181] Elastic band training has shown equivalent results when compared with dumbbell training,[182] free weights, and variable resistance devices.[183,184] Improvements in strength and power following elastic band training have been shown in adults with and without musculoskeletal pain,[185] in patients with COPD[186] females with knee osteoarthritis,[187] and in women performing squat activities.[188]

Considerations

There are some issues to be considered when prescribing elastic band resistive exercises. First, although there is some data about the amount of resistance provided from different colors of elastic bands, patient implementation variables render it an inexact quantity. The amount of resistance varies with the elongation, so if the patient grasps the band at a different location, or initiates the exercise at a greater percent elongation, the torque may vary from one session to the next. The patient may not understand why the exercise seems easier 1 day and harder the next.

Although the reproducibility of testing or exercise with elastic bands may be questioned due to issues of cross-sectional area, length, and origin/stabilization, the reliability and validity of elastic band use has been established under controlled conditions. Researchers found a 30-second elastic band elbow flexion test to be significantly correlated with a 30-second elbow flexion test using dumbbells ($r = 0.62$) and maximal isokinetic testing ($r = 0.46$). The test–retest reliability was high as well ($ICC = 0.89$).[179]

Another consideration is the impact of cyclic loading. Like any other elastic medium, loading the material results in changes such as creep. Additionally, cyclic loading (repeatedly stretching and relaxing the bands or tubing) can result in fatigue to the material. Over time, this fatigue can decrease the performance of the elastic and can eventually lead to failure. Research has shown that elastic bands stretch to 100% elongation for 500 cycles, resulting in a 5% to 12% decrease in force.[177] More importantly, the majority of the change occurred within the first 50 cycles. If patients are performing sets of 30 or more repetitions, the elastic can fatigue quickly. Therefore, it is important to replace elastic bands frequently.

Like pulleys, elastic resistance exercises can be performed with or without external stabilization. If no stabilization is provided, be sure the patient is performing the exercise without substitution.

Dosage

Like any resistive exercise, the proper dosage is necessary to ensure achievement of rehabilitation goals. Dosage is more difficult with elastic resistance because of the number of variables associated with this resistance mode. The length of the band, the percentage elongation, the color of band, and the origin of the elastic resistance all impact the torque developed.

Elastic resistance typically comes in a variety of colors and each color provides a different amount of resistance. Research on Thera-Band elastic bands showed a 20% to 30% increase in force production between colors.[176] Increases in intensity should be accomplished by moving to the next higher level of resistance rather than doubling the elastic band. Doubling the elastic band will double the resistance, whereas increasing to the next higher level will provide only a 20% to 30% increase, a safer intensity increase.

Another important variable in dosing elastic band exercise is the **length of the band** or tubing. The band should be elongated to no more than 250% of its original length.[178] To maintain the optimal ascending–descending torque curve, the length of the elastic should be equal to the length of the lever arm. In the case of exercise at the shoulder (i.e., abduction or flexion), the tubing should be equal to the length of the arm. This way, the elongation through the full ROM will be twice the length of the lever (a 200% elongation) resulting in an optimal torque curve for the shoulder musculature.

The **angle of the origin** of the tubing also impacts the torque curve and the subsequent resistance. An angle that is too acute will shift the torque curve to the left, increasing torque earlier in the ROM. An angle that is too obtuse will shift the torque curve to the right, increasing torque later in the ROM. This may be desirable in specific rehabilitation situations, but in general does not reproduce the torque curve of a normal muscle–joint interaction. The therapist should be aware of the impact of this angle on torque production. The origin of the elastic should be in the plane of the axis of rotation and in the direction of the desired motion.[178]

Finally, the **resistance arm angle** should be considered during exercise prescription. The resistance arm angle is the angle produced by the band or tubing and the lever arm (i.e., the hand and the band in the shoulder abduction example). The band and the limb should be aligned to ensure a normal physiologic ascending–descending torque curve. If this alignment is incorrect, excessive torque may be produced at end range, where the least amount is available. It is recommended that the band or tubing be aligned with the ending lever arm at a resistive arm angle of 15 degrees to 0 degree.[178] For example, in shoulder flexion, the band should be placed under the foot so that in the full 180 degrees overhead position, the band pulls nearly straight down, with the wrist:band angle at <15 degrees. A higher angle would place excessive load on the wrist extensor muscles.

Once the patient is properly positioned and the band or tubing color (resistance) and length determined, the number of sets and repetitions should be determined. The patient should start with slight tension on the band (approximately 25% elongation) and perform the exercise through the desired ROM. Depending on the patient's goals (strength, power, endurance, etc.) an increase or decrease in the band color might be indicated. Like free weights or weight machines, the resistance and number of repetitions depend on the goal. For traditional strength or endurance training, repetitions at approximately 6 to 10 RM would be appropriate. For those doing power training, the intensity would be greater, with intensity at 90% of a 3 RM.[178]

As with any resistive exercise, substitution, form fatigue, and stabilization are factors to be considered. Do not sacrifice form for additional resistance or repetitions. Training programs can be designed similar to those with traditional weights. As the patient fatigues, consider performing additional sets at a lower elastic band resistance, just as one might to a decreasing training schedule with free weights.

Free Weights

Free-weight training is the resistive exercise technique of choice for body builders and power lifters. Free weights and cuff weights are also commonly used in rehabilitation. Free-weight training is usually performed with hand-held weights that range from 0.5 to 75 lb or more. Free weights can also be combined on a bar with weight plates. Cuff weights typically range from 0.5 to 25 lb.

Free-weight training allows more discrete increases in resistance, and resistance can differ from one side to the other (see **Self-Management 5-2**). For example, reciprocal biceps curls can be performed with 10 lb on the injured side and 15 lb on the uninjured side. Incremental increases of 1 to 2 lb or less are available, allowing a more gradual overload. Free-weight equipment is affordable, and a multitude of exercises can be performed with the same free weights. These exercises can include simple strengthening and endurance activities or power training techniques.

Free-weight exercises can be performed in a multitude of different ways that meet the needs of individual patients or clients. For example, a variety of positions are available and are not restricted by the design of the machine. Biceps curls can be performed in standing, sitting, supine or even prone. They can be performed symmetrically or reciprocally and the patient may have different weights in each hand. The exercise can be performed at a variety of different speeds and the working ROM can be altered. Changing the position and/or ROM can alter the relationship with gravity, affecting the working muscle group and contraction type. For example, a hamstring curl performed in standing provides concentric resistance during shortening and eccentric resistance while lengthening, both to the hamstring muscle group. This same exercise performed in prone provides concentric resistance with a decreasing moment arm against gravity until the knee approaches the 90-degree angle. At this position, there is no moment arm against gravity and no significant resistance. Continuing into further flexion produces an eccentric contraction of the quadriceps as they are lengthened while trying to slow the flexing knee (**Fig. 5-17A** and **B**). Free-weight exercises provide a multitude of possibilities to match the exercise with the patient's goals.

One of the biggest advantages of free-weight training is the neural component of balance. Compared with the external stabilization provided by a weight machine, the free weight usually has little external stabilization. These exercises require postural muscle stabilization beyond the work required to

SELF-MANAGEMENT 5-2
Standing Biceps Curls

Purpose: To strengthen the biceps muscles.

Position: Standing position, with shoulder girdles, spine, and pelvis in neutral. Hold a weight in each hand, palms facing toward your thighs.

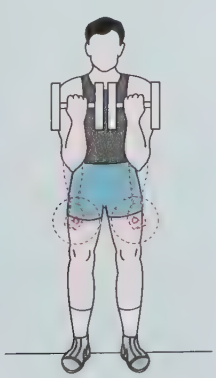
Movement Technique: Level 1: Alternately bend your elbows, turning your palms upward as the weights clear your hips; bend your elbows so your hands come within 4 inches of your shoulder; slowly straighten your elbows, turning your palms sideways again as you move lower your forearms. Maintain your neutral shoulder, spine, and pelvic position as you lift and lower the weight.
Level 2: Bend and straighten your elbows simultaneously.

Hold _____ lb in each hand.

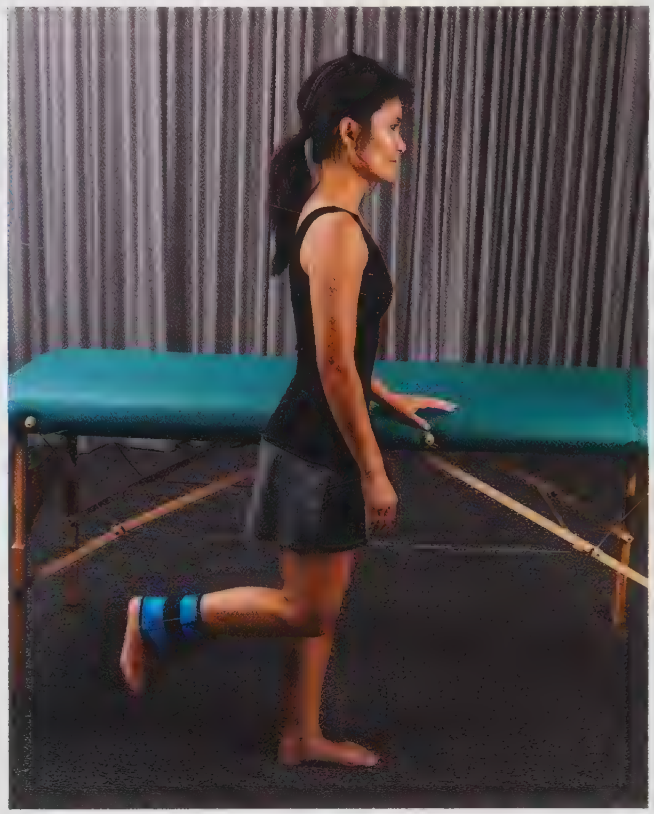
Dosage:

Repetitions: ______________________________
per set, ______________________________ sets

Frequency: ______________________________
sessions per day, ____________________ sessions per week



Level 2



A

B

FIGURE 5-17 **(A)** Hamstring curl in standing and **(B)** hamstring curl in prone.

move the weight. The individual lifting with free weights must understand proper posture and spinal stabilization to prevent injury to the back. If balance is a rehabilitation goal, free-weight exercise may be indicated.

The neural demands of free-weight exercise are a disadvantage for some. It takes longer to learn free-weight exercise, because the free-weight tasks usually are more complex than those with weight machines. Novice lifters may be at greater risk for injury because of poor technique (**Fig. 5-18A** and **B**). Spotters are necessary for many of the free-weight lifts, increasing the personnel demands of this resistive technique. Because of the time required to load and unload bars, free-weight training can be less time efficient. However, for those using smaller hand-held weights, these can be more time efficient than weight machines, due to the lack of setup time.

Safety for individuals training with free weights includes working with a knowledgeable partner who can spot safely. Collars should always be used to lock the weights on the bar and prevent movement of the plates on the bar. Correct form and technique, including proper breathing, should be mastered before performing the exercise with load.

Free weights are used in a similar fashion to elastic bands, tubing, and pulleys. However unlike bands and pulleys, free-weight exercises still need to be positioned with regard to gravity (see **Self-Management 5-3**). Free weights, resistive bands, and pulleys have the advantage of movement in a variety of three-dimensional patterns without fixed movement patterns. This allows highly specific training that matches individual needs. For example, resisted lunging patterns forward, backward, laterally, or diagonally can be performed with elastic bands, pulleys, or free weights. These movement patterns can be performed in whatever range is necessary for the individual, rather than in ranges dictated by a weight machine.

SELF-MANAGEMENT 5-3
Supine Shoulder Flexion

Purpose: To increase the strength of the shoulder muscles, especially serratus anterior.

Position: Lying on your back with the band tied around your foot. Hold the band in the ipsilateral hand with the arm next to your side and elbow bent to 90 degrees.

Movement Technique: Level 1: Keeping your elbow bent, punch your hand toward the ceiling until your elbow is straight, then move your straight arm upward toward your head. Press backward into the surface you are lying on or pillow(s) as needed to support you at the end of your ROM. Push back with an isometric contraction for 10 seconds. Return arm in reverse movement pattern. Repeat as prescribed.
Level 2: Perform level 1 with a straight arm.

Dosage:

Repetitions: ____________________
per set ____________________ sets

Frequency: ____________________
sessions per day, ____________________ sessions per week

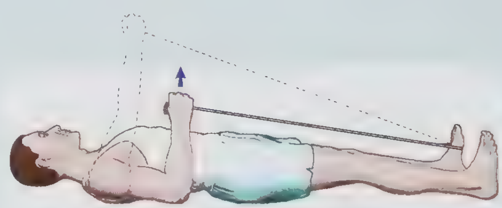


FIGURE 5-18 Biceps curl performed **(A)** incorrectly with lumbar extension and **(B)** correctly with lumbar stabilization.

A B

Isokinetic Devices

Isokinetic dynamometers are designed to provide maximum resistance through the entire ROM. The resistance provided by these devices is termed *accommodating*, because once the preset speed is achieved, the dynamometer "matches" the force applied by the patient. The dynamometer provides a counterforce equal to the force applied by the patient. Therefore, the patient can obtain the maximum amount of resistance tolerated throughout the ROM. If a patient has pain or weakness in a specific portion of the ROM, the remaining portion can still be fully challenged. Additionally, patients can train at a variety of speeds.

Currently, isokinetic devices are active computerized training and testing devices that are capable of actively moving the patient's limb for him or her. These dynamometers provide reciprocal concentric resistance at fixed speeds, and they provide multiangle isometric resistance, fixed resistance concentric and eccentric contractions, passive motion, and fixed speed concentric and eccentric contractions. Because these dynamometers now function in a variety of modes, they have become multipurpose testing and training devices. Although many dynamometers are capable of providing isometric and isotonic resistance, most providers still refer to these devices as isokinetic dynamometers and emphasize the isokinetic capabilities of these devices.

Indications

The isokinetic mode is used most frequently for muscle performance testing and training. The dynamometers are capable of testing and training muscle groups around most major joints of the body. Muscles around the shoulder, elbow, forearm, and wrist in the upper extremity and the hip, knee, and ankle in the lower extremity are all readily tested and trained using an isokinetic dynamometer. Adaptive attachments allow training for pediatric patients, industrial medicine (i.e., lifting and work simulation attachments) and closed chain exercise and testing. Isokinetic testing is frequently performed as an alternative to 1-RM testing due to the computerized capabilities of the devices and safety issues. The dynamometer matches the patient's force output, thereby minimizing the chance of injury that may be found when performing 1-RM testing, particularly in the presence of an injury. Tests can be performed in a limited ROM and at a fixed speed to assess muscle strength or endurance. Test results are stored in the computer and can be compared with the results of future tests or to population-based norms.

Isokinetic testing is performed to assess muscle performance against some standard. The standard may be the contralateral side, a population norm, or a percentage of the antagonist muscle performance. Testing is performed to assess progress after injury or surgery and to determine readiness to advance the rehabilitation program or to return to activity. In some situations, testing is performed pre-season to provide guidance for the training program or to provide a baseline measure in the case of a future injury.

Testing is typically performed at two or three different speeds to capture speed-specific muscle impairments. Each company that produces dynamometers has specific testing protocols and standards to follow to ensure validity and test–retest reliability. The data are captured in a computer file and can be examined and manipulated in a variety of different ways (**Fig. 5-19**). Several important terms are used to describe isokinetic data results.

- *Peak torque* is the most common variable measured and is the maximum torque generated regardless of where in the ROM it is achieved.
- *Work* is the total amount of work performed under the torque curve, regardless of ROM, time, or speed.
- *Average power* is the amount of work (total work under the curve) performed per time unit ($P = W/T$).
- *Time to peak torque* is the amount of time it takes to achieve peak torque.
- *Peak torque angle* is the joint angle at which peak torque occurred.

Other important and common comparisons are bilateral comparisons and agonist–antagonist ratios. In bilateral comparisons, one extremity is compared with the other to determine the absolute and/or relative difference from side to side. In agonist–antagonist ratios, the opposing muscle groups (i.e., quadriceps and hamstrings) are compared with the antagonist given as a proportion of the agonist (i.e., the hamstrings are 70% of the quadriceps). Normative standards for some agonist–antagonist ratios exist.

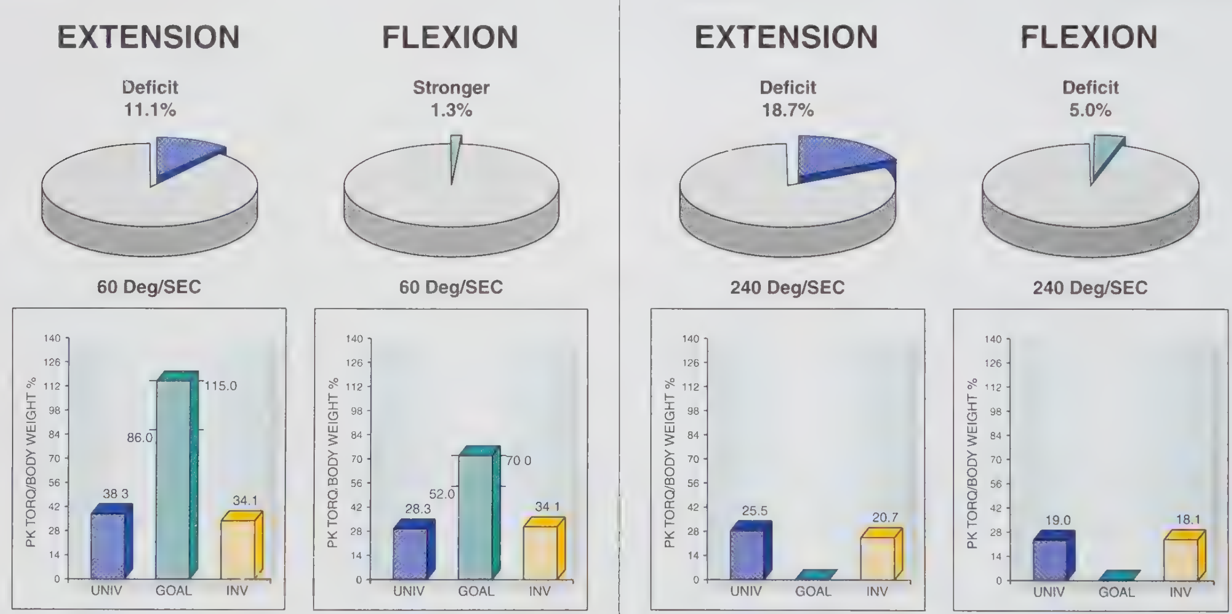
Isokinetic training is indicated any time the patient needs muscle activation throughout the ROM. Isokinetics works well when there are fluctuations in torque production due to changes in the length–tension relationships or due to pain or pathology causing significant variation in torque production through the range. Unlike a fixed, constant load (i.e., isotonic), there is no minimum load to lift to complete the activity. If the patient is unable to continue the exercise, he or she can simply stop without worrying about dropping a weight. Isokinetic training also works well when a variety of speeds need to be trained. Velocity spectrum training (VSRP, velocity spectrum rehabilitation program), or training through a variety of speeds, is a commonly used training regimen. Patients may start at a slow velocity (i.e., 60 degrees per second) and increase speed by 30 degrees per second up to a maximum velocity (i.e., 300 degrees per second), and then decrease speed incrementally until the starting speed is reached. A variety of training programs can be designed using this technique.

The passive mode on an isokinetic dynamometer can be used to train isokinetically as well. The passive mode does precisely what the name implies: it passively moves the limb at a preselected velocity. The patient can use this mode in a variety of different ways. The patient might be instructed to relax and let the machine move and mobilize the joint. Alternatively, the patient might be asked to assist the machine in the direction it is moving (a concentric contraction) or to resist against it (an eccentric contraction). Why choose resisting against the passive movement rather than the active isokinetic or isotonic concentric and eccentric contractions? In the active modes, the patient must still generate enough torque to actively move the dynamometer arm and match the preset speed of the machine. In some cases, such as a postoperative surgery or an acute injury, this amount of force may still exceed the muscle's capacity. In the passive mode, the machine moves continuously, and the patient can provide resistance at the level and in the appropriate ROM given the current injury status.

General Evaluation

Name:		Session:		Windowing:	**None**
ID:		Involved:	**Left**	Protocol:	**Isokinetic Bilateral**
Birth Date:	**(M/d/yyyy)**	Clinician:		Pattern:	**Extension/Flexion**
Ht:		Referral:		Mode:	**Isokinetic**
Wt:		Joint:	**Knee**	Contraction:	**CON/CON**
Gender:		Diagnosis:		GET:	**18 FT-LBS at 30 Degrees**

		EXTENSION 60 DEG/SEC			FLEXION 60 DEG/SEC			EXTENSION 240 DEG/SEC			FLEXION 240 DEG/SEC		
# OF REPS (60/60): 5		UNINVOL	INVOLVED	DEFICIT	UNINVOL	INVOLVED	DEFICIT	UNINVOL	INVOLVED	DEFICIT	UNINVOL	INVOLVED	DEFICIT
# OF REPS (240/240): 15		RIGHT	LEFT		RIGHT	LEFT		RIGHT	LEFT		RIGHT	LEFT	
PEAK TORQUE	FT-LBS	92.0	81.8	11.1	68.0	68.9	-1.3	61.2	49.8	18.7	45.7	43.4	5.0
PEAK TQ/BW	5	38.3	34.1		28.3	28.7		25.5	20.7		19.0	18.1	
MAX REP TOT WORK	FT-LBS	113 1	76 4	32 4	69 5	69 8	[illegible]	70 0	50 3	28 1	35 6	38 2	[illegible]
COEFF. OF VAR.	%	6.6	6.8		5.5	6.2		9.6	12.5		16.0	7.9	
AVG. POWER	WATTS	83.5	60.0	28.1	52.6	56.0	-6.4	164.5	116.1	29.4	75.9	79.8	-5.2
TOTAL WORK	FT-LBS	496.8	346.5	30.3	304.4	317.2	-4 2	917.2	643.1	29.9	440.9	445.5	-1.0
ACCELERATION TIME	MSEC	30.0	30.0		40.0	40.0		50.0	50.0		80.0	80.0	
DECELERATION TIME	MSEC	40.0	100.0		80.0	90.0		80.0	90.0		100.0	80.0	
ROM	DEG	106.2	96.2		106.2	96.2		104.1	95.8		104.1	95.8	
AVG PEAK TQ	FT-LBS	84.0	76.8		64.9	64.6		54.7	41.3		37.1	35.9	
AGON/ANTAG RATION	%	74.0	84.3	G: 61.0				74.6	87.2	G: N/A			



Comments:

PEAK TORQUE:	Highest muscular force output at any moment during a repetition. Indicative of a muscle's strength capabilities.
PEAK TQ/BW:	Represented as a percentage normalized to bodyweight and compared to an established goal
MAX REP TOT WORK:	Total muscular force output for the repetition with greatest amount of work. Work is indicative of a muscle's capability to produce force throughout the range of motion
AVG POWER:	Total work divided by time. Power represents how quickly a muscle can produce force
ACCELERATION TIME:	Total time to reach Isokinetic speed. Indicative of a muscle's neuromuscular capabilities to move the limb at the beginning of the range of motion.
DECELERATION TIME:	Total time to go from Isokinetic speed to zero speed. Indicative of a muscle's neuromuscular capability to eccentrically control the limb at the end of the range of motion.
AGON/ANTAG RATIO:	The Reciprocol muscle group ratio. Excessive imbalances may predispose a joint to injury
DEFICITS:	1 to 10% No significant difference between extremities 11 to 25% Rehabilitation recommended to improve muscle performance balance.

Biodex Rev 4.18b Sep 25 2006

FIGURE 5-19 Isokinetic test data analysis.

Considerations

The major advantage of isokinetic resistive training is its ability to fully activate more muscle fibers for longer periods. Because the machine matches the torque provided by the patient, it "accommodates" the patient's changing abilities throughout the ROM. In contrast, free weights (i.e., fixed resistance training) overload only the weakest portion of the range, but the stronger portion (usually the middle third) is not overloaded. For testing purposes, isokinetic dynamometers allow individuals to be tested at a variety of speeds, potentially identifying deficits at more functional speeds. Compared to a 1-RM strength measure, the isokinetic dynamometer produces a force curve through the ROM rather than a single measure. This allows more detailed evaluation of muscle function characteristics (i.e., time to peak torque, total work performed, etc.).

Isokinetic devices allow training at a variety of speeds. The positive effect of fast-speed training on performance is highlighted with isokinetic training. Training at faster speeds can assist the return to functional activities that require less muscle torque development but faster speeds of contraction. Speeds that more closely match the patient's function can be chosen to match functional velocities. Higher speeds can decrease joint compression forces in areas such as the patellofemoral joint, decreasing the pain and discomfort often seen with heavy resistance exercises. Although less torque is generated at high speeds, the decrease in pain and more functional speeds may produce better results.

Studies assessing the speed variable favor slow-speed isokinetic training over fast-speed training for the development of strength.[193] High muscular tension is necessary for generating strength gains and is achieved when the isokinetic speed is slow enough to allow full recruitment and generation of a high resisting force.

Isokinetic dynamometers with computer interface also provide feedback for training purposes. This feedback can take many forms, such as visual when trying to reproduce a torque curve or producing enough force to raise a bar to a preset level. Feedback can be auditory with bells when a preset goal is met. Isokinetics can also provide neuromuscular training by requiring the patient to resist at a specific level that is submaximal, a relatively challenging task. Although it may be easy for patients to push as hard as they can to achieve maximum torque production, it is often harder to regulate torque production at lower levels.

Isokinetic resistive training also has disadvantages. These devices are expensive to purchase and maintain. They require trained personnel for setting up patient training programs, testing, and data interpretation. From a biomechanical perspective, most training is done in a single plane, with a fixed axis at a constant velocity in an open kinetic chain. Testing and training in a single plane improve test reproducibility but do not necessarily carry over to function. We rarely move at a constant velocity in functional activities, although this feature provides for maximal loading through the ROM. Some isokinetic devices offer closed-chain components, which have the advantage of testing a functional movement pattern but the disadvantage of being unable to tell where the muscle performance impairment lies.

Dosage

Isokinetic exercise is dosed similarly to other types of quantitative resistive training. Isokinetic devices have the advantage of computerized data reduction, which helps to see and manage resistive exercise volume and intensity. The computerized system allows for storage of exercise training programs, which can be programmed and executed with minimal setup. This data can then be tracked over time. Like any resistive exercise program, the volume of activity must be balanced with intensity and viewed within the context of the patient's daily activities.

Body Weight

Body weight can be effectively used as resistance. Resistive exercises for the lower extremity are the most obvious application of body weight as resistance, due to the high number of functional activities that require the lower extremity muscles to move body weight. Walking, running, sports, stair climbing, and transfers of all sorts are examples of activities requiring the movement of body weight. Examples of upper extremity exercises using body weight include push-ups, planks, pushing or pulling oneself out of bed or a chair, suspension exercises, or sporting activities such as gymnastics. Many exercises using body weight as the primary resistance are classified as **closed chain** exercises. Closed chain exercises are those activities where the distal segment is fixed on a rigid or semi-rigid surface. Squats, lunges, step-ups, or push-ups are considered closed chain exercises. **Open chain** exercises are those where the distal segment is free, as in performing a straight leg raise, resistive knee extension, or biceps curl.

Body weight can be decreased by altering the position of the body (i.e., push-ups from the knees rather than the feet), using a harness unweighting system, or using a pool. An advantage of using body weight as resistance is that it is always available and rarely requires equipment. A disadvantage is that it is difficult to isolate specific muscles that need strengthening, and the multijoint nature of closed chain exercises lends itself to subtle substitution. See more on closed and open chain exercise in Chapter 14.

THERAPEUTIC EXERCISE INTERVENTION FOR IMPAIRED MUSCLE PERFORMANCE

Therapeutic activities to enhance muscle performance are at the core of the intervention program for many patients. The clinician is faced with a multitude of variables to consider when designing this program. These variables are found in the intervention model in Chapter 2. Prioritizing and balancing all these variables to achieve the best patient outcome requires both knowledge and experience. The following sections will highlight the key variables to consider when designing a resistive exercise program for patients with impairments.

Program Initiation

One of the first variables to consider is the initial physical or training status of the patient. Realize that recommendations about the intervention model variables will change with the training status of the individual patient. Two patients with identical impairments related to an inflammatory shoulder condition may present very differently: one who is a regular exerciser, lifting weights 5 days per week and working construction, whereas the other is a sedentary individual, working at a desk job. The initial exercise prescription and progression plan will differ based on the difference in their initial physical condition and training status. The initial examination and evaluation is used to determine the starting point for the therapeutic exercise program. Once the starting point is determined, progress the rehabilitation program based upon the goals established and the gains made. Based upon the initial examination, the following questions should guide the therapist in determining the appropriate starting point for the program:

- What muscle or muscle group(s) need training? What type of muscle contraction does that muscle utilize to perform the functional activities that are limited?
- What type of training is required (i.e., strength, endurance, power, etc.) at this stage of the rehabilitation program? Should the muscle be isolated or worked as a synergist?
- What activity will best accomplish this goal? What range should be exercised?
- What is their current performance/training/strength status? Is strength above or below fair? Are the manual muscle tests normal? Approximately what resistance do you think they will tolerate and for how many repetitions?
- Given the patient's strength, what is the best mode to perform the exercise (i.e., manual resistance, free weights, body weight, isokinetics, etc.)?
- Are there any precautions necessary (i.e., blood pressure, diabetes, joint instability)?
- What is the injury, pathology, and stage of healing? Other medical comorbidities?

Answering these questions will provide the therapist with a starting place for the rehabilitation program (**Table 5-8**). If the patient reports increased symptoms or is unable to perform the exercise at the level chosen based upon the initial evaluation, a number of opportunities to decrease the exercise challenge exist. Many of these possibilities can be found in Chapter 2 and in Display 2-13. In general, decreasing the intensity, volume, complexity, or environment/stabilization can increase exercise tolerance. Once a set of exercises that do not exacerbate symptoms is developed, then the therapist can consider how to progress the exercise program.

Oftentimes, using palpation combined with manual resistance in the clinic for 1 to 2 sets of 10 to 12 repetitions can help the therapist appropriately dose the exercise. The therapist can monitor for improper muscle recruitment and assess how the muscle(s) of interest are recruited throughout the range of movement, and it assists the therapist determine the appropriate resistance to provide the patient for their home program.

TABLE 5-8

Template for Determining Initial Therapeutic Exercise Prescription

EXAMINATION QUESTION	THERAPEUTIC EXERCISE INTERVENTION MODEL DIMENSION	THERAEPEUTIC EXERCISE PRESCRIPTION OBTAINED
What muscle is impaired?	Muscle or muscle group	Muscle group to be trained
How does this muscle function primarily in this patient's activities? Is this the appropriate contraction type to begin with?	Movement	Type of muscle contraction for initial rehabilitation program, as well as contraction type to be progressed toward (if different)
In what range does the muscle function and does it need to be trained through that full range?	Movement	Working ROM
What is the best mode for applying the resistance?	Mode	Exercise mode such as manual, pulley, elastic band, variable resistance equipment, etc.
What posture or position is this muscle used in functionally for this patient? Is this the best position to initiate training?	Posture	Beginning exercise posture as well as postural goal (if different)
At what speed does this muscle typically function? Is this the best speed to initiate training?	Speed	Beginning exercise speed as well as speed goal (if different)
What is the patient's baseline strength? What are the functional strength demands?	Intensity	Initial training resistance and resistance goals
What muscle function is the primary requirement? (i.e., power, strength, endurance) and at what frequency?	Frequency/duration	Initial training sets and repetitions and sets and repetition goal
What other associated muscle or muscle groups need training? How do they work with the muscle group of interest? (i.e., synergist)	Sequence	Other supportive muscle groups to be trained and sequence for training
Are there any medical precautions or contraindications?	Overarching	Precautions and contraindications to exercise
What is the stage of healing?	Overarching	Volume and intensity limitations

Program Progression

Once the rehabilitation goals and the initial rehabilitation program are determined, the next step is determining the appropriate exercise progression. Exercises can be progressed in a multitude of different ways, ranging from the most obvious of increasing the exercise intensity to changing the exercise to a more complex activity. It is possible to achieve continual advancement toward rehabilitation goals with the appropriate manipulation of program variables. Advancing an exercise program in a healthy individual training for health and wellness follows a more predictable pattern. However, progression in the presence of pathology or deficits is much more challenging.

The goal inpatient progression is to narrow or eliminate the gap between the patient's current status and the desired functional status. How the therapist guides the patient to bridge that gap will likely vary from one individual to the next. The progression from program initiation to discharge requires a balance between exercise load and the loads applied with daily activities.

- *Exercise load* is the amount of stress and strain applied to the tissue of interest as a result of the rehabilitation program.
- *Daily activity load* is the stress and strain applied to the same tissue as a result of daily activities.

The daily activity load may change from 1 day to the next depending on the patient's activities on a given day. The therapist must teach the patient how to modify the exercise load based upon that activity level. This will ensure that the total load placed on the tissue stays within the tissue tolerance. If not, then the likely result is an increase in symptoms.

Display 2-13 (Chapter 2) describes exercise modification parameters that can be used to increase or progress the program. Similarly, if a patient reports an increase in symptoms following program initiation, or the patient is not tolerating the activities at the level they were initiated, the display provides suggested modifications that can decrease the exercise challenge. The overarching goal is to continuously challenge the patient and to expand the training volume to bridge the gap between current and desired functional status. **Figure 5-20** shows the relationship between progression variables/opportunities and expanding exercise volume. By systematically alternating expanding volume and increasing intensity, patients can continue progressing toward their goals.

How much the volume is increased depends on the discrepancy between current and desired function. If a patient is functioning at a very low level due to injury, surgery, or pathology, then the increase in their total quantity of activity may be substantial. For others who may be very physically

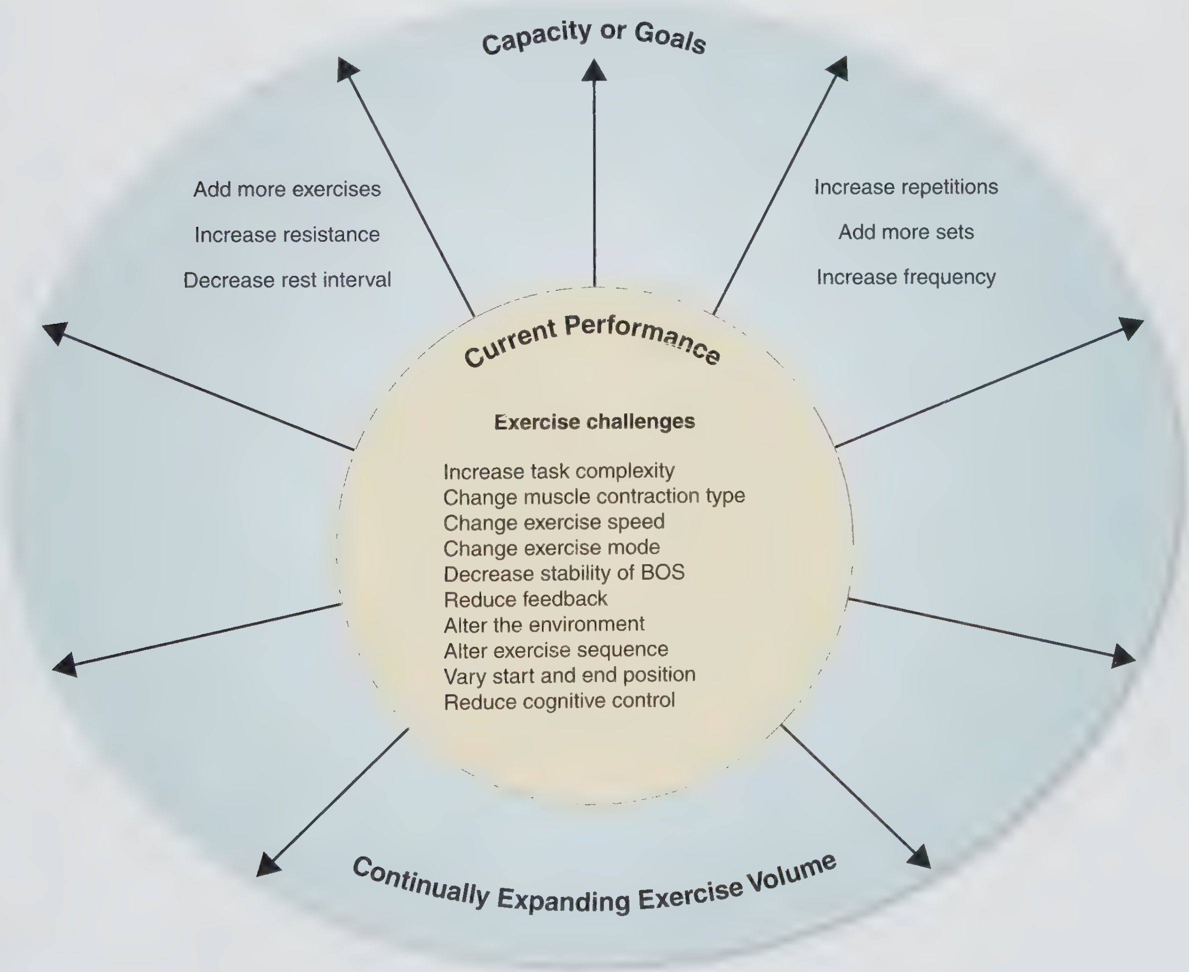


FIGURE 5-20 Exercise progression model.

active but who still have pain, changing the exercise parameters within the same exercise volume may be preferable. For most patients trying to restore a previous level or to obtain a higher level of function, program progression likely follows a variable course with volume increases balanced with exercise parameter changes. For example, a patient recovering from rotator cuff tendinosis may alternate exercise volume increases with changes from isometric or concentric contractions to eccentric, changes from slow speed to fast, and mode changes from free weights to elastic resistance and variable resistance machines (see **Building Block 5-5**). A variety of options exist depending on patient goals and preferences. The therapist must use solid clinical decision-making skills to best fit the appropriate type of exercise progression to the patient's goals.

BUILDING BLOCK 5-5

A 22-year-old marathon runner has had Achilles tendinitis for 6 weeks. She is currently able to run only 3 miles per day every other day before the symptoms prevent her from running any further. Describe how you might progress her strength program to prepare her to return to marathon training. The patient is unwilling to decrease her running at this point.

Another consideration during program progression is the difference between current performance and current capacity. Although a higher capacity or level of function is the long-term goal, the program should be viewed in phases, each with a short-term goal. For example, a patient who sustained a second degree ankle sprain 2 weeks previously may desire to return to long-distance running. However, at this stage of healing, she is doing a series of rehabilitative exercises, deep water running and walking and standing intermittently as part of her job. She is experiencing some increased pain and swelling at the end of the day. It resolves by morning, and overall is making steady improvement. At this point, she is likely performing close to her current physical capacity given the stage of healing. Therefore, increasing her exercise volume might be inappropriate at this point as it may overwork the healing tissue. Rehabilitative exercise changes within the same working volume may be more appropriate at this stage of healing. Looking at the model in Figure 5-20, consider alternative changes to progress her program that do not include increasing exercise volume.

Options to increase the total volume are relatively clear; adding new exercises, resistance, sets, or repetitions are obvious ways to expand the exercise volume. Within a given volume, exercise parameter changes allow exercise progression toward a specific goal without (or with, if that is preferred) a change in total volume. **Increasing task complexity** can be accomplished in a number of different ways. Increasing the number of body segments, the cognitive challenge, or the number of steps are examples of increasing task complexity. For example, increased coordination might be a patient goal. Rather than performing several exercises independently of several repetitions (blocked exercise), different exercises might be combined into a single task (i.e., rise out of a chair, walk across the room around a series of cones, reach up five times, then turn and sit down).

Changing **muscle contraction type** is another way to change and progress the exercise challenge. For someone recovering from knee surgery, changing from isometric quadriceps sets to straight leg raises and knee extension exercises is an exercise progression. For someone recovering from tendinosis, progressing from isometric contractions to eccentric contractions is another way to progress the exercise program without increasing the exercise volume. For general training purposes, it is important to train both concentric and eccentric muscle actions unless one type of action is preferred based on the pathology, impairments, or activity limitations. For example, patients who have difficulty descending stairs because of poor quadriceps control, but no trouble ascending stairs, should emphasize eccentric muscle contractions.

Altering **exercise speed** can change the exercise impact. For many exercises, resistance varies with speed. For example, in the pool, increasing the speed increases resistance, whereas with isokinetic concentric exercise, decreasing the speed increases the resistance. When treating tendinosis, the rehabilitation program often progresses from exercises performed slowly to higher speeds.

Changing the **exercise mode** can alter the exercise challenge. Moving from isotonic resistance to isokinetic can provide more challenge through the ROM. Changing from variable resistance machines to free weights can encourage more balance and stability. Likewise, decreasing stabilization in any way (with or without changing the mode) will place more challenge on the patient as he or she must provide internal stabilization to maintain balance and control in the exercise. Similarly, decreasing feedback requires the patient to rely on internal memory trace of correct motor performance rather than on external feedback provided by the therapist.

Changing the **environment** can provide numerous differing challenges to the patient. One important environmental change is moving from performing exercises in the pool in a minimally or unweighted environment to performing similar exercises on land, or vice versa. Another example is progressing from the structured environment of the clinic where the patient is used to focusing solely on the exercises at hand to a community environment where there are many competing stimuli. Similarly, changing the exercise sequence can be a form of progression. **Sequence** preferences were discussed earlier in this chapter. A sample sequence progression might be performing two exercises training the same muscle group back to back rather than alternating the exercises with a different activity. For example, the patient might perform resisted knee extension immediately followed by resisted straight leg lifts rather than performing a hamstring curl or an upper body exercise in between.

For many individuals, changing the **movement pattern or posture** can significantly alter the activity. For example, patients with spinal stenosis may need to perform exercises in slight flexion in the early stages. As symptoms improve, progression might include performing the same exercises closer to neutral or neutral toward an extended position. The movement for trunk stabilization exercises might progress from performing an exercise bilaterally (where the bilateral nature of the exercise provides balance and some stability) to performing the same movement unilaterally with the contralateral limb held close to the side. This asymmetric pattern would provide increase trunk stability challenge.

Finally, removing **cognitive control** asks the patient to progress the exercise from the cognitive motor control stage to the autonomous stage (see Chapter 3). This is simply done by engaging the patient cognitively while asking him or her to perform a motor skill. Thus the same task becomes more challenging as the patient is no longer allowed to cognitively focus on the exercise demands.

Finding the right balance of expanding volume and program changes within the same volume is no easy task. However, taking smaller incremental steps to progress the patient will minimize any significant regression should the program changes be too challenging. Ongoing communication and close monitoring either face to face or by other means can help ensure continuous forward progress toward goals. This communication should include patient education on the expected response to the exercise program and instructions for modification should symptoms increase.

THERAPEUTIC EXERCISE INTERVENTION FOR PREVENTION, HEALTH PROMOTION, AND WELLNESS

Patients who successfully complete a rehabilitation program may want to continue a resistive exercise program to further the gains they have made and/or to prevent a recurrence of their injury. These individuals can transition into a fitness exercise program. Exercise progression following a rehabilitation program, or designing a program for injury prevention or wellness, must consider the current training level of the individual.

The ACSM defines a *novice* as someone with no training experience, *intermediate* as someone with 6 months of consistent resistance training experience, and *advanced* as someone with years of resistive training experience.[37] *Elite* individuals are highly competitive athletes. Strength gains vary considerably among these training groups. You can expect muscle strength gains of approximately 40% in untrained individuals, 16% to 20% gains in intermediate, 10% in advanced, and 2% in elite athletes.[37] These gains can be expected over the course of 4 weeks to 2 years, with the majority of gains (especially in the untrained) occurring in the first 4 to 8 weeks. For untrained individuals, the responses to just about any training program will be profound, whereas making gains in intermediate, advanced, or elite athletes is much more difficult. Exercise prescription will need to be more creative and variable in these individuals.

Although strength gains in the short-term (4 to 8 weeks) can be encouraging for the participant, this rate of progress will level off after an initial period of training. At this point, program changes must be considered to continue progression toward exercise goals. The ACSM defines **progression** as the continued improvement in a desired variable (i.e., strength, power, endurance, muscle hypertrophy, etc.) over time until the individual goal has been achieved.[30] Continuing the initial training program for several months following program initiation is unlikely to sustain forward progress. Changes to the resistive training program are necessary to minimize training plateaus and to sustain forward progress. Like resistive training for rehabilitation, progressive overload can occur by increasing the exercise load, repetitions, or volume, or by changing the exercise speed, decreasing rest intervals, or by any combination of these variables. A periodized program to systematically vary exercise volume and intensity has been shown to be most effective for long-term progression.[37,194,195]

Dosage for Strength Training

For strength development, the ACSM recommends that novice and intermediate lifters train at an intensity of 60% to 70% of 1 RM for 8 to 12 repetitions.[37] All lifters should use both concentric and eccentric contractions. Untrained individuals require very little load to improve strength. Loads as little as 45% to 50% of 1 RM and less have been shown to increase strength in previously untrained individuals.[195,196] Novices should train the entire body 2 to 3 days per week whereas intermediate lifters should train similarly, unless desiring to progress to split workouts (upper body 1 day and lower another). In this case, the frequency should be 3 to 4 days per week, allowing training of each muscle group 1 to 2 days per week. The volume prescription should include either single or multiple sets initially (such as the DeLorme or DAPRE) and progressed to periodized training using multiple sets. Advanced lifters should train at 80% to 100% of 1 RM in a periodized plan.[37] Apply an approximately 2% to 10% increase in load when the individual can perform the current intensity for one to two repetitions over the desired number on two consecutive training sessions.[37] Base the intensity progression on the muscle group and activity.

The total training volume should be varied and progressed to continue strength gains. The training volume can be varied by changing the number of exercises performed in a session, by changing the number of repetitions performed in a set or the number of sets of exercise. Training volume dose–response recommendations for different populations have been made.[33] For untrained individuals, maximum strength gains were achieved at an intensity of 60% of 1 RM, 3 days per week with a mean training of four sets per muscle group. Recreationally trained athletes showed maximum strength gains at a dosage of 80% of 1 RM, 2 days per week also training four sets per muscle group. For athletes, maximal strength gains were made when training at 85% of 1 RM, 2 days per week at a mean training volume of eight sets per muscle group.[33,196]

Some ongoing debate surrounds the question of single- versus multiple-set resistance training programs.[197–201] Many gen exercisers, either single- or eral strength training programs include a single exercise set of 8 to 12 repetitions.[102] For novice exercisers, either single- or multiple-set resistance programs will achieve strength gains, although multiple sets produced superior gains in some research.[37,200,201] However, for trained individuals, multiple sets are more effective for strength building.[37,198,199]

Slow to moderate velocities are recommended for novice trainers unless the patient has difficulty generating torque or controlling movement at a specific functional speed. The ACSM recommends moderate velocities for intermediate training, and a spectrum of velocities from unintentionally slow to fast to maximize training gains in the advanced and elite athlete.[37] Unintentionally slow velocities are those where the load is so high that it requires the individual to lift slowly due to loading and/or fatigue. This type of training produces overload and a training response, whereas intentionally slow lifting, or submaximal lifting performed at a slow velocity (i.e., 5- to 10-second concentric, 5-second eccentric), do not produce sufficient overload.[203,204]

For novice, intermediate, or advanced training, the ACSM recommends rest intervals of 2 to 3 minutes for multijoint exercises using heavy loads.[37] For other exercises (including weight machines), they recommend a shorter rest interval of 1 to 2 minutes. This recommendation is the same for developing both strength and power.

Dosage for Power Training

Power requires a combination of strength, speed, and skill and the training program should reflect these variables. Effective use of power requires baseline strength at both fast and slow speeds, the ability to generate force quickly, efficient use of the SSC, and good neuromuscular coordination.

For power development, one to three sets of 30% to 60% of 1 RM for three to six repetitions should be incorporated into the intermediate training program.[37] Progression should use various loads planned in a periodized fashion. Advanced training should include a three- to six-set (one to six repetitions per set) power program incorporated into the strength program. Progression of power training requires both heavy loading (85% to 100% of 1 RM) for force development, and light to moderate loading (30% to 60% of 1 RM) performed at high velocity for increasing fast force production.[37] Focus only on heavy loading may actually decrease power output if not accompanied by quick, explosive-type exercises such as the loaded jump squat.[94] Rest period recommendations are the same as for strength training (see **Building Block 5-6**).

BUILDING BLOCK 5-6

A sprint athlete would like advice on how to increase performance for the 220-yard hurdles. Please provide some suggested strategies.

Plyometric Exercise

Functional activity seldom involves pure forms of isolated isometric, concentric, or eccentric actions, because the body is subjected to impact forces (**Fig. 5-21**), as in running or jumping, or because some external force, such as gravity, lengthens the muscle. In these movement patterns, the muscles are acting eccentrically and then concentrically. By definition of eccentric action, the muscle must be active during the lengthening phase. The SSC is the combination of an eccentric action followed by a concentric action. Training techniques that employ the SSC are called *plyometrics*. Examples of plyometric exercises include hopping, skipping, bounding, and jumping drills for the lower extremity, and plyometric ball or elastic resistive exercises for the upper extremity. However, not all jumping or resistive band exercises are plyometric. Plyometrics are done with a specific goal in mind: to increase power and speed.

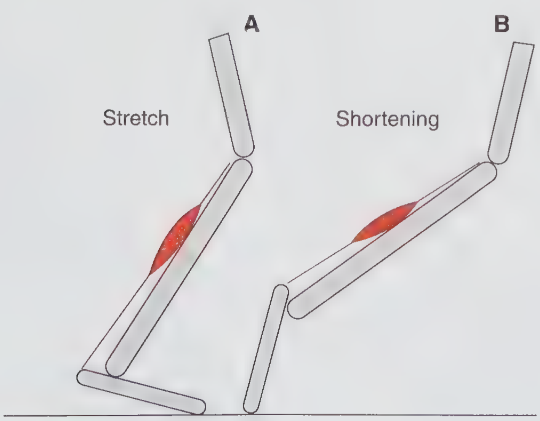


FIGURE 5-21 The SSC cycle in daily activities. At contact, the muscle is stretched and contracts in a lengthening action (eccentric) **(A)**. The stretch phase is followed by a shortening (concentric) action **(B)**. The figure demonstrates the SSC, which is the natural form of the muscle function.

Plyometrics are quick, powerful movements that are used to increase the reactivity of the nervous system. Plyometrics enhance work performance by storing elastic energy in the muscle–tendon unit during the stretch phase and reusing it as mechanical work during the concentric phase. Bosco et al.[205] found that the amount of elastic energy stored in a muscle during eccentric work determines the recoil of elastic energy during positive work. Part of the developed tension during the stretching phase is taken up by the elastic elements arranged in series with sarcomeres (i.e., series elastic component or tendon). This mechanical work is stored in the sarcomere cross-bridges and can be reused during the following positive work if the muscle is contracted immediately after the stretch. The muscle's ability to use the stored energy is determined by the timing of the eccentric and concentric contractions and by the velocity and magnitude of stretch. A quick transition from eccentric to concentric (i.e., undamped landings) along with a high-velocity stretch of high magnitude produces the greatest benefits. The transition time between the eccentric and concentric contractions is called the amortization phase, and the distinction between plyometrics and other impact activities is the goal of decreasing this phase as much as possible.

Plyometrics are high-level activities. Because of the stored energy in the series elastic component, the tendon is susceptible to overuse injury when performing plyometric exercises. The individual should be in an advanced training stage before these techniques are employed. In an advanced exercise program, these techniques develop power and speed, the key muscle performance elements of athletics. Jumping from or to different heights, bounding (i.e., jumping for distance), progressive throwing programs, and throwing for speed or distance are methods of using SSC for enhancing speed or power performance. Before performing lower-extremity plyometrics, the individual must be able to squat his or her body weight, perform a standing long jump equal to his or her height, and balance on a single leg with eyes closed. Programs should be well planned and progressed slowly and appropriately for the individual and the goals. An example of a plyometric program can be found in **Display 5-3**. See Additional Reading for more plyometric materials.

DISPLAY 5-3

Sample Plyometric Activities

Easy

- Ankle bounces in place
- Ankle bounces side to side
- Ankle bounces with 90-degree turn
- Ankle bounces in stride
- Single leg push offs from box
- Lateral hopping over cones
- Forward hopping over cones

Intermediate

- Jump ups on box
- Side jumps on to box

DISPLAY 5-3

Sample Plyometric Activities (*continued*)

- Tuck jump
- Multiple jumps forward
- Multiple jumps sideways
- Split squat jump
- Cone hops with turn
- Cone hops with land and sprint

Advanced

- Multiple box jumps with single leg land
- Squat jumps to multiple boxes
- Depth jumps with ball catch
- Standing long jump with 90-degree turn and sprint
- Depth jump with 90-degree turn and sprint
- Single leg bounding
- Bounding and vertical jump combination

Dosage for Endurance Training

Muscle endurance is necessary for a variety of activities and muscle groups. For example, postural muscles must provide sustained or repetitive contractions for long periods during prolonged standing, walking, or work activities. Many lower extremity muscles need endurance distance running, tennis, or other sports and leisure activities. Repetitive work activities such as carpentry, factory work, or other manual labor require local muscle endurance to fulfill job requirements during 8- to 12-hour work shifts.

For development of muscular endurance in novice and intermediate training, the ACSM recommends relatively light loads with moderate to high volume (10 to 15 repetitions). For advanced training, various loading strategies should be used for multiple sets per exercise (10 to 25 repetitions) using a periodization scheme.[37]

Use shorter rest periods such as 1 to 2 minutes for high repetition (15 to 20 repetitions) and <1 minute for moderate (10 to 15 repetitions) sets.[37] The training frequency is the same as for strength training, and the training velocity should be slow when doing a moderate (10 to 15) number of repetitions, and moderate or fast velocities when performing higher numbers of repetitions (15 to 25 or more).

Dosage for the Advanced or Elite Athlete

The following techniques are used by those who train competitive athletes. These techniques can be used to provide variety, increase resistance, or maximize the workout time in daily workouts. These specific techniques provide the recommended variability necessary for training the advanced or elite athlete. They are introduced to familiarize the therapist with the terminology used in training these athletes. Use good judgment based on scientific principles when using these techniques.

A **superset** consists of two sets of exercise involving opposing muscles that are performed in sequence without a rest between sets (e.g., a biceps curl followed by a triceps extension, without rest, proceeding to the remaining sets). Supersets can reduce workout time or allow more exercise to be performed during the same period.

A **triset** is a group of three exercises, each done after the other with little rest between muscle groups. Trisets can be used to exercise three different muscle groups or three angles of a complex muscle (e.g., flat, incline, decline bench press for the different fiber directions of the pectoralis major).

Pyramid training is a modification of the DeLorme training program. The regimen starts with a high number of repetitions and low weight (to warm up), but instead of maintaining the repetitions constant and increasing the weight, the repetitions are reduced and weight is increased. After the series is completed, the individual works backward, taking off weight and adding repetitions. The number of repetitions and sets is arbitrarily established as long as the high-repetition, low-weight progression to a heavier-weight, low-repetition regimen is followed (**Table 5-9**).

A typical **split routine** consists of a series of exercises that usually emphasize two or three major muscle groups or body parts. This allows the individual to train on two consecutive days without overtraining muscle groups, because one muscle group is resting, whereas the other is exercising. Body builders often follow a double-split routine, in which two sessions are performed on each day (**Table 5-10**).

Matveyev[206] described the basic ideas of periodized training programs for these athletes. A program is periodized when it is divided into phases, each of which has primary and secondary goals. The program is based on the premise that maximum strength gains are not made by constant heavy training but are made possible by different training cycles or periods. These

TABLE 5-9

Sample Pyramid Training for a Squat Exercise for a Highly Trained Individual

SETS	REPETITIONS	WEIGHT
1	12	100
1	8	135
1	6	185
1	4	225
1	2	250
1	1	275

TABLE 5-10

Example of a Split Routine for Total-Body Resistive Training

FOUR-DAY PROGRAM[a]	SIX-DAY, TWO SESSIONS PER DAY PROGRAM[a]
Monday: upper body	Monday AM: chest
Tuesday: lower body	Monday PM: back
Wednesday: rest	Tuesday AM: shoulders
Thursday: upper body	Tuesday AM: upper legs
Friday: lower body	Wednesday AM: triceps
Saturday: rest	Wednesday PM: biceps
Sunday: repeat sequence	Thursday AM: chest
	Thursday PM: back

[a]Abdominal and calf muscles are exercised each day.

cycles allow the athlete to reach maximum performance level at a predesignated time, usually the day of competition.

In his original model, Matveyev[206] suggested that the initial phase of a strength-power program should contain a high volume (i.e., many repetitions) with lower intensity (i.e., low average weight lifted relative to maximum possible in each movement). Typical high-volume phases for weight lifters contain more training sessions per week (6 to 15), more exercises per session (3 to 6), more sets per exercise (4 to 8), and more repetitions per set (4 to 6). As weeks pass, the volume decreases and intensity increases. The resulting higher intensity and lower volume represent the characteristics of a basic strength phase of training. Typical high-intensity phases for weight lifters contain fewer training sessions per week (5 to 12), fewer exercises per workout session (1 to 4), fewer sets per exercise (3 to 5), and fewer repetitions per set (1 to 3). A third, optional phase may include low volume (low repetitions) with high intensity (heavy weights) to work on power. The final phase is considered an active rest phase with very low volume and very low intensity.

Each phase may be several weeks to several months long. Two or more complete cycles may fit into a training year.

Stone et al.[207] proposed and successfully tested a periodized model of strength-power training with sequential phases that change rather drastically. An example is a phase to increase muscle size (5 sets of 10 RM in core exercises), a phase to improve specific strength (3 to 5 sets of 3 RM), and a phase to "peak" for competition (1 to 3 sets of 1 to 3 repetitions). The use of 10 RM is higher than typically recommended in the early preparation phase but has proved to be successful in a number of studies.[207]

PRECAUTIONS AND CONTRAINDICATIONS

Be sure to consider certain precautions and contraindications when prescribing resistive exercise. Avoid using the Valsalva maneuver during resistive training, especially by patients with cardiopulmonary disease or after recent abdominal, intervertebral disk, or eye surgery. Educate patients to breathe properly during exercise, typically exhaling on exertion. Use isometric exercise with caution by persons at risk for pressor response effects (e.g., high blood pressure after an aneurysm).

Overwork phenomena may exist even at moderate training regimens over an extended period. Overtraining may lead to mood disturbances and reduce the effect of training by a decrease in performance. Avoid fatigue and overtraining by patients with metabolic diseases (e.g., diabetes, alcoholism), neurologic diseases, or severe degenerative joint diseases because of the risk of further joint damage. Overtraining may be the reason for a lack of progress, decreased performance, or development of joint pain and swelling.

Use thoughtful consideration when developing resistive exercise programs for prepubertal and pubertal children and adolescents. Emphasize correct form and technique over weight lifted and develop comprehensive exercise programs to avoid muscle imbalances and overtraining specific tissues.

An absolute contraindication to resistive exercise is acute or chronic myopathy, as occurs in some forms of neuromuscular disease or in acute alcohol myopathy. Resistive exercise in the presence of myopathy may stress and permanently damage an already compromised muscular system.

Scientific knowledge and common sense should be applied in prescribing resistive exercise. Caution should be taken with exercise in the presence of pain, inflammation, and infection. Although resistive exercise may be indicated, the mode and dosage should be carefully chosen.

KEY POINTS

- The term *muscle performance* includes strength, power, and endurance.
- The term *strength* should be clarified in terms of force, torque, and work.
- Muscle actions are static and dynamic. Static muscle actions are called *isometric*.
- A thorough knowledge of muscle morphology is necessary for effective/efficient therapeutic exercise prescription to improve muscle performance.
- *Dynamic action* is the preferred term over *isotonic*. Dynamic actions can be further divided into concentric and eccentric actions.
- Overload training produces changes in the size of the muscle primarily through hypertrophy but also through hyperplasia.
- Muscle strength must be evaluated relative to the muscle's length because of length–tension relationships.
- Muscle architecture can significantly affect muscle force production.
- Specificity of training exists, especially relative to training velocity.
- Eccentric muscle contractions are the most energy-efficient contraction type and can develop the greatest tension of any muscle contraction type.
- Adaptations to resistive training are partially neurologic in that changes in performance often precede morphologic changes.
- *Form fatigue* is the point at which the individual must discontinue the exercise or sacrifice technique.
- Although dosage and goals differ, resistive training is beneficial from late childhood through old age.
- Impaired muscle performance can result from neurologic pathology, muscle strain, muscle disuse, or length-associated changes.
- Adaptations to resistive training extend beyond the muscle to include connective tissues, the cardiovascular system, and bone.
- Activities to improve muscle performance include isometric, dynamic, plyometric, and isokinetic exercise.
- Dynamic exercise can be performed with a variety of modes, including free weight, resistive bands, pulleys, weight machines, or body weight, including various combinations of concentric and eccentric contractions.
- Plyometric activities use the SSC to enhance muscle performance.
- The dosage of exercise to improve muscle performance depends on the goal (i.e., strength, power, and endurance) as well as the initial fitness level of the individual (i.e., novice, intermediate, advanced, and elite).
- Precautions and contraindications to resistive exercise must be known to ensure safety to the patient/client.

LAB ACTIVITIES

1. A series of musculoskeletal conditions is listed from i to viii. For each condition, perform the following:
   a. Determine which muscles are involved. Include possible underused synergists that may lead to overuse of the muscle involved. List each muscle and describe its specific action.
   b. Design and perform one exercise for each muscle (group) given the manual muscle test grade of fair minus (3–/5). Include complete dosage parameters.
   c. Design and perform two exercises for each muscle (group) given the manual muscle test grade of good (4/5). Use an elastic band for one and a free weight for the other, and include complete dosage parameters.
   d. Progress the exercises in question 1c to two functional activities.

Musculoskeletal and Neuromuscular Conditions

i. Achilles tendinopathy
ii. Iliotibial band fascitis
iii. Patellar tendinopathy
iv. Hamstring strain
v. Peroneal nerve palsy (i.e., common peroneal nerve; list muscles innervated)
vi. Supraspinatus tendinopathy
vii. Middle trapezius strain resulting from overstretch
viii. Lateral epicondylitis

2. Using free weights or a weight machine, determine the 1, 6, and 10 RM for a bench press and leg extension. Determine the dosage for Oxford, DeLorme, and DAPRE programs.
3. Pick three muscle groups throughout your body (one upper quarter, one lower quarter, and one trunk). Design two different resistive exercises for each muscle group using a variety of equipment, including elastic bands, free weights, and pulleys and weight machines if available. Determine the dosage for a DeLorme program.

CRITICAL THINKING QUESTIONS

1. Consider each of the questions in the Lab Activities in the next section. How would your dosage differ if you were training for:
   a. strength
   b. power
   c. muscle endurance

   How would your training differ for:
   d. an adolescent cross-country runner who wanted to improve performance
   e. a preadolescent: gymnast, dancer, football player, soccer player
   f. an elderly man who was training for a 10-day hike in the mountains
2. Design a muscle performance program for a woman confined to bed rest for 3 weeks after an acute lumbar fracture without neurologic involvement. Include dosage parameters for strength and endurance.
3. Consider Case Study No. 5 in Unit 7. List muscles with impaired muscle performance. Determine whether the muscle requires strength, endurance, or power training. Decide on one activity for each muscle and determine the dosage relative to the goal (i.e., strength, power, and endurance) and initial fitness level for this patient. Develop the sequence of exercise for each session and include the frequency in the dosage parameters.

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CHAPTER

6

Impaired Aerobic Capacity/Endurance

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Cardiovascular endurance is the ability of the cardiovascular system (i.e., heart, lungs, and vascular system) to take in, extract, deliver, and use oxygen and to remove waste products. Cardiovascular endurance, or aerobic capacity, supports the performance of repetitive activities using large muscle groups for extended periods. All patients and clients require adequate aerobic capacity, especially those who work at home or on the job; participate in athletic endeavors of all levels, skill, and type; and perform physical activity for fun or leisure. Concurrently, these activities also improve impairments in aerobic capacity, and are thus useful therapeutically in a rehabilitation setting.

The literature contains strong evidence that the regular performance of cardiorespiratory endurance activities reduces the risk of developing disease, such as cardiorespiratory disease, metabolic disease (diabetes and metabolic syndrome), and breast and colon cancer, as well as decreases risk of depression and cognitive decline, and is associated with lower mortality rates in both older and younger adults.[1–3] Despite this evidence, recent surveys of exercise trends among inhabitants of the United States illustrate that approximately 51.6% of US adults perform 150 minutes of aerobic physical activity per week.[4] Adolescents and young adults (ages 12 to 21) were found to be similarly inactive, with approximately 47.3% performing 60 minutes per day of physical activity 5 days per week.[4] Since the Surgeon General's report on physical activity and health was published in 1996,[5] numerous efforts have been undertaken to monitor the prevalence of physical activity in the population. Based on Behavioral Risk Factor Surveillance System data collected between 2001 and 2005, the prevalence of regular physical activity (either vigorous or sustained as defined above) increased significantly by 8.6% (from 43.0% to 46.7%) among women overall and by 3.5% (from 48.0% to 49.7%) among men. Except for women between the ages of 18 and 24 years, significant increases in regular activity were reported in all racial/ethnic, age, and education-level categories examined. For men, significant increases in regular physical activity were found among 45- to 64-year-old respondents, non-Hispanic white males, non-Hispanic black males, high school graduates, and college graduates.[5]

Because of the widespread prevalence of physical inactivity among the US population, the US Public Health Service has created goals for exercise participation in the *Healthy People 2020*, *Healthy People 2010*, and *Healthy People 2000* documents, aimed at improving the quality and increasing the years of healthy life.[6,7] In the mid-1990s, the US Department of Health and Human Services, the Centers for Disease Control and Prevention, the National Center for Chronic Disease Prevention and Health Promotion, the President's Council on Physical Fitness and Sports, and the American College of Sports Medicine (ACSM) recommended that all adults should accumulate 30 minutes or more of moderate-intensity physical activity on most, and preferably all, days of the week.[8] In 2007, the recommendation was updated by the ACSM and the American Heart Association (AHA) for adults between 18 and 65 years of age, including adults in this age range with chronic conditions not related to physical activity.[9] The recommendation for adults to promote and maintain health was to perform moderate-intensity aerobic physical activity for a minimum of 30 minutes on 5 days each week or vigorous-intensity aerobic activity for a minimum of 20 minutes on 3 days each week. Also, a combination of moderate- and vigorous-intensity activity could be performed to achieve the recommendation.[9] The US Department of Health and Human Services, Office of Disease Prevention and Health Promotion published yet another guideline in 2008 called the 2008 Physical Activity Guidelines for Americans that compiled all of the research about the impact of physical activity on health and well-being.[10] These guidelines include a recommendation for:

- All adults 18 to 65 to accumulate:
  - 150 minutes per week of moderate aerobic physical activity
  - 75 minutes of vigorous aerobic physical activity
  - or an equivalent combination, plus 2 days of muscle strengthening activities per week[10]
- Children and adolescents should accumulate:
  - 60 minutes a day of moderate or vigorous physical activity including vigorous activity 3 days per week[10]
- Adults over the age of 65 should follow the same guidelines as adults and add balance actvivities.[10]

Toward this end, health care professionals have an opportunity to contribute to the overall well-being of the patients and clients we serve by prescribing meaningful physical activity programs based on the most contemporary scientific evidence. In order to adequately address the plethora of chronic diseases that are prevalent in individuals we serve, it is our responsibility to ensure that every patient/client is assessed and educated about the importance and power of regular physical activity related to the treatment and prevention of disease. In this chapter, the scientific basis of aerobic training will be presented along with guidelines for prescribing and supervising aerobic exercise and physical activity.

AEROBIC CAPACITY AND ENDURANCE

Definitions

There are many terms used in relationship to aerobic capacity and exercise that require clarification. Common terms are defined in **Table 6-1** and examples are provided.

Normal and Abnormal Responses to Acute Aerobic Exercise

The performance of aerobic exercise can be easily assessed using commonly measured parameters, such as heart rate (HR), blood pressure (BP), and respiratory rate (RR). It is important for the clinician to know and recognize the normal and abnormal response to acute aerobic exercise so that a judgment can be made about the patient/client's response and exercise stopped prior to the development of a situation that could put the patient/client in danger. Moreover, patient/clients typically have several comorbidities that may lead to abnormal responses, and therefore a safe environment for exercising can be created with careful monitoring of responses and application of the knowledge about what the responses indicate.

Normal Responses to Acute Aerobic Exercise

To assess an individual's response to exercise, it is important to understand the normal physiologic changes that occur as a result of the performance of physical activity. The ability to sustain aerobic exercise depends on numerous cardiovascular and respiratory mechanisms aimed at delivering oxygen to the tissues. The following changes would be expected *during* aerobic exercise and would be considered normal responses.[12–16]

Heart Rate There is a linear relationship between HR, measured in beats per minute (bpm), and intensity of exercise, indicating that as workload or intensity increases, HR increases proportionally. The magnitude of increase in HR is influenced by many factors, including age, fitness level, type of activity being performed, presence of disease, medications, blood volume, and environmental factors such as temperature and humidity.

Stroke Volume The volume or amount of blood ejected from the left ventricle per heart beat is termed the stroke volume (SV), measured in mL per beat. As workload increases, SV increases linearly up to approximately 50% of aerobic capacity, after which it increases only slightly. Factors that influence the magnitude of change in SV include ventricular function, body position, and exercise intensity.

Cardiac Output The product of HR and SV is cardiac output (Q), or the amount of blood ejected from the left ventricle per minute (L per minute), ($Q = HR \times SV$). Cardiac output (CO) increases linearly with workload because of the increases in HR and SV in response to increasing exercise intensity. Changes in Q depend on age, posture, body size, presence of disease, and level of physical conditioning.

TABLE 6-1

Definitions and Examples of Common Terms Associated with Aerobic Capacity/Endurance Training

TERM	DEFINITION	EXAMPLES
Physical activity	Any bodily movement produced by skeletal muscles that results in energy expenditure.[11]	Walking a dog House work such as sweeping, vacuuming Mowing the lawn
Exercise	A type of physical activity that is planned, structured, repetitive, and is purposely aimed at improving physical fitness.[11]	Jogging to prepare to run a 5K race Walking 60 min/d to lose weight Resistance training to build muscle mass
Physical fitness	A set of attributes that people have or achieve including components of health-related (cardiorespiratory endurance, body composition, muscular endurance, muscular strength, flexibility) and athletic-related skills.[11] Being physically fit enables an individual to perform daily tasks without undue fatigue and with sufficient energy to enjoy leisure-time activities and to respond in an emergency situation, if one arises.	VO_2 max of 35 mL/kg/min Body fat = 27% Ability to perform 55 sit-ups in 1 min Ability to bench press 150 lb 10 repetitions 6 inches on the sit and reach test of flexibility
Cardiorespiratory endurance training (aerobic training)	Repetitive movements of large muscle groups fueled by an adequate response from the circulatory and respiratory systems to sustain physical activity and eliminate fatigue; designed to achieve physical fitness.[1] The ability of the whole body to sustain prolonged exercise.	Jogging 10 min or longer Walking 10 min or longer Bicycle riding 10 min or longer Playing basketball 10 min or longer
Anaerobic training	Exercise performed in short bursts that does not require an ongoing supply of oxygen.[12]	Strength or resistance training
VO_2 max (aerobic capacity, maximal oxygen uptake)	The highest rate of oxygen that the body can consume during maximal exercise.[12]	35 mL/kg/min

Arterial-Venous Oxygen Difference The amount of oxygen extracted by the tissues from the blood represents the difference between arterial blood oxygen content and venous blood oxygen content and is referred to as the arterial-venous oxygen difference (a-vo_2 diff), measured in mL per dL. As exercise intensity increases, a-vo_2 diff increases linearly, indicating that the tissues are extracting more oxygen from the blood, decreasing venous oxygen content as exercise progresses.

Blood Flow The distribution of blood flow (mL) to the body changes dramatically during acute exercise. Whereas at rest, approximately 15% to 20% of the CO goes to muscle, during exercise approximately 80% to 85% is distributed to working muscle and shunted away from the viscera. During heavy exercise, or when the body starts to overheat, increased blood flow is delivered to the skin to conduct heat away from the body's core, leaving less blood for working muscles.

Blood Pressure The two components of BP, systolic (SBP) and diastolic (DBP) pressure, respond differently during acute bouts of exercise. To facilitate blood and oxygen delivery to the tissues, SBP increases linearly with workload. Because DBP represents the pressure in the arteries when the heart is at rest, it changes little during aerobic exercise, regardless of intensity. A change in DBP of <15 mm Hg from the resting value is considered a normal response. Both SBP and DBP are higher during upper extremity aerobic activity, compared to lower extremity aerobic activity. This increase is thought to be because of increased resistance to blood flow and a resulting increase in BP to overcome the increased resistance as a result of the smaller muscle mass and vasculature of the upper extremities compared to the lower extremities.[10]

Pulmonary Ventilation The respiratory system responds during exercise by increasing the rate and depth of breathing in order to increase the amount of air exchanged per minute (L per minute). An immediate increase in rate and depth occurs in response to exercise and is thought to be facilitated by the nervous system, initiated by the movement of the body. A second, more gradual, increase occurs in response to body temperature and blood chemical changes as a result of the increased oxygen use by the tissues. Thus both tidal volume, or the amount of air moved into and out of the lungs during regular breathing, and RR, the number of breaths per minute, increase in proportion to the intensity of exercise.

Abnormal Responses to Acute Aerobic Exercise

Individuals with suspected cardiovascular disease or any other type of disease that may produce an abnormal response to exercise should be appropriately screened and tested before the initiation of an exercise program. This topic will be discussed in greater detail later in this chapter. However, abnormal responses may occur in individuals without known or documented disease and thus routine monitoring of exercise response is important and can be used to evaluate the appropriateness of the exercise prescription and as an indication that further diagnostic testing may be indicated.

In general, responses that are inconsistent with the normal response guidelines described previously are considered abnormal responses. Of the parameters described, HR and BP are most commonly assessed during exercise. The failure of HR to rise in proportion to exercise intensity, a failure of SBP to rise or a decrease in SBP ≥ 20 mm Hg during exercise, and an increase in DBP ≥ 15 mm Hg would all be examples of abnormal responses to aerobic exercise.[15]

Signs and symptoms of exercise intolerance should also be recognized and include those listed in **Display 6-1**. Abnormal exercise responses, such as failure of HR to rise, often occur with patient-related signs and symptoms; however, they can occur independently, so the clinician should be familiar with both. Knowledge of the normal and abnormal physiologic and symptom responses to exercise will enable the clinician to prescribe and monitor exercise safely and confidently and to minimize the occurrence of untoward events during exercise. Regular exposure to aerobic exercise results in changes to the cardiovascular and respiratory systems that can also be assessed by monitoring basic physiologic variables during rest and exercise. These adaptations will be discussed next.[16]

DISPLAY 6-1

Major Signs and Symptoms of Cardiovascular, Pulmonary, and Metabolic Disease

- Pain, discomfort (or other anginal equivalent) in the chest, neck, jaw, arms, or other areas that may result from ischemia
- Shortness of breath at rest or with mild exertion
- Dizziness or syncope
- Orthopnea or paroxysmal nocturnal dyspnea
- Ankle edema
- Palpitations or tachycardia
- Intermittent claudication
- Known heart murmur
- Unusual fatigue or shortness of breath with usual activities

American College of Sports Medicine. Resource Manual for Guidelines for Exercise Testing and Prescription. 6th Ed. Baltimore, MD: Lippincott Williams & Wilkins, 2010:540.

Physiologic and Psychological Adaptations to Cardiorespiratory Endurance Training

In healthy individuals, cardiovascular training produces profound changes throughout the cardiorespiratory and vascular systems. The documented benefits of aerobic exercise are a result of the adaptations the oxygen delivery system undergoes secondary to the performance of regular activity. These adaptations, considered chronic changes, enable more efficient performance of exercise and thus affect cardiorespiratory endurance and fitness level. These chronic adaptations occur in the cardiovascular and respiratory systems and affect the values of both VO_2 max and body composition (see **Display 6-2**).

Cardiovascular Adaptations

Factors involving the heart that adapt in response to a regular exercise stimulus include heart size, HR, SV, and CO. The weight and volume of the heart and the thickness and chamber size of the left ventricle increase in trained individuals. As a result,

DISPLAY 6-2

Benefits of Regular Physical Activity and/or Exercise

Improvement in Cardiovascular and Respiratory Function

- Increased maximal oxygen uptake resulting from both central and peripheral adaptations
- Decreased minute ventilation at a given absolute submaximal intensity
- Decreased myocardial oxygen cost for a given absolute submaximal intensity
- Decreased HR and BP at a given submaximal intensity
- Increased capillary density in skeletal muscle
- Increased exercise threshold for the accumulation of lactate in the blood
- Increased exercise threshold for the onset of disease signs or symptoms (e.g., angina pectoris, ischemic ST-segment depression, claudication)

Reduction in Coronary Artery Disease Risk Factors

- Reduced resting systolic/diastolic pressures
- Increased serum high-density lipoprotein cholesterol and decreased serum triglycerides
- Reduced total body fat, reduced intra-abdominal fat
- Reduced insulin needs, improved glucose tolerance
- Reduced blood platelet adhesiveness and aggregation

Decreased Morbidity and Mortality

- Primary prevention
  - Higher activity and/or fitness levels are associated with lower death rates from coronary artery disease
  - Higher activity and/or fitness levels are associated with lower incidence rates for combined cardiovascular diseases, coronary artery disease (CAD), stroke, type 2 diabetes, osteoporotic fractures, cancer of the colon and breast, and gallbladder disease
- Secondary prevention
  - Based on meta-analyses, cardiovascular and all-cause mortality are reduced in postmyocardial infarction patients who participate in cardiac rehabilitation exercise training, especially as a component of multifactorial risk factor reduction
  - Randomized controlled trials of cardiac rehabilitation exercise training involving postmyocardial infarction patients do not support a reduction in the rate of nonfatal reinfarction

Other Benefits

- Decreased anxiety and depression
- Enhanced physical function and independent living in older persons
- Enhanced feelings of well-being
- Enhanced performance of work, recreational, and sport activities
- Reduced risk of falls and injuries from falls in older persons
- Prevention or mitigation of functional limitations in older adults
- Effective therapy for many chronic diseases in older adults

American College of Sports Medicine. ACSM's Guidelines for Exercise Testing and Prescription. 8th Ed. Baltimore, MD: Lippincott Williams & Wilkins, 2010.

the heart pumps more blood out per beat (SV) and the force of each contraction is stronger. SV is thus increased at rest, as well as during submaximal and maximal exercise, because of more complete filling of the left ventricle during diastole compared with an untrained heart and an increase in plasma blood volume, discussed in the following section. Changes to HR include a decreased resting HR and a decreased HR at submaximal exercise levels, indicating that the individual can perform the same amount of work with less effort after training. Maximal HR typically does not change as a result of training. The amount of time it takes for HR to return to resting after exercise decreases as a result of training and is a useful indicator of progress toward better fitness. Because Q is the product of HR and SV ($Q = HR \times SV$), it does not change much at rest or during submaximal exercise because HR decreases and SV increases. However, because of the increase in maximal SV, maximal Q increases considerably.[12,15,16]

Adaptations also occur in the vascular system and include blood volume, BP, and blood flow changes. Aerobic training increases overall blood volume, primarily because of an increase in plasma volume. The increase in blood plasma results from an increased release of hormones (antidiuretic and aldosterone) that promote water retention by the kidney and an increase in the amount of plasma proteins, namely albumin. A small increase in the number of red blood cells may also contribute to the increase in blood volume. The net effect of greater blood volume is the delivery of more oxygen to the tissues. Resting BP changes with training are most noteworthy in hypertensive or borderline hypertensive individuals, in whom aerobic training can decrease both SBP and DBP up to 10 mm Hg. During the performance of submaximal and maximal exercise, there is little change, if any, in BP as a result of training. Several adaptations are responsible for the increase in blood flow to muscle in a trained individual, including greater capillarization in the trained muscle(s), greater opening of existing capillaries in trained muscle(s), and more efficient distribution of blood flow to active muscles.[12,15,16]

Respiratory Adaptations

The capacity of the respiratory system to deliver oxygen to the body typically surpasses the ability of the body to use oxygen, thus the respiratory component of performance is not a limiting factor in the development of cardiorespiratory endurance. Nevertheless, adaptations in the respiratory system do occur in response to aerobic training. The amount of air in the lungs, represented by lung volume measures, is unchanged at rest and during submaximal exercise in trained individuals. However, tidal volume, the amount of air breathed in and out during normal respiration, increases during maximal exercise. RR is lower at rest and during submaximal exercise and increases at maximal levels of exercise. The combined increases in tidal volume and RR during maximal exercise of trained individuals produce a substantial increase in pulmonary ventilation, or the process of movement of air into and out of the lungs. Pulmonary ventilation at rest is either unchanged or slightly reduced and during submaximal exercise is slightly reduced following training. The process of gas exchange in the alveoli, or pulmonary diffusion, is unchanged at rest and at submaximal exercise levels, but increases during maximal exercise because of the increased blood flow to the lungs and the increased ventilation as discussed previously.

These two factors create a situation that enables more alveoli to participate in gas exchange, and thus the perfusion of oxygen into the arterial system is enhanced during maximal exercise. Finally, a-vo_2 diff increases at maximal exercise in response to training as a result of increased oxygen distraction by the tissues and greater blood flow to the tissues because of more effective blood distribution.[12,15,16]

One net effect of these cardiovascular and respiratory adaptations on aerobic capacity is an increased VO_2 max after endurance training. A typical training program consisting of three times per week, 30 minutes per session exercise at 75% of VO_2 max, as discussed in a later section of this chapter, over the course of 6 months can improve VO_2 max 5% to 30% in a previously sedentary individual. Resting VO_2 max is either unchanged or slightly increased following training, and submaximal VO_2 is either unchanged or slightly reduced, representing greater efficiency.[12] The second net effect relates to body composition changes that have been documented as a result of aerobic exercise training. Whether caloric intake stays the same during training or is decreased, individuals lose fat mass as a result of training. Several mechanisms have been postulated to produce a loss of body fat secondary to training, including appetite suppression, an increase in the resting metabolic rate, and an increase in lipid mobilization from adipose tissue and thus the burning of fat for energy.[12]

Psychological Benefits of Training

In addition to the myriad of cardiovascular, respiratory, and metabolic improvements that occur after aerobic training, *psychological* benefits have also been documented, although they are less well understood. An overall assessment of the literature in this area indicates that depression, mood, anxiety, psychological well-being, and perceptions of physical function and overall well-being improve in response to the performance of physical activity.[1,15] The finding that exercise can decrease symptoms of depression and anxiety is consistent with the fact that individuals who are inactive are more likely to have depressive symptoms compared to active persons. Improvements in depression and mood have been found in populations with and without clinically diagnosed psychological impairment, as well as in those with good psychological health, although the literature is less conclusive in this specific area.

A number of factors have been postulated to explain the beneficial effects of aerobic training on psychological function, including changes in neurotransmitter concentrations, body temperature, hormones, cardiorespiratory function, and metabolic processes, as well as improvements in psychosocial factors such as social support, self-efficacy, and stress relief. Further research is needed to verify the potential contribution of changes in these factors resulting from aerobic training to improvement in psychological function.

Despite the inability to explain why psychological parameters improve in response to training, the effect on overall quality of life is positive.[17,18] Improvement in quality of life as a result of physical activity has been demonstrated in individuals without[19–23] and with disease, including coronary heart disease patients who are obese,[24] coronary heart disease patients who are elderly,[25] patients with chronic heart failure,[26,27] patients after coronary bypass graft surgery,[28] and patients with multiple sclerosis[29] and cancer.[30] For individuals with disabilities, physical activity has many important benefits beyond psychological function. Because those with disabilities are especially at risk of being sedentary, physical activity is a valuable intervention tool that should be prescribed to match individual levels of ability.[1,31]

Dose–Response Relationship

The amount of physical activity associated with decreased risk for cardiovascular disease and death has been the topic of numerous studies.[32–36] Authors agree that an inverse linear dose–response exists between the amount of physical activity performed and all-cause mortality.[32–34] The 2008 Physical Activity Guidelines clarify that a dose–response relationship exists between physical activity and health benefits, with 500 to 1,000 MET-minutes of activity per week providing considerable health benefits, recognizing that 150 minutes of moderate-activity per week is roughly equivalent to 500 MET-minutes per week.[1] The higher range (1,000 MET-minutes per week) provides more health benefits than the lower range, and activity amounts above 1,000 MET-minutes per week provide even more health benefits.[1] For adults, therefore, at least 150 minutes of moderate-intensity (3.0 to 5.9 METs) activity per week will produce meaningful health benefits.

The dose–response relationship relative to improvements in quality of life has also been examined. The observed improvement in quality of life in individuals who participate in regular exercise is achieved from quantities of exercise considered to produce health-related (versus fitness-related) benefits. Fitness-related benefits include those resulting in significant changes in physical fitness level, as measured by cardiorespiratory endurance and body composition changes. Specific recommendations for fitness-related changes usually include vigorous, continuous activities with a focus on the specific parameters of exercise (intensity, mode, duration, and frequency). Health-related benefits can be achieved through the performance of moderate-intensity, intermittent activity wherein the focus is on the accumulated amount of activity performed.[1,8] The documented health-related benefits from the performance of regular exercise are shown in Display 6-2.

Although improvement in fitness level is a worthwhile goal and also results in the health-related benefits listed previously, exercise to achieve health-related benefits appears to be easier for most people to incorporate into their lifestyle and thus provides a valuable exercise option.[37–39] The specific parameters necessary to achieve both fitness-related and health-related benefits of aerobic exercise are presented later in this chapter.

CAUSES OF IMPAIRED AEROBIC CAPACITY/REHABILITATION INDICATIONS

The ability of the body to use oxygen can be limited by disease and is affected by aging and inactivity. A systems review, conducted as a part of the examination, discussed in the next section, can identify the presence of or risk for pathology/pathophysiology, impairments, functional limitations, or disabilities that impact aerobic capacity.[40] Although injury to or diseases of the heart, lungs, and vascular system—the primary tissues involved in cardiovascular endurance—are the most obvious causes of impairment or functional limitation, diseases and conditions of other body systems also affect aerobic capacity.

There are three categories of diseases that directly affect the heart, including conditions of the heart muscle, diseases affecting the heart valves, and cardiac nervous system conditions.[41] Heart muscle conditions include CAD, myocardial infarction, pericarditis, congestive heart failure, and aneurysms.[41] The pathologic processes involved in the impairment of aerobic capacity in these heart muscle conditions involve obstruction or restriction of blood flow, inflammation, or dilation or distention of one or more heart chambers.[41] Aerobic capacity is impaired because the heart is weakened as a result of the disease or condition or blood flow is impaired, resulting in ischemia and necrosis of heart muscle and an inability to pump enough blood in response to increased demand from activity.

The heart valves can become diseased by rheumatic fever, endocarditis, mitral valve prolapse, and various congenital deformities. Valve defects increase the workload of the heart, as the heart must work harder to pump blood through a malfunctioning valve, resulting in impaired aerobic capacity.[41] The nervous system that controls cardiac muscle contraction, when diseased, produces arrhythmias such as tachycardia and bradycardia. Arrhythmias impair aerobic capacity by causing changes in circulatory dynamics because the heart is beating too slow or too fast, or skipping beats.[41]

There are numerous types of peripheral vascular disease, including arterial, venous, and lymphatic disorders, such as atherosclerosis, embolism, Buerger disease, Raynaud disease, deep venous thrombosis, venous stasis, and lymphedema.[41] Because aerobic capacity is determined by the condition and capacity of both the heart and the peripheral circulation, these conditions also produce impairments. The vascular system is used to transport oxygen to exercising muscles so that diseases of the peripheral vascular system disrupt circulation to peripheral muscles, producing a loss of function at rest and during exercise, impairing aerobic capacity. The most common disease of the vascular system is hypertension, considered a major risk factor for myocardial infarction, stroke, and cardiovascular death.

Conditions affecting the pulmonary system influence the ability of the lungs to bring in and absorb oxygen and expel carbon dioxide from cells in the body. These processes are of primary importance to cardiorespiratory endurance; therefore, diseases affecting ventilation and respiration impact aerobic capacity. Diseases affecting the lungs include lung tumors, chronic obstructive pulmonary disease (including bronchitis, bronchiectasis, emphysema), asthma, pneumonia, tuberculosis, cystic fibrosis, and various occupational lung diseases (pneumoconiosis).[41]

Disease of the neurologic, musculoskeletal, endocrine/metabolic, and integumentary systems may also negatively affect aerobic capacity. Conditions such as cancer, neuromuscular disease, cerebrovascular attacks, traumatic brain injury, spinal cord injury, osteoporosis, arthritis, and AIDS either directly or indirectly impair aerobic capacity and thus limit cardiovascular endurance.

Any medical condition necessitating hospitalization or bed rest can result in deconditioning of the cardiovascular system. Surgical procedures for the gallbladder, appendix, uterus, or other internal organs require a period of decreased activity. Accidents resulting in multiple system injuries can limit activity for long periods of time, resulting in deconditioning.

The effects of aging on the cardiovascular and respiratory systems are numerous, resulting in an overall decrease in aerobic capacity. Some of the factors that have been attributed to the decline in aerobic capacity documented with age include decrements in central and peripheral circulation including a decrease in maximal HR, SV, and a-vO_2 diff; increases in body fat and decreases in lean body mass; and lung function decline including a decrease in vital capacity and forced expiratory volume, an increase in residual volume, and a loss of elasticity in the lung tissue and chest wall.[10] Because the elderly respond to cardiovascular training with impressive improvements in aerobic capacity, it is difficult to differentiate between biologic aging and physical inactivity as the primary cause of the decline in aerobic capacity that occurs with age.

A sedentary lifestyle, or physical inactivity, impairs aerobic capacity and is considered a modifiable risk factor for cardiovascular disease (**Display 6-3**). Considering that more than 25.3% of the US adult population report engaging in no physical activity or exercise other than their regular job in the last 30 days, physical inactivity is more prevalent than the diseases discussed previously that cause impairment in aerobic capacity, and thus is a major public health concern.[1,42] On the positive side, as a modifiable risk factor, physical inactivity is mutable and can and should be addressed when identified during the examination of a patient.

DISPLAY 6-3

Risk Factors for Coronary Heart Disease

Major Risk Factors—Nonmodifiable

Increasing age
Male gender
Family history

Major Risk Factors—Modifiable

High blood cholesterol and triglyceride levels
High BP
Diabetes and prediabetes
Smoking
Overweight and obesity
Lack of physical activity
Unhealthy diet
Stress

US Department of Health & Human Services, National Institutes of Health, National Heart, Lung, and Blood Institute, What are coronary heart disease risk factors? Available at: http://www.nhlbi.nih.gov/health/health-topics/topics/hd#slide-2-field_video_items-924. Accessed September 25, 2015.

EXAMINATION/EVALUATION OF AEROBIC CAPACITY

With the exception of clients with cardiovascular and pulmonary diseases, most clients who are referred to physical therapy do not have as their primary diagnosis impaired aerobic capacity. Because aerobic capacity influences any exercise a client may perform as part of an intervention, and thus the outcomes that client will achieve, it is important that examination and evaluation of the cardiovascular and respiratory systems be included as a part of the examination and evaluation of all clients. The tests and measures described in this section are aimed at identifying the presence of disease, describing baseline aerobic capacity, and measuring change in aerobic capacity as a result of intervention(s). The clinician is assumed to have the knowledge and skill to perform the *basic* tests necessary to diagnose impairments and functional limitations in aerobic capacity; however, detailed information will be provided for the more *advanced* tests of aerobic capacity because many clinicians may not have experience performing these tests on a regular basis. Additional information may be obtained from the ACSM text[43] on exercise testing and prescription.

Patient/Client History

Specific portions of the general data generated from a patient/client history as defined in Chapter 2 are important to note when attempting to identify the presence of an impairment in aerobic capacity that either should be directly addressed in the intervention or may influence the clinician's ability to set and achieve goals related to other impairments. Knowledge of the risk factors for coronary heart disease provides a basis for collecting the most relevant information regarding impaired aerobic capacity. As shown in Display 6-3, general demographic information such as age, gender, and ethnicity is very important to consider. Social/health habits such as smoking, physical activity, and nutrition are important behaviors to inquire about during the history. Assessment of general health status in terms of general health perceptions, mental functions, and physical function can provide additional indication of limitations in cardiovascular endurance. Clinical tests of blood cholesterol are useful to identify clients at risk for coronary heart disease. Other factors that should be noted from the history include medical/surgical history, family history, social history, personality/behavior, pregnancy, and breast-feeding status, factors that may also modify the exercise prescription.[15,40] A review of systems, also part of the history, includes a review of major body systems (endocrine, gastrointestinal, genitourinary, hematologic, etc.) to determine if there are symptoms that require further medical evaluation.[40]

Medication history is of primary importance to review, especially for clients with documented cardiovascular and pulmonary disease, but also for those with risk factors for disease. Many cardiac and pulmonary system drugs affect aerobic capacity, and thus clients using these drugs should be carefully monitored during any intervention that affects the cardiovascular and pulmonary systems, including therapeutic exercise, functional training, airway clearance techniques, integumentary repair techniques, electrotherapeutic modalities, and physical agents and mechanical modalities.

Specific questions that should be posed during the patient/client history to identify the presence of cardiovascular and pulmonary disease and the relevant aspects of the client's overall status that may affect aerobic capacity as discussed above can be found in Goodman and Snyder's text[41] on differential diagnosis.

Systems Review

After, and based on, the patient/client history, a systems review is conducted as a brief or limited examination of the status of the other major body systems (integumentary, musculoskeletal, neuromuscular), and the communication ability, affect, cognition, language, and learning style of the patient.[40] The systems review helps to identify impairments in other areas that may affect the performance of an activity or task within the plan of care. Further, the systems review may identify potential problems that require referral to another provider.

Because the primary intervention used to address aerobic capacity impairments, therapeutic exercise, requires adequate musculoskeletal, neuromuscular, and integumentary function, it is especially important to perform a thorough systems review in clients with cardiovascular and pulmonary impairments. Failure to do so could result in prescribing an intervention that the patient either cannot perform or that compromises the safety of the patient. At a minimum, skin integrity, muscle strength, joint range of motion, balance, gait function, and assessment of the ability to make needs known should be assessed.

Screening Examination

Before the initiation of an exercise program, individuals should be assessed to ensure safety and minimize risks.[15] Preparticipation screening can be performed using a self-report questionnaire, such as the Physical Activity Readiness Questionnaire or PAR-Q[15,43] (see Appendix 3). Based on the answers to the seven questions on the PAR-Q, individuals between the ages of 15 and 69 can either appropriately participate in exercise or be referred to a physician for further evaluation before beginning an exercise program. All individuals who fall outside of the boundaries described should be referred to a physician for medical evaluation before participating in exercise training.

The ACSM[43] has created guidelines delineating who should be medically evaluated, including maximal or submaximal exercise testing, before participation in vigorous exercise (defined as intensity >60% VO_2 max). Those who do not require medical evaluation include those who meet the definition of low risk as per the ACSM Risk Stratification Categories (**Display 6-4**).[43]

For those meeting the criteria for moderate risk in Display 6-4, it is recommended that medical examination and exercise testing be performed prior to the initiation of vigorous exercise training. In addition, for those in the moderate risk category, it is recommended that medical supervision (a physician should be in proximity and readily available should there be an emergent need) occur for maximal exercise testing.

Finally, for those in the high-risk category, medical examination prior to moderate or vigorous exercise and medical supervision for maximal or submaximal exercise testing is recommended.

DISPLAY 6-4

ACSM Risk Stratification Categories for Atherosclerotic Cardiovascular Disease

Low risk = Asymptomatic men and women who have ≤1 CVD risk factor from **Display 6-5**

Moderate risk = Asymptomatic men and women who have ≥2 risk factors from Display 6-5

High risk = Individuals who have known cardiovascular, pulmonary, or metabolic disease or one or more signs and symptoms listed in **Display 6-6**

American College of Sports Medicine. ACSM's Guidelines for Exercise Testing and Prescription. 8th Ed. Baltimore, MD: Lippincott Williams & Wilkins, 2010.

DISPLAY 6-5

Atherosclerotic Cardiovascular Disease (CVD) Risk Factor Thresholds for Use with ACSM Risk Stratification

Positive Risk Factors and Defining Criteria

1. Age—men ≥ 45 years, women ≥ 55 years
2. Family history—myocardial infarction, coronary revascularization, or sudden death before 55 years of age in father or other male first-degree relative, or before 65 years of age in mother or other female first-degree relative
3. Cigarette smoking—current cigarette smoker or those who quit within the previous 6 months or exposure to environmental tobacco smoke
4. Sedentary lifestyle—not participating in at least 30 minutes of moderate intensity (40% to 60% VO_2) physical activity on at least 3 days of the week for at least 3 months
5. Obesity—BMI ≥ 30 kg per m^2 or waist girth >102 cm (40 inches) for men and >88 cm (35 inches) for women
6. Hypertension—SBP ≥ 140 mm Hg and/or DBP ≥ 90 mm Hg, confirmed by measurements on at least two separate occasions, or on antihypertensive medication
7. Dyslipidemia—low-density lipoprotein cholesterol (LDL-C) ≥130 mg per dL or high-density lipoprotein cholesterol (HDL-C) <40 mg per dL or on lipid-lowering medication. If total serum cholesterol is all that is available use ≥200 mg per dL
8. Prediabetes—impaired fasting glucose = fasting plasma glucose ≥100 mg per dL but <126 mg per dL or impaired glucose tolerance = 2-hour values in oral glucose tolerance test ≥140 mg per dL but <200 mg per dL confirmed by measurements on at least two separate occasions

Negative Risk Factor and Defining Criteria

1. High-serum HDL cholesterol ≥60 mg per dL

American College of Sports Medicine. ACSM's Guidelines for Exercise Testing and Prescription. 8th Ed. Baltimore, MD: Lippincott Williams & Wilkins, 2010.

Tests and Measures

The examination categories directly relevant for the client with aerobic capacity impairment include tests and measures of aerobic capacity/endurance, anthropometric characteristics, and circulation and environmental factors.[40] There are numerous tests and measures in each of these categories, and often the most difficult task for the clinician is selecting the most appropriate test. Tests and measures should be selected based on data collected from the history, systems review, and screening; the means the client has available for following through with a program of aerobic exercise; client goals; and the equipment and monitoring equipment available (see **Building Block 6-1**).

DISPLAY 6-6

Major Signs or Symptoms Suggestive of Cardiovascular, Pulmonary, or Metabolic Disease

Signs or Symptoms

- Pain, discomfort (or other anginal equivalent) in the chest, neck, jaw, arms, or other areas that may result from ischemia
- Shortness of breath at rest or with mild exertion
- Dizziness or syncope
- Orthopnea or paroxysmal nocturnal dyspnea
- Ankle edema
- Palpitations or tachycardia
- Intermittent claudication
- Known heart murmur
- Unusual fatigue or shortness of breath with usual activities

American College of Sports Medicine. ACSM's Guidelines for Exercise Testing and Prescription. 8th Ed. Baltimore, MD: Lippincott Williams & Wilkins, 2010.

BUILDING BLOCK 6-1

Patient/Client History and General Information

Susan is a 47-year-old nurse who consulted a physical therapist for primary complaints of posterolateral right (R) thigh pain. Past medical history was unremarkable. The pain was worse with weight-bearing first thing in the morning, got better with limited activity, but worsened by the end of the day—especially if she had been on her feet quite a bit during the day. Secondary complaints included intermittent, dull low back pain and occasional bouts of sharp pain in the arch of her R foot. She was diagnosed and treated by the physical therapist for iliotibial band fasciitis and intermittent plantar fasciitis. The short- and long-term goals set for her were aimed at decreasing disability and returning the patient to a pain-free level of functioning. Susan met the goals established with regular treatment and requested that the physical therapist assist her with establishing a regular physical activity habit.

Based on the information provided, does the patient/client require medical evaluation prior to participating in aerobic exercise?

Aerobic Capacity/Endurance

The development of an appropriate and useful exercise prescription for cardiorespiratory endurance depends on an accurate assessment of VO_2 max, which is most commonly achieved through the performance of a graded exercise test (GXT). Exercise tests can be maximal, in which an individual performs to his or her physiologic or symptom limit, or submaximal, in which an arbitrary stopping or limiting criterion is used.

Maximal Graded Exercise Tests The most important characteristics of a maximal GXT are that it has a variable or graded workload that increases gradually and that the total test time equal approximately 8 to 12 minutes.[43] In addition, individuals undergoing maximal GXT testing are usually electrocardiogram (ECG)-monitored. The direct measurement of VO_2 max requires the analysis of expired gases, which requires special equipment and personnel and is thus costly and time-consuming.[43] VO_2 max can be estimated from prediction equations after the individual exercises to the point of volitional fatigue, or it can be estimated from submaximal tests. For most clinicians, maximal exercise testing is not feasible because of the special equipment required and the ECG monitoring, although it is the most accurate test of aerobic capacity. Additionally, it is recommended that maximal GXT be reserved for research purposes, testing of diseased individuals, and athletic populations.[15] Thus submaximal testing is most commonly used, especially with low-risk, apparently healthy individuals, and will be further described in this section. Individuals who wish to conduct maximal GXT are referred to the ACSM Guidelines for Exercise Testing[43] or the ACSM Resource Manual[15] for more detailed information.

Submaximal Graded Exercise Tests Submaximal exercise tests can be used to estimate VO_2 max because of the linear relationship between HR and VO_2, and HR and workload.[15] That is, as workload or VO_2 increases, HR increases in a linear, predictable fashion. Therefore, the clinician can estimate VO_2 max by plotting HR against workload for at least two exercise workloads and extrapolating to age-predicted maximal HR (220 – age) to estimate VO_2 max (**Fig. 6-1**).[43] Submaximal exercise testing is based on several assumptions, as shown in **Display 6-7**. Failure to meet these assumptions fully, which is usually the case, results in errors in the prediction of VO_2 max. Therefore, submaximal testing typically results in less accurate VO_2 max estimations. However, submaximal tests are appropriately used to document change over time in response to aerobic training and, given the time and money saved, are very useful clinically.

The ACSM[43] provides recommendations for physician supervision during GXT. For those individuals at low risk (Displays 6-4 and 6-5), physician supervision is not deemed necessary during maximal or submaximal testing. Individuals at moderate risk who have two or more risk factors but no symptoms or disease can undergo submaximal testing without physician supervision. Physician supervision during maximal testing is recommended for those at moderate risk.[43] Physician supervision during submaximal and maximal testing is recommended for any individual with CAD or with symptoms of CAD. Therefore, submaximal testing can be performed safely by physical therapists with any age individual who is symptom or disease free, as defined by the ACSM.[43]

Numerous testing protocols have been published and are available for submaximal exercise testing.[43] Because of the requirement of reproducible workloads, treadmills, bicycle ergometers, and stepping protocols are most commonly used. Test selection should be based on safety concerns, familiarity with and knowledge of the testing protocol, equipment availability, and client/patient goals, abilities, and conditions (e.g., the presence of orthopedic limitations).

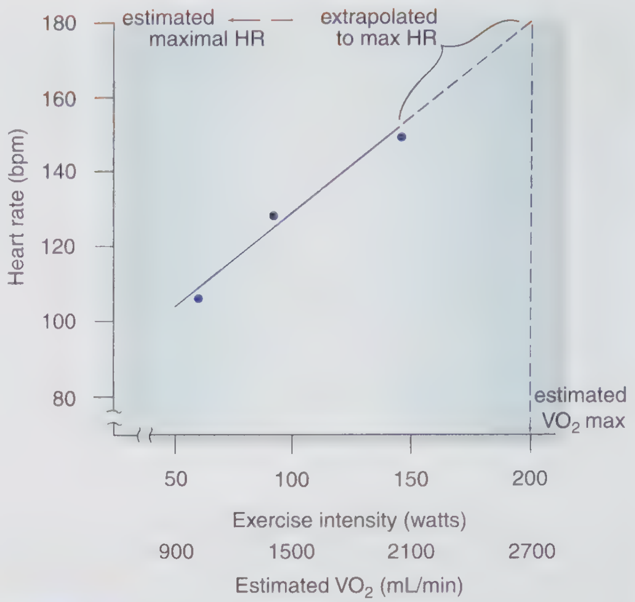


FIGURE 6-1 HR obtained from at least two (more are preferable) submaximal exercise intensities may be extrapolated to the age-predicted maximal HR. A vertical line to the intensity scale estimates maximal exercise intensity from which an estimated VO_2 max can be calculated. (From American College of Sports Medicine. ACSM's Guidelines for Exercise Testing and Prescription. 8th Ed. Philadelphia, PA: Lippincott Williams & Wilkins, 2010.)

DISPLAY 6-7
Assumptions for Submaximal Exercise Testing

- A steady-state HR is obtained for each exercise work rate and is consistent each day.
- A linear relationship exists between HR and work rate.
- The maximal workload is indicative of maximal VO_2.
- The maximal HR for a given age is uniform.
- Mechanical efficiency is the same for everyone (e.g., VO_2 at a given work rate).
- The subject is not on medications that alter HR.

Note: The most accurate estimate of VO_2 max is achieved if all of the preceding assumptions are met.

American College of Sports Medicine. ACSM's Guidelines for Exercise Testing and Prescription. 8th Ed. Baltimore, MD: Lippincott Williams & Wilkins, 2010:73–74.

Bicycle Ergometer Tests Two common bicycle ergometer tests are the YMCA protocol and the Astrand–Rhyming test.[43] In the YMCA protocol, the client performs two to four, 3-minute stages of continuous cycling, designed to elevate the HR to between 110 and 150 bpm during two consecutive stages. The client begins cycling at 50 revolutions per minute (rpm) at a resistance of 150 kg per minute or 0.5 kg and progresses to greater resistance in subsequent stages based on HR recorded during the last minute of the first stage according to **Table 6-2**.

TABLE 6-2

YMCA Submaximal Bicycle Ergometer Test Protocol—Workload Settings

	HR < 80	HR 80–89	HR 90–100	HR > 100
Second Stage	750 kg/min	600 kg/min	450 kg/min	300 kg/min
	(2.5 kg)	(2.0 kg)	(1.5 kg)	(1.0 kg)
	(125 W)	(100 W)	(75 W)	(50 W)
Third Stage	900 kg/min	750 kg/min	600 kg/min	450 kg/min
	(3.0 kg)	(2.5 kg)	(2.0 kg)	(1.5 kg)
	(150 W)	(125 W)	(100 W)	(75 W)
Fourth Stage	1050 kg/min	900 kg/min	750 kg/min	600 kg/min
	(3.5 kg)	(3.0 kg)	(2.5 kg)	(2.0 kg)
	(175 W)	(150 W)	(125 W)	(100 W)

Resistance settings shown apply to ergometers with a 6 m/revolution flywheel.

For example, if HR = 85 at the end of the first stage, the second stage workload would be 600 kg per minute and the third stage workload would be 750 kg per minute.

The test is terminated when two consecutive stages yield a HR reading between 110 and 150 bpm. The two HR measures and corresponding workloads are plotted on a graph, and the line generated from the plotted points is extended to the age-predicted maximal HR and an estimation of VO_2 max is obtained.[43]

The Astrand–Rhyming test involves a single 6-minute stage, with workload based on sex and activity status:

- unconditioned females, 300 or 450 kg per minute (50 or 75 W)
- conditioned females, 450 or 600 kg per minute (75 or 100 W)
- unconditioned males, 300 or 600 kg per minute (50 or 100 W)
- conditioned males, 600 or 900 kg per minute (100 or 150 W)

Individuals pedal at 50 rpm and HR is measured during the fifth and sixth minutes. The two HR measures must be within 5 beats of one another and the HR between 130 and 170 bpm for the test to be completed. If the HR is <130 bpm, the resistance should be increased by 50 to 100 W and the test continued for another 6 minutes. The test may be terminated when the HR in the fifth and sixth minute differs by no more than 5 beats and is between 130 and 170 bpm. An average of the HRs is calculated and a nomogram is used to estimate VO_2 max (**Fig. 6-2**).[43] The value determined from the nomogram is corrected for age by multiplication of a correction factor (**Table 6-3**).

Treadmill Tests Submaximal treadmill tests are also used to estimate VO_2 max (**Table 6-4**). A single-stage submaximal treadmill test has been developed for assessing VO_2 max in low-risk individuals.[44] It involves beginning with a comfortable walking pace between 2.0 and 4.5 mph at 0% grade for a 2- to 4-minute warm-up, designed to increase HR to within 50% to 75% of age-predicted (220 – age) maximum HR, followed by 4 minutes at 5% grade at the same self-selected walking speed. HR is measured at the end of the 4-minute stage and VO_2 max is estimated using the following equation:

$$VO_2 \text{ max (mL/kg/min)} = 15.1 + 21.8 \times \text{speed (mph)} - 0.327 \times \text{HR (bpm)} - 0.263 \times \text{speed} \times \text{age (years)} + 0.00504 \times \text{HR} \times \text{age} + 5.98 \times \text{sex } (0 = \text{F}, 1 = \text{M})$$

Step Tests Step tests were developed based on a need to test large numbers of individuals expeditiously and represent another mode of submaximal exercise testing. Several protocols have been developed,[45] but only one will be presented. The Queens College Step Test requires a 16.25-inch step (similar to the height of a bleacher step).[45,46] Individuals step up and down to a 4-count rhythm (on Count 1 subject places one foot on step, on Count 2 subject places the other foot on the step, on Count 3 the first foot is brought back to the ground, on Count 4 the second foot is brought down). A metronome is useful to maintain the prescribed stepping beat. Females step for 3 minutes at a rate of 22 steps per minute, whereas males step at a rate of 24 steps per minute. At the end of the 3 minutes, a recovery 15-second pulse is measured, starting at 5 seconds into recovery while the individual remains standing. The pulse rate is attained and is converted to bpm by multiplying by 4. This value is termed the recovery HR. The following equations are used to estimate VO_2 max:

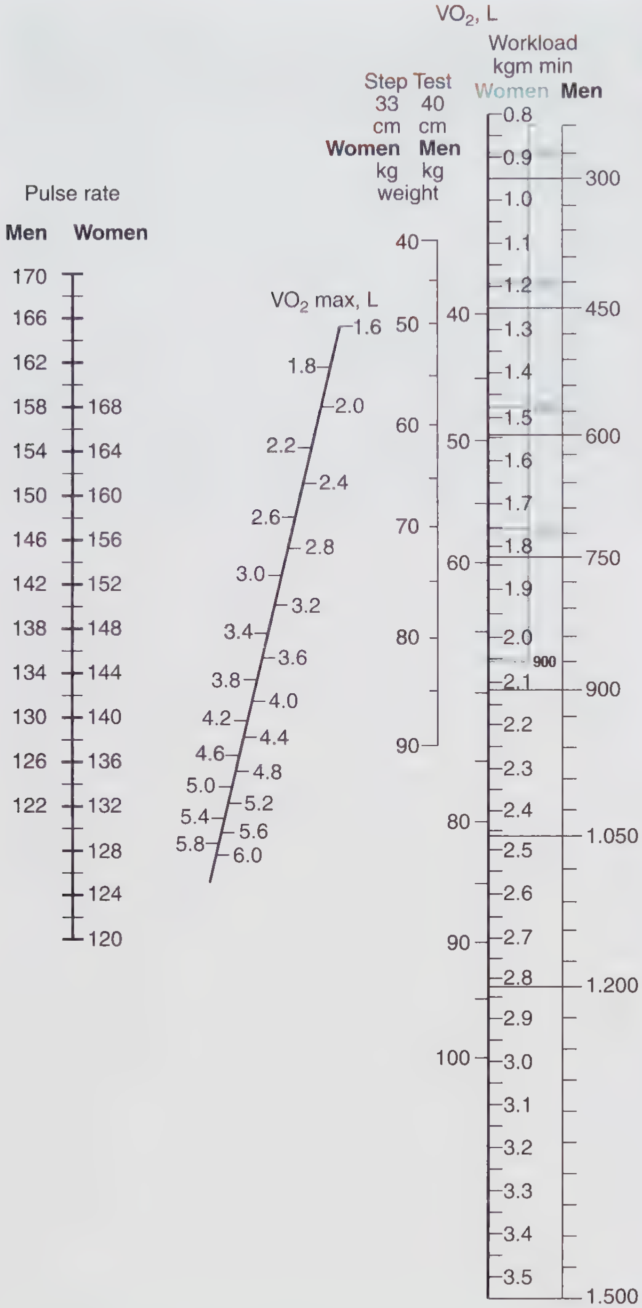
$$\text{Females: } VO_2 \text{ max (mL/kg/min)} = 65.81 - (0.1847 \times \text{recovery HR [bpm]})$$

$$\text{Males: } VO_2 \text{ max (mL/kg/min)} = 111.33 - (0.42 \times \text{recovery HR [bpm]})$$

Field Tests Field tests refer to exercise testing protocols derived from events performed outside, or in the "field." They are also submaximal tests and, as with the step test, are more practical for testing large groups of people, appropriate when time or equipment is limited, and when assessing individuals older than age 40.[45] A variety of field tests exist[45]; the Cooper 12-minute test and the 1-mile walk test will be discussed. In the Cooper 12-minute test, individuals are instructed to cover the most distance possible in 12 minutes, preferably by running, although walking is acceptable. The distance covered in the 12 minutes is recorded and VO_2 max estimated according to the following equation[45]:

$$VO_2 \text{ max (mL/kg/min)} = 35.97 \text{ (mile)} - \text{s } 11.29$$

A 1-mile walk test is another option in the field test category.[47] Individuals walk 1 mile as fast as possible without running and



Males: VO_2, max (mL/kg/min) = 111.3 – (0.42 × recovery HR [bpm])

FIGURE 6-2 The Astrand–Rhyming nomogram. A nomogram used to calculate aerobic capacity (VO_2 max) from pulse rate during submaximal work. The clinician must know the pulse rate, sex, and workload from the bicycle ergometer test performed on the client to determine absolute VO_2 max. VO_2 max values obtained from the nomogram should be adjusted for age by a correction factor (Table 6-3). (Reprinted from Astrand PO, Rhyming I. A nomogram for calculation of aerobic capacity [physical fitness] from pulse rate during submaximal work. J Appl Physiol 1954;7:218–221, with permission.)

TABLE 6-3

Correction Factor for Age for Astrand–Rhyming Nomogram

AGE	CORRECTION FACTOR
15	1.10
25	1.00
35	0.87
40	0.83
45	0.78
50	0.75
55	0.71
60	0.68
65	0.65

From p. 223 Bandy and Sanders, which was reprinted from American College of Sports Medicine, Guidelines for Exercise Testing and Prescription, 7th Ed. Baltimore, MD: Lippincott Williams & Wilkins, 2006:72.

the average HR for the last two complete minutes of the walk is recorded. A HR monitor is necessary to record and average the HR over the last 2 minutes. If a HR monitor is not available, a 15-second pulse can be measured immediately on test completion. VO_2 max is estimated from the following equation[47]:

$$VO_2 \text{ max (mL/kg/min)} = 132.85 - 0.077 \times \text{body weight (lb)} - 0.39 \times \text{age (years)} + 6.32 \times \text{sex } (0 = F, 1 = M) - 3.26 \times \text{elapsed time (min)} - 0.16 \times \text{HR (bpm)}$$

All clients should be closely monitored during exercise test performance. Vital signs should be assessed before, during each stage or workload of the test, and after the test for 4 to 8 minutes of recovery.[15] In addition, the rating of perceived exertion (RPE) is commonly used to monitor exercise tolerance.[48] RPE refers to the "degree of heaviness and strain experienced in physical work as estimated according to a specific rating method"[48(p.9)] and is an indicator of overall perceived exertion. The Borg RPE scale and instructions for use are shown in **Figure 6-3**.

Anthropometric Characteristics

Body composition is important to assess in individuals partaking in an aerobic exercise program because of the changes experienced in fat mass as a result of chronic training discussed earlier in this chapter. In addition, body composition is an important examination tool in the presence of obesity and is considered superior to simple measures of height and weight. The gold standard measure of body composition is hydrostatic or underwater weighing that requires specialized equipment and the patient to tolerate total body immersion. Because of these limitations, several reliable measures of body composition estimation have been developed and are used widely, including body mass index (BMI), bioelectric impedance, near-infrared interactance, skinfold measurements, and waist-to-hip ratio. Bioelectric impedance, near-infrared interactance, and skinfold measurements require specialized equipment and, in the case of skinfold measurements, specialized training; whereas the

TABLE 6-4

Submaximal Treadmill Exercise Test Results

STAGE	TREADMILL SETTINGS	DURATION	HEART RATE	BLOOD PRESSURE	SIGNS AND SYMPTOMS
Rest	N/A	N/A	85	132/86	None
Warm-up	3.0 mph 0% grade	3 min 15 s	102	140/84	None
Main	3.0 mph 5% grade	4 min	135	145/80	None
Cooldown	2.0 mph 0% grade	4 min	90	130/80	None

RATING	DESCRIPTION
6	None at all
7	Extremely light
8	
9	Light
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard (heavy)
16	
17	Very hard
18	
19	Extremely hard
20	Maximal

FIGURE 6-3 The rating of perceived exertion scale. (From Bezner J. Principles of aerobic conditioning. In: Bandy WD, Sanders B, eds. Therapeutic Exercise. Techniques for Intervention. Baltimore, MD: Lippincott Williams & Wilkins, 2001. Data from American College of Sports Medicine. The recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness in healthy adults. Med Sci Sports Exerc 1990;22:265–274.)

BMI and waist-to-hip ratio can be measured using height, weight, and circumferential measurements. The clinician is referred to the ACSM's Guidelines for Exercise Testing and Prescription[43] for additional information about performing these tests (see **Building Blocks 6-2** to **6-6**).

BUILDING BLOCK 6-2

When answering this question, consider the case presented in Building Block 6-1:

How would you screen this patient/client prior to proceeding with an exercise program?

BUILDING BLOCK 6-3

When answering this question, consider the case presented in Building Block 6-1:

How would you approach establishing an exercise prescription for this patient/client?

BUILDING BLOCK 6-4

When answering this question, consider the case presented in Building Block 6-1:

What exercise test would you utilize with this patient/client?

BUILDING BLOCK 6-5

When answering this question, consider the case presented in Building Block 6-1:

How would you conduct the exercise test?

BUILDING BLOCK 6-6

When answering this question, consider the case presented in Building Block 6-1:

What is the patient/client's VO_2 max?

Circulation

Assessment of BP; HR, rhythm, and sounds; and RR, rhythm, and pattern is important to establish a baseline and to determine impairments. In addition, these measures can be assessed over time to determine the effect of aerobic training on the cardiovascular and pulmonary systems and to document improvement.

Environmental Factors

Because environmental factors may be barriers and facilitators of participation in aerobic exercise programs, it is important to examine the physical, social, and attitudinal environment impacting the patient.[40] For example, if the physical therapist prescribes an appropriate exercise to address an aerobic capacity impairment, yet the patient does not have access to a safe place to perform the exercise, the exercise prescription is rendered useless and the patient will not benefit. Ecologic models of health support that environmental factors are the most important to address in health behaviors such as physical activity and exercise; thus, they are very important for the physical therapist to assess prior to intervention.[49] This category of examination includes access to safe places to exercise and appropriate equipment; the presence of emergency procedures and plans; and the ability to participate in self-care, domestic life, work life, and community life.[40]

THERAPEUTIC EXERCISE INTERVENTION

Impaired aerobic capacity/endurance involves the support element of the movement system, and as such is the underlying impairment for numerous functional limitations and disabilities and is thus a priority to address with the intervention plan. A wide variety of aerobic endurance activities exist and are the most efficient techniques to achieve the goal of improved aerobic capacity. The modes and dosage specifics used when establishing an aerobic endurance exercise prescription will be presented. A primary objective of the exercise prescription is to assist in the adoption of regular physical activity as a lifestyle habit and thus should take into consideration the behavioral characteristics, personal goals, and exercise preferences of the individual.[43] Given the critical epidemic of obesity and physical inactivity in the United States and the strength of the association between regular physical activity and reduction in mortality and morbidity, physical therapists should ensure that they include exercise testing and exercise prescription with all patients/clients with whom they interact.[1]

Mode

Several modes of cardiovascular endurance training are available. Any activity that uses large muscle groups and is repetitive is capable of producing the desired changes. Such activities include walking, jogging, cross-country skiing, bicycling, rope jumping, rowing, swimming, or aerobic dance (see **Selected Intervention 6-1**). Although lap swimming is the most common aquatic cardiovascular exercise, water jogging, cross-country skiing, and water aerobics are also effective aquatic training methods. An upper body ergometer is a good cardiovascular training tool and is especially well suited for individuals unable to use their legs (see **Fig. 6-4**).

The choice of exercise mode depends on the patient's goals, likes, and specific physical condition. Performing an activity that is convenient, comfortable, and enjoyable increases the likelihood of adherence. The amount of impact is also an important consideration when choosing the exercise mode. For the individual with lower extremity degenerative joint disease or the overweight individual, impact activities should

SELECTED INTERVENTION 6-1

Elliptical

Refer to Case Study No. 10

Although this patient requires comprehensive intervention, only one exercise is described:

ACTIVITY: Elliptical

PURPOSE: To increase cardiovascular endurance and musculoskeletal muscle endurance of quadriceps, gluteals, hamstrings, calf, trunk, and upper extremity muscle groups

SUBSYSTEMS OF THE MOVEMENT SYSTEM: Passive, support

STAGE OF MOTOR CONTROL: Skill

POSTURE: Shoulders should be back, head up and slightly forward, chin up level and abdominals tight. Look forward, not down at your feet. Do not grip the handrails too tightly. Or "maintain a light grip on the handrails." Make sure that your weight is evenly distributed and that your lower body supports the majority of your weight.

MOVEMENT: Alternate hip flexion and extension in a walking pattern. Transfer weight completely from leg to leg during the activity, rather than shuffling or sliding the feet while bearing weight bilaterally. Move your arms in an alternate fashion with the legs (range of motion may be limited by individual needs).

SPECIAL CONSIDERATIONS: (a) All precautions to cardiovascular endurance exercise must be considered. (b) Individuals with balance and coordination difficulty should be assessed for ability to perform the activity safely.

DOSAGE: Ten minutes, adding 5 minutes every three sessions

RATIONALE FOR EXERCISE CHOICE: The elliptical is a total body exercise. Aerobic conditioning can be achieved, along with shoulder, trunk, hip, and leg extensor muscle endurance training.

EXERCISE GRADATION: This exercise can be progressed by increasing the frequency, intensity, or duration of activity.

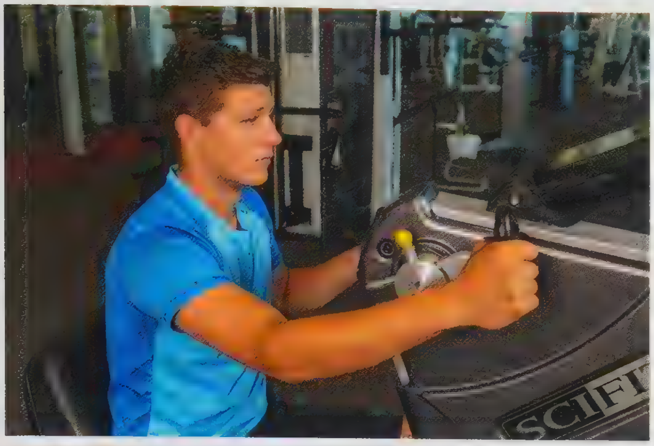


FIGURE 6-4 Upper body ergometer. An upper body ergometer is an exercise mode that provides an aerobic exercise alternative for those with significant lower extremity impairments or to provide variety in an exercise prescription. Because the smaller upper extremity muscles perform the exercise, lower HRs are experienced. In addition, it is difficult to monitor vital signs during activity. The seat on the device should be adjusted to allow slight elbow flexion in the outstretched position of the arm while the back maintains contact with the seat, and the seat height position should ensure that the shoulder is even with the axis of the crank arm.

be minimized. The pool is a better choice for those who need to minimize weight-bearing or impact. Weight-bearing can be completely negated by exercising in the deep end of the pool. For those desiring to return to impact activities, gradual impact progression can prepare the body for the demands of this type of loading (see **Patient-Related Instruction 6-1**).

Variety and cross-training in the cardiovascular endurance program are imperative. Alternating modes of activity can alleviate boredom and prevent overuse injuries resulting from repetitive activity. Individuals who have such low muscular endurance that they are incapable of performing the same repetitive activity for more than a few minutes can alternate activities within the training session and among sessions. Whereas one individual may bicycle 2 days per week, swim 2 days, and walk 2 days, another may bike, walk, and stair step for 10 minutes each daily.

Within one mode of exercise, several postures or equipment types are available. For example, during bicycling, the trunk posture selected depends on the goals. Bicycling may be performed on a recumbent bike (**Fig. 6-5A**), with the hips flexed 90 degrees or more and the low back supported, or it may be performed in an upright position with the arms moving (Fig. 6-5B), or in a forward-leaning position (Fig. 6-5C). The optimal posture for maximal exercise benefit should be emphasized (see **Patient-Related Instruction 6-2**).

Dosage

Type

The training session itself may be performed using a variety of training techniques, from continuous activity to interval training. Continuous training relies on the aerobic energy system to supply energy for the exercise session and can be carried out for prolonged periods (see website for review of energy systems). The individual exercises continuously, without rest, at a steady exercise rate. Although continuous in nature, several different activities can be combined within the same session, such as treadmill and bicycle or swimming and deep-water running.

Interval training incorporates rest sessions between bouts of exercise. This technique is useful for clients who are unable to maintain continuous exercise for the optimal length of time (e.g., 30 minutes) and for those recuperating from an orthopedic injury or who are deconditioned. When prescribing interval training, the ratio of the rest period to the training period determines the activity intensity and the energy system used. The aerobic energy system is used to a greater extent with longer training intervals and shorter rest periods. For example, performance of three bouts (intervals) of activity at an intensity of 50% of VO_2 max or greater for 10 minutes with a 2-minute rest period in between each bout would use the aerobic energy system.

The rest periods can be true rest (i.e., no activity) or a work-relief interval, during which light activity such as walking may be performed. High-intensity activity usually is combined with longer complete-rest intervals, and low to medium intensities are combined with shorter rest intervals or work-relief intervals. For example, a training session might include a set of ten 100-m sprints, in which each sprint may take only 10 to 20

Patient-Related Instruction 6-1

Return to Impact Activity

Any return to impact activities such as jogging, impact aerobics, or sports requiring running or jumping should be preceded by impact progression. This approach ensures readiness to return to the activity and decreases the likelihood of setback. Prerequisites for impact progression include the following:

1. Adequate muscle strength and endurance
2. Full range of motion in the joints
3. No swelling

A suggested progression is as follows:

1. Two-footed hopping
2. Alternate-footed hopping
3. Single-footed hopping (optional)
4. Skill drills (optional)

This progression should be implemented as follows:

1. Begin on a low-impact surface (e.g., pool, mini-tramp, shock-absorptive floor).
2. Subsequently progress to the terrain you will be using.
3. Begin with 5 minutes, and increase by 2- to 5-minute increments when you are able to complete three consecutive sessions without pain, swelling, or technique compromise.
4. Return to your full activity is determined by the criteria set by your clinician. Remember that returning to activity is different from performing sport drills. During practice drills, mental attention is often given to awareness and protection of a recovering injury. When returning to the game, the majority of mental attention is given to the game. Therefore, practicing skills while mentally engaging in that sport activity is an important component of return to sport.

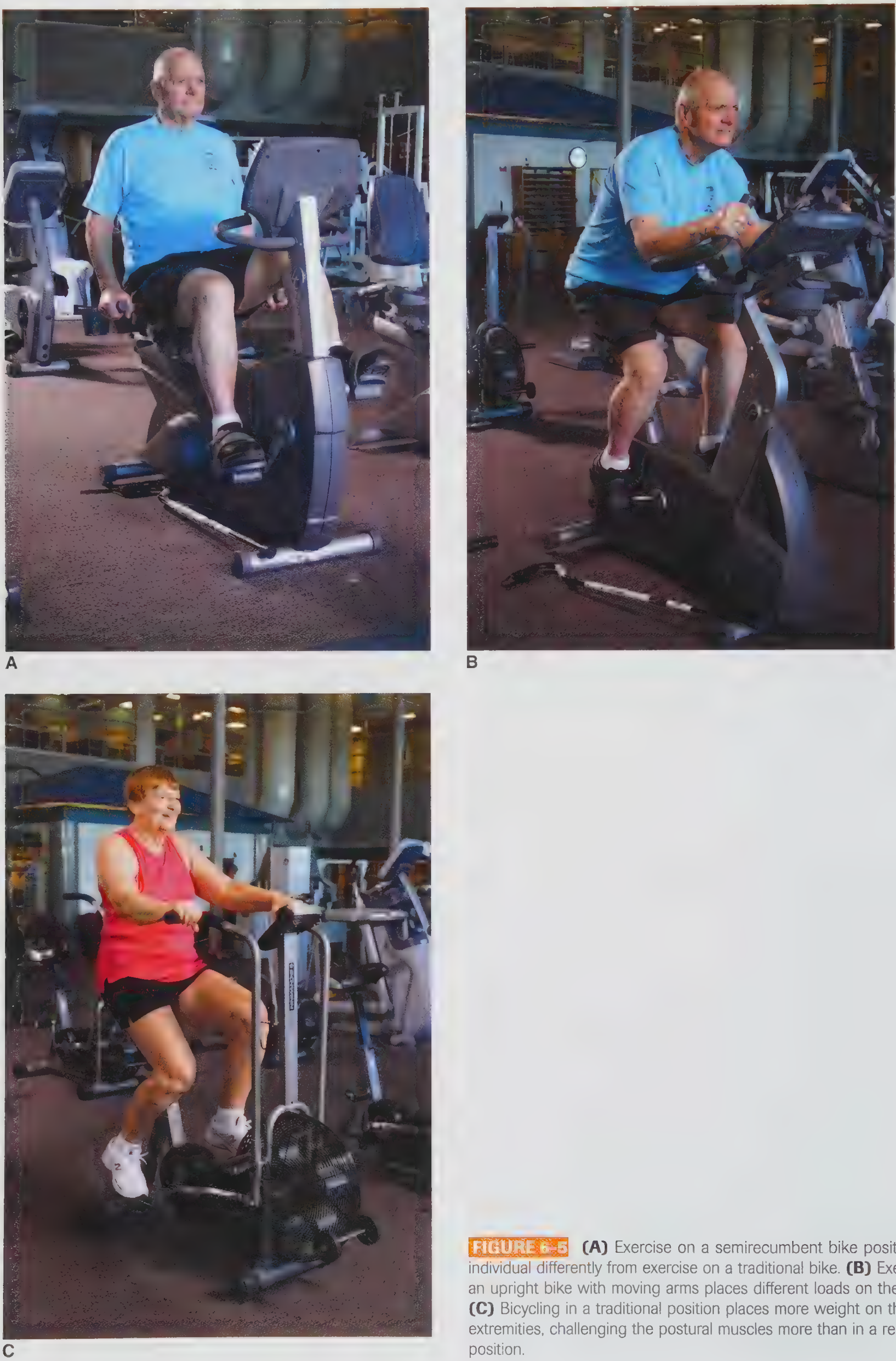


FIGURE 6-5 **(A)** Exercise on a semirecumbent bike positions the individual differently from exercise on a traditional bike. **(B)** Exercise on an upright bike with moving arms places different loads on the patient. **(C)** Bicycling in a traditional position places more weight on the upper extremities, challenging the postural muscles more than in a recumbent position.

Patient-Related Instruction 6-2

Bicycling Guidelines

The following guidelines will keep your bicycling experience healthy and safe:

1. Seat height: The seat should be set so that your knee is slightly bent in the down-most position. If you place your heel on the pedal in the down position, your knee should be perfectly straight. When you place the ball of your foot on the pedal, your knee should be bent at the correct angle (15 to 20 degrees of knee flexion with the ankle in 90 degrees of dorsiflexion).
2. Cadence: Your pedal cadence should be high, at least 60 rpm or more. Your clinician may have other recommendations, depending on your specific situation.
3. Resistance: The resistance should be low enough to allow a higher cadence. Resistance too high can place extra stress on the knee. Keeping the resistance low and the cadence high produces the desired benefits without hurting your knees.
4. Safety: If riding outside, always wear a helmet, and obey your local bicycle laws.

seconds to complete, with a 10-minute complete-rest interval between each sprint. Because high-intensity exercise of short duration uses the ATP-PCr and glycolysis systems for the provision of ATP, a longer rest period is required to allow muscle energy stores to be replenished (see Physiology Information on website). Less intense exercise, concomitantly, relying on the aerobic oxidative pathway, can be performed adequately from an energy availability standpoint for longer periods of time with shorter rest intervals that may consist of complete-rest or work-relief intervals.

Circuit training can be continuous or interval. Circuit training is a training technique in which the individual rotates through a series of exercise stations. A variety of upper extremity, lower extremity, core, and cardiovascular training exercises typically are included. The individual performs the activity at each station for a specified time (i.e., 30 seconds) and then moves on to the next station. The activity choices, activity intensity, and rest between stations determine the energy system used and whether the activity is interval or continuous. This type of training provides the opportunity for a well-balanced exercise program with variety. Multiple individuals can be trained simultaneously if there are adequate stations (see **Patient-Related Instruction 6-3**).

Patient-Related Instruction 6-3

Setting Up a Circuit

Your regular exercise routine can be enhanced and made more enjoyable by breaking up a continuous activity with stations of alternative activities. A circuit can be created outside along a normal walking or running route, or at your indoor exercise location. For example, a walking or jogging program through the neighborhood or on the treadmill can be broken up with the following activities performed at certain intervals throughout the session:

1. Calf raises
2. Abdominal curls or trunk plank
3. Push-ups
4. Squats
5. Dips
6. Lunge walks
7. Quadriceps, hamstring, and calf stretches

Sequence

Cardiovascular endurance training may be performed as part of a comprehensive rehabilitation program that includes mobility, stretching, and strengthening activities. General warm-up activities should be performed initially, followed by the cardiovascular training session and a cooldown including stretching. The warm-up period should last 5 to 10 minutes to prepare the body for exercise. Large muscle group activity such as walking, calisthenics, or bicycling should be performed with gradually increasing intensity. The warm-up session may be a lower-intensity version of the cardiovascular training activity. Walking at a slower speed for 5 minutes may be used as a warm-up activity for faster walking or jogging. The warm-up activities increase muscle blood flow, muscle temperature, and neural conduction. These changes, along with mental preparedness, can decrease the risk of muscle injury during exercise. After the warm-up, the more vigorous cardiovascular endurance session should be performed.

The exercise session should be concluded with a cool-down period of 5 to 10 minutes to allow redistribution of blood flow that has changed with exercise, including prevention of lower extremity pooling of blood by enhancing venous return to the heart. Active muscle contraction by continued walking, cycling, or low-level calisthenics assists with blood flow redistribution. Stretching should conclude the session to ensure maintenance of the working muscle's optimal length, which is more effective when performed once the muscles and joints are warm.

Frequency

The frequency of cardiovascular training should be determined through consideration of the patient/client's goals, the intensity and duration of exercise, and the patient/client's baseline fitness level. The optimal frequency to achieve fitness-related benefits for most individuals is three to five times per week,[1,43] with those initiating a program beginning at three to four times per week and progressing to five. The optimal frequency to attain health-related benefits is 3 days per week of moderate-intensity activity, although all 150 minutes could be achieved in 1 day.[1] Spreading activity out over several days per week reduces the risk of injury and prevents excessive fatigue.[1] The minimum amount of time that is thought to provide health-related benefits is 10 minutes of continuous activity.[1] The overload principle in terms of the interaction among intensity, duration, and frequency is important to consider when prescribing exercise. Individuals with very low functional capacities can perform daily or twice-daily exercise because the total amount of exercise, considering intensity, duration, and frequency, is low.[43] In a highly trained individual, exercise at a greater frequency may be necessary to produce overload, depending on the exercise intensity.

Intensity

As with frequency and duration, setting the intensity of exercise should be based on the overload principle and consideration should be given to the functional limitations, goals, and fitness level of the individual. Exercise intensity indicates how much exercise should be performed or how hard one must exercise and is typically prescribed on the basis of HR max, HR reserve, VO_2 max, RPE, or METs (metabolic equivalents). Prescribing exercise intensity using HR is considered the preferred method because of the correlation between HR and the stress on the heart and because it is readily accessible for monitoring during exercise.[12] Several methods involving HR can be used.

When prescribing exercise as a percentage of maximum HR, either directly measured or on the basis of age-predicted maximum HR, the training range should be between 55% and 65% to 90% of HR max.[43] A second method involves the use of the HR reserve or Karvonen formula:

$$\text{Target HR range} = ([HR_{max} - HR_{rest}] \times 0.60 \text{ and } 0.80) + HR_{rest}$$ [43]

To obtain a HR range, two intensity levels are calculated in the formula, one equivalent to 0.60 of VO_2 max and one equivalent to 0.80 of VO_2 max. If exercise is prescribed using VO_2 max, 55% to 75% is also used as a training range and VO_2 max should be stated in relative terms (mL/kg/min), which accounts for the individual's body weight. The RPE can also be used to prescribe exercise intensity, within the range of 12 to 16 on the RPE scale shown in Figure 6-3. RPE is especially useful for prescribing intensity for individuals who are unable to palpate pulse or when HR is altered because of the influence of medication and should be considered an adjunct to monitoring HR in all other individuals.[43]

METs may also be used to prescribe activity intensity. METs are used to estimate the metabolic cost of physical activity relative to the resting state. One MET is equal to 3.5 mL of oxygen consumed per kilogram of body weight per minute (mL/kg/min).[43] Therefore, when VO_2 is known, the intensity can be prescribed in METs by dividing relative VO_2 by 3.5 mL/kg/min. In general, walking at 2 mph is the equivalent of approximately 2.0 METs, and walking at 4 mph is the equivalent of approximately 4.6 METs.

Selection of an appropriate training range versus a specific training value has been recommended to provide greater flexibility in the exercise prescription, yet ensure that a training response will be achieved.[12] For example, an individual who is starting an exercise program might be given a target HR range between 60% and 70% of HR max instead of being told to keep target HR at a value equivalent to 60% of HR max.

Intensities between 70% and 85% HR max or 60% and 80% HR reserve are recommended for most people to experience improvements in cardiorespiratory endurance.[43] Health-related benefits can be realized at lower intensities, and thus lower intensities may be appropriate if the goal of exercise is to improve health rather than fitness.[1] The 2008 Physical Activity Guidelines support adults, including older adults, children, and adolescents performing moderately intense aerobic activity 150 minutes per week or vigorous activity 75 minutes per week. These guidelines can be applied without the need to measure HR when patients/clients are safe to perform activity without specific cardiovascular monitoring.[1] Suggestions for prescribing physical activity for health-related benefits can be found in the Duration section.

In the pool, HR is decreased when exercising while immersed to the neck because of the Starling reflex and is therefore a poor gauge of workload. The HR of deep-water exercise is 17 to 20 bpm less than that of the comparable land-based activity.[50]

Increase exercise intensity by adding resistance, increasing speed, changing terrain (e.g., uphills), removing stabilization, or adding upper extremity activity. The method for increasing intensity is goal specific and may be limited by other medical or physical conditions (e.g., rotator cuff tendinitis limiting the use of upper extremities). The intensity necessary to achieve a workload in the target training zone varies among individuals and usually correlates with the previously determined conditioning level.

Duration

Exercise duration can be manipulated to produce overload and a resultant cardiovascular training effect. Duration depends on the frequency, intensity, and the conditioning level of the patient. In general, exercise of greater intensity is performed for a shorter duration and exercise of lower intensity can be performed for a longer duration. Manipulation of these variables is goal dependent. If the patient is required to perform an activity for a longer duration (i.e., continuous walking as part of a job or recreation), progression of the activity program should focus more on increasing the duration and less on increasing the intensity.

The optimal duration recommended for aerobic training is between 20 and 30 minutes per session of exercise.[43] For individuals who are unable to perform 20 minutes of continuous exercise, discontinuous exercise can be prescribed. That is, several 10-minute bouts can be performed, for example, until eventually exercise can be tolerated for 20 to 30 minutes continually. Duration can be progressed up to 60 minutes of continual activity.[43] The same activity or different activities may be performed in each of these sessions (see **Patient-Related Instruction 6-4**).

Patient-Related Instruction 6-4

Frequency, Intensity, and Duration

Determining how often (frequency), how hard (intensity), and how long (duration) to exercise can be difficult. These parameters are related and must be balanced to find the right quantity of exercise for you. The following broad guidelines can be refined by your clinician:

1. Frequency: Generally, if you exercise more frequently (more times per day or days per week), the intensity and duration of those sessions should be lower. This recommendation allows adequate recovery before the next session. If the intensity and duration are high, you may not be fully recovered before the next session.
2. Intensity: The more intense the exercise, the shorter is the duration. Intense exercise cannot be sustained very long by most people.
3. Duration: Exercise that is lower in intensity can be sustained for longer periods. For example, sprinting can be sustained for seconds, but jogging can be sustained for up to several hours. The intensity and duration are inversely related; as one increases, the other must decrease.

Prescribing duration for a patient/client desiring health-related benefits should follow the 2008 Physical Activity Guidelines, aiming for 150 minutes of moderate aerobic activity per week or 75 minutes of vigorous activity.[1] Moderate activities like walking, bicycling under 10 mph, housework, and yard work can be performed for as little as 10 minutes at a time to count toward the 150-minute minimum. Collaborating with the patient/client to identify opportunities during the day and week to consistently be active can promote performance of physical activity and assist in meeting the 150-minute goal.[1]

PRECAUTIONS AND CONTRAINDICATIONS

In addition to the signs and symptoms of exercise intolerance described in the physiology of aerobic capacity and endurance section and Display 6-1, clinicians should be aware of the risks associated with exercise, as well as monitoring and supervision guidelines. The incidence of cardiovascular complications during exercise has been documented to be extremely low for individuals without significant cardiac disease, yet is higher for the most sedentary individuals when they perform unaccustomed or infrequent exercise.[43] For persons with cardiovascular disease, the incidence of cardiovascular complications during exercise is considerably greater; however, the overall absolute risk of cardiovascular complications during exercise is low when considered in light of the health benefits associated with chronic exercise (see **Building Blocks 6-7** and **6-8**).

BUILDING BLOCK 6-7

When answering this question, consider the case presented in Building Block 6-1:

How would you create an exercise prescription for the patient/client?

BUILDING BLOCK 6-8

When answering this question, consider the case presented in Building Block 6-1:

What normal cardiovascular changes would you expect during exercise?

In addition to understanding and following the risk stratification recommendations for supervision of exercise and exercise testing, the wise clinician will ensure that exercise prescriptions for sedentary individuals and those unaccustomed to exercise will start at lower intensities and progress at a slower rate. Patients should be educated about the signs and symptoms of exercise intolerance and to seek immediate assistance when these signs or symptoms occur. Clinicians who supervise patients engaging in vigorous exercise should have current training in cardiac life support and emergency procedures.

Endurance exercise places a significant load on the cardiovascular and musculoskeletal systems. Consideration should be given to any injury or disease affecting either of these systems. Individuals with degenerative joint disease should be encouraged to participate in non–weight-bearing exercises such as bicycling and water exercise, and those with low back pain should participate in activities that support or safely strengthen the back (e.g., semirecumbent biking, water activities). Individuals with osteoporosis should be encouraged to participate in weight-bearing activities. Positions and postures should be chosen that minimize the risk of fracture.

Graded Exercise Testing Contraindications and Supervision Guidelines

There are numerous contraindications to exercise testing, and guidelines for supervision of GXTs. **Display 6-8** lists the absolute and relative contraindications to exercise testing. The relative contraindications should be considered in light of the potential benefits of exercise and a less vigorous prescription created for individuals in this category.

DISPLAY 6-8

Contraindications to Exercise Testing

Absolute

- A recent significant change in the resting ECG suggesting significant ischemia, recent myocardial infarction (within 2 days), or other acute cardiac event
- Unstable angina
- Uncontrolled cardiac arrhythmias causing symptoms or hemodynamic compromise
- Severe symptomatic aortic stenosis
- Uncontrolled symptomatic heart failure
- Acute pulmonary embolus or pulmonary infarction
- Acute myocarditis or pericarditis
- Suspected or known dissecting aneurysm
- Acute systemic infection, accompanied by fever, body aches, or swollen lymph glands

Relative*

- Left main coronary stenosis
- Moderate stenotic valvular heart disease
- Electrolyte abnormalities (e.g., hypokalemia, hypomagnesemia)
- Severe arterial hypertension (i.e., SBP > 200 mm Hg and/or DBP > 110 mm Hg) at rest
- Tachydysrhythmia or bradydysrhythmia
- Hypertrophic cardiomyopathy and other forms of outflow tract obstruction
- Neuromuscular, musculoskeletal, or rheumatoid disorders that are exacerbated by exercise
- High-degree atrioventricular block
- Ventricular aneurysm
- Uncontrolled metabolic disease (e.g., diabetes, thyrotoxicosis, or myxedema)
- Chronic infectious disease (e.g., mononucleosis, hepatitis, AIDS)
- Mental or physical impairment leading to inability to exercise adequately

**Relative contraindications can be superseded if benefits outweigh risks of exercise. In some instances, these individuals can be exercised with caution and/or using low-level end points, especially if they are asymptomatic at rest.*

American College of Sports Medicine. ACSM's Guidelines for Exercise Testing and Prescription. 8th Ed. Baltimore, MD: Lippincott Williams & Wilkins, 2010:54.

All clients should be closely monitored during exercise test performance. Vital signs should be assessed before, during each stage or workload of the test, and after the test for 4 to 8 minutes of recovery.[15] In addition, the RPE is commonly used to monitor exercise tolerance (Fig. 6-3).[48] Finally, individuals should be monitored for signs and symptoms of exercise intolerance. The guidelines for stopping an exercise test are presented in **Display 6-9**.

Supervision During Exercise

The screening or medical evaluation discussed in the screening examination section of this chapter provides information for determining which individuals may require supervision during exercise.[43] Referring to **Displays** 6-4 and **6-10** the clinician can determine whether a patient/client can exercise unsupervised or requires supervision. Notably, individuals with symptoms and cardiorespiratory disease who are considered by their physician to be clinically stable and who have been medically cleared for participation in an exercise program should be supervised during exercise.[43] Supervision means that the clinician is present during the exercise program and can monitor the patient/client response to exercise and provide support in the event that the patient/client develops symptoms during exercise.

DISPLAY 6-9
Indications for Terminating Exercise Testing

Absolute Indications

- Drop in SBP > 10 mm Hg from baseline BP despite an increase in workload when accompanied by other evidence of ischemia
- Moderately severe angina (defined as a 3 on standard scale)
- Increasing nervous system symptoms (e.g., ataxia, dizziness, or near syncope)
- Signs of poor perfusion (cyanosis or pallor)
- Technical difficulties in monitoring the ECG or SBP
- Subject's desire to stop
- Sustained ventricular tachycardia
- ST elevation (+1.0 mm) in leads without diagnostic Q-waves (other than V_1 or aVR)
- Relative Indications
- Drop in SBP of >10 mm Hg from baseline* BP despite an increase in workload in the absence of other evidence of ischemia
- ST or QRS changes such as excessive ST depression (>2 mm horizontal or downsloping ST-segment depression) or marked axis shift
- Arrhythmias other than sustained ventricular tachycardia, including multifocal PVCs, triplets of PVCs, supraventricular tachycardia, heart block, or bradyarrhythmias
- Fatigue, shortness of breath, wheezing, leg cramps, or claudication
- Development of bundle-branch block or intraventricular conduction delay that cannot be distinguished from ventricular tachycardia
- Increasing chest pain
- Hypertensive response (SBP of >250 mm Hg and/or a DBP of >115 mm Hg)

**Baseline refers to a measurement obtained immediately before the test and in the same position as the test is being performed.*

American College of Sports Medicine. ACSM's Guidelines for Exercise Testing and Prescription. 8th Ed. Baltimore, MD: Lippincott Williams & Wilkins, 2010:119.

DISPLAY 6-10
General Guidelines for Exercise Program Supervision

Unsupervised = Low-risk individuals from Display 6-4 with a functional capacity >7 METs

Professionally* supervised = Moderate or high-risk individuals from Display 6-4 with stable disease and regular physical activity habit with a functional capacity >7 METs

Clinically supervised = High-risk individuals from Display 6-4 with a functional capacity <7 METs

**Professional refers to a health/fitness professional supervision possessing a combination of academic training and certification equivalent to the ACSM Certified Health Fitness Specialist or higher Clinical supervision refers to a health/fitness professional possessing a combination of advanced college training and certification equivalent to the ACSM Registered Clinical Exercise Physiologist and ACSM Certified Clinical Exercise Specialist (or higher).*

Modified from American College of Sports Medicine. ACSM's Guidelines for Exercise Testing and Prescription. 8th Ed. Baltimore, MD: Lippincott Williams & Wilkins, 2010:175.

PATIENT-RELATED INSTRUCTION/ EDUCATION AND ADJUNCTIVE INTERVENTIONS

Patient education regarding cardiovascular endurance training and its effects is a critical component of a physical activity or exercise program. Clinicians should recall the recent recommendation of the U.S. Department of Health & Human Services that adults should perform moderate-intensity aerobic physical activity for a minimum of 150 minutes each week or vigorous-intensity aerobic activity for a minimum of 75 minutes each week to promote and maintain health. A combination of moderate and vigorous-intensity activity can be performed to achieve the recommendation.[1]

Patient education should include the "why" and the "how to" of the warm-up, training session, and cool-down phases. The patient should be alerted to signs or symptoms necessitating early cessation of the activity (including those in Display 6-1). These symptoms may be musculoskeletal (e.g., joint pain, muscle pain, cramps) or cardiovascular (e.g., shortness of breath, chest pain, light-headedness), or they may be specific to the patient's particular diagnosis (i.e., reproducing the patient's original symptoms). The patient should be counseled regarding modifications in the exercise program based on fatigue level and other activities performed that day.

As the patient is prepared for discharge, education regarding a maintenance program is critical to continued adherence with the exercise program. Progression through a conditioning program should be individualized and is dependent on the client's functional capacity, premorbid state, health status, age, and individual preferences, goals, and tolerance of the training.[43] The client's objective and subjective training responses should most heavily influence training progression.[15] Signs and symptoms of overtraining include exercise and nonexercise fatigue, reduction in maximum performance, decreased interest in training compared with normal, decreased HR and RPE values at the same workload, and increased complaints of aches and pains.[51]

Emphasizing the importance of continued physical activity in long-term health maintenance as a part of a healthy lifestyle can assist the patient in making physical activity a lifelong commitment. Information about safe progression, dosage, and signs and symptoms of overload can assist the patient in making appropriate choices.

The documented success of programs designed to encourage the adoption of regular physical activity is poor, with approximately one in five adults meeting the 2008 recommendation for 150 minutes of moderate physical activity per week.[52] Variations in adherence to the guidelines exist along geographic and socioeconomic factors, such as ethnicity, education, and income (http://www.cdc.gov/physicalactivity/data/facts.htm). Significant effort has been expended to identify factors that increase adherence to the recommended guidelines. These factors in sum indicate that programs and individuals prescribing exercise can and should adopt specific strategies to enhance compliance with exercise prescription, including regular physical activity to improve health. Examples of these strategies are shown in **Display 6-11**.

DISPLAY 6-11

Practical Recommendations to Enhance Exercise Adherence

- Obtain health care provider support of the exercise program.
- Clarify individual needs to establish the motive for exercise.
- Identify individualized, attainable goals and objectives for exercise.
- Identify safe, convenient, and well-maintained facilities for exercise.
- Identify social support for exercise.
- Identify environmental supports and reminders for exercise.
- Identify motivational exercise outcomes for self-monitoring of exercise progress and achievements, such as exercise logs and step counters.
- Emphasize and monitor the acute or immediate effects of exercise (i.e., reduced BP, blood glucose, and need for certain medications).
- Emphasize variety and enjoyment in the exercise program.
- Establish a regular schedule of exercise.
- Provide qualified, personable, and enthusiastic exercise professionals.
- Minimize muscle soreness and injury by participation in exercise of moderate intensity, particularly in the early phase of exercise adoption.

American College of Sports Medicine. ACSM's Guidelines for Exercise Testing and Prescription. 8th Ed. Baltimore, MD: Lippincott Williams & Wilkins, 2010:177–178.

The use of behavior change theories to enhance the adoption of exercise has received increased attention recently in the literature, specifically the application of the stages of change model, as discussed in Chapter 3. After identifying the stage the patient is currently in, the intervention can be tailored to enhance compliance and movement toward a lifelong habit. For example, an individual in contemplation is not quite ready for an exercise prescription. Efforts in this stage should focus on the provision of information about the costs and benefits of exercise, strategies to increase activity within the present lifestyle, and the social benefits of activity, for example.[53] Those in the preparation stage would benefit most from a thorough examination and exercise prescription, whereas those in the action or maintenance stage would benefit from learning about strategies to prevent relapse, making exercise enjoyable, and diversifying the exercise prescription to include more variety. Given the difficulty most people encounter when changing health-related behaviors, it seems prudent to use documented behavior change theories when possible, such as the stages of change model (see **Building Blocks 6-9** to **6-12**).

BUILDING BLOCK 6-9

When answering this question, consider the case presented in Building Block 6-1:

How would you recommend the patient/client progress the exercise program?

BUILDING BLOCK 6-10

When answering this question, consider the case presented in Building Block 6-1:

What education would you provide for the patient/client?

BUILDING BLOCK 6-11

When answering this question, consider the case presented in Building Block 6-1:

What physiologic adaptations to the exercise program would you expect after 6 months?

BUILDING BLOCK 6-12

When answering this question, consider the case presented in Building Block 6-1:

What psychological adaptations to the exercise program would you expect after 6 months?

LIFE SPAN ISSUES

Guidelines for Cardiovascular Endurance Training in the Young

Adolescents and children receive health-related benefits from regular exercise and should be encouraged to participate in regular activity because adopting an active lifestyle early in life may increase the likelihood of participating in physical activity in adulthood.[1] There are several key physiologic differences between children and adolescents compared with adults that the clinician should be aware of when prescribing aerobic exercise in young people. Resting and exercise BP values are lower in children than in adults, with a progressive increase with age seen until late adolescence when the values are similar to that of adults.[8] Children have smaller hearts and less total blood volume compared with adults, so SV is lower at rest and during exercise. To maintain CO, HR is higher in children compared with adults. Overall CO in children is lower than in adults for the same absolute rate of work, so a-vo_2 difference increases to compensate for the lower SV.[12] Aerobic capacity, when expressed in L/min, is lower in children because of a lower maximal CO capacity. However, as children develop and their pulmonary and cardiovascular function improves, aerobic capacity improves as well.[12]

Children lose more energy during exercise compared with adults when performing the same activity at the same intensity. In addition, children are less efficient at dissipating heat during exercise because they generate more metabolic heat per unit body size, sweat at a lower rate, and begin sweating at a higher core body temperature compared with adults.[43] Taken together, these factors indicate that children exercising in hot environments should do so at a lower intensity and they will need more time to acclimatize compared with adults.

Exercise testing in children is typically reserved for those with specific conditions in which cardiopulmonary capacity is useful to assess.[43] Exercise testing in children can be performed for the same reasons the clinician would test adults—to assess symptoms, tolerance, and cardiopulmonary response to exercise in a monitored setting.[43] There are both treadmill and bicycle protocols and norms for children that can be referenced for use when exercise testing children.[43] Further, equipment that is safe and sized correctly for children is necessary for accurate testing and may not be available in all testing laboratory settings. More commonly, physical fitness testing performed with children is more similar to the field tests discussed in the adult exercise testing section of this chapter. A popular physical fitness testing program is the Presidential Youth Fitness Program, measuring the major components of physical fitness (aerobic capacity, body composition, muscle strength and endurance, flexibility).[54] This program offers educational materials, tools, criterion-referenced standards, and interpretation of results for schools and communities to apply in group or individual programs.

Regular participation in physical activity during childhood will result in gains in strength, endurance, bone formation, self-esteem and self-efficacy, and skill development.[43] A program of activity will also minimize risk factors for cardiovascular disease, manage weight, reduce anxiety and stress, provide social interaction, and can be a great source of fun and enjoyment.[43] The 2008 Physical Activity Guidelines recommend that children and adolescents aged 6 to 17:

- Should do 60 minutes (1 hour) or more of physical activity daily.
  - Aerobic: most of the 60 or more minutes per day should be either moderate- or vigorous-intensity aerobic physical activity (activities in which large muscles are rhythmically moved). Vigorous-intensity physical activity should be performed at least 3 days per week.
  - Muscle-strengthening activities at least 3 days per week as a part of the 60 minutes or more of daily activity (these activities can be unstructured and part of play, including playing on playground equipment, climbing trees, and playing tug-of-war; or structured such as lifting weights or working with resistance bands).
  - Bone-strengthening physical activity at least 3 days per week as a part of the 60 minutes or more of daily activity (these activities should produce a force on bones that promotes bone growth and strength, such as running, jumping rope, basketball, tennis, hopscotch).
- Should engage in physical activities that are age-appropriate, enjoyable, and offer variety.[1]

Children are at low risk for cardiovascular disease and are able to adjust exercise intensity to tolerance, so they do not need a HR prescription.[43] No one program, activity, or methodology has been demonstrated to best improve physical activity in children.[43] Increasing children's physical activity participation on a regular basis and decreasing the amount of sedentary time spent are basic goals for a physical activity program for children. Fitness-based games and lifestyle activities should be used when addressing physical activity participation in children because they are fun and children are more likely to participate in activities that are fun versus highly structured. As children age, they can progress to league and team sports. Adolescents can benefit from league sports as well as cardiovascular exercise such as swimming, bicycling, and jogging. If desired, prescribing exercise using the parameters recommended for adults is safe for adolescents.

Children and adolescents are susceptible to overuse injuries; therefore, clinicians and parents should be aware of the signs and symptoms of overtraining. It is also important to recognize that children and adolescents should balance cardiovascular training with muscle strength and endurance training and activities to address flexibility, to address all of the elements of physical fitness.

Guidelines for Cardiovascular Endurance Training in the Elderly

Several factors affect the decline in physiologic function and physical performance that has been documented to occur with age. Technologic advances that require humans to expend less physical effort, decreased motivation levels and less energy, and the effects of aging all may contribute to the changes seen in the elderly and are sometimes difficult to differentiate. Maximum oxygen consumption decreases approximately 10% per decade with aging, beginning in the middle of the third decade in men and toward the end of the second decade in women. Maximum HR, SV, CO, and peripheral blood flow also decrease with age.[12] In the lungs, residual volume increases with age but total lung capacity remains unchanged, so less air can be exchanged with each breath. The lungs and chest wall also lose elasticity with aging.[12] Body composition changes seen with aging include an increase in relative body fat and a decline in fat-free mass.[12] All of these changes documented in the elderly can be slowed by participation in regular physical activity, making a physically active lifestyle a powerful age deterrent.

The same exercise testing principles presented earlier in this chapter apply to the elderly population. A wide variety of testing protocols exist that are appropriate for use with the elderly population and traditional protocols can be used with slight modification. Appropriate tests are those in which the initial workload is low (2 to 3 METs) and workload increments small (0.5 to 1.0 METs), and the test accommodates for impaired balance, coordination, vision, gait patterns, and weight-bearing.[43] The 6-minute walk test is used often as a measure of aerobic capacity in elderly patients and in elderly clients without disease.[55,56] To perform the test, patients walk as quickly as they can along a level surface for 6 minutes. The outcome measure of interest is the distance walked in feet or miles. The 6-minute walk test is a practical alternative to other exercise testing means in the elderly because it is easy to perform, patients can stop and rest anytime during the test, assistive ambulation devices may be used to perform the test, and it has been shown to be a reliable indicator of functional ability.[55,57]

The exercise prescription guidelines discussed in this chapter can be safely and appropriately applied to the elderly population. The 2008 Physical Activity Guidelines recommend the following guidelines for adults aged 65 years and older:

- 150 minutes a week of moderate-intensity, or 75 minutes a week of vigorous-intensity aerobic physical activity, or an equivalent combination. Aerobic activity should be performed in sessions of at least 10 minutes and preferably spread throughout the week.
    - To realize additional health benefits, 300 minutes per week of moderate-intensity aerobic physical activity or 150 minutes of vigorous-intensity aerobic physical activity can be performed per week, or an equivalent combination.
    - Muscle strengthening that is moderate or high intensity and involve all major muscle groups on 2 or more days per week.
    - Exercises that maintain or improve balance should be performed by adults at risk of falling.
    - When older adults are unable to do 150 minutes of moderate-intensity aerobic activity a week because of chronic conditions, they should be as physically active as their abilities and conditions allow.[1]

The effects of cardiovascular endurance training in the elderly include decreased BP, increased HDL-C, improved cardiovascular mortality rates, increased bone density, and maintenance of oxygen consumption values.[58] Chosen activities should minimize impact on the joints, emphasizing activities such as water exercise, bicycling, or stair climbing. As is true for all ages, exercise need not be vigorous and continuous to be beneficial. Select activities that are accessible, convenient, enjoyable, and safe for the participant. Older adults who are currently inactive should gradually increase their physical activity and should avoid vigorous aerobic activity at first. Although it may take months for those with a low level of initial fitness to achieve the recommended amount of regular physical activity, a gradual increase in the number of days per week and duration of activity will ensure a safe and injury-free approach to becoming more active.[1]

KEY POINTS

- Physical fitness is defined as a set of attributes that people have or achieve and includes cardiovascular endurance, or the ability of the whole body to sustain prolonged exercise.
- Aerobic capacity or maximal oxygen uptake (VO_2 max) is the highest rate of oxygen the body can consume during maximal exercise.
- During acute exercise, HR, SV, Q, a-vo_2 diff, BP, and RR increase proportionally to the exercise workload.
- Benefits of cardiovascular endurance training include positive changes in the cardiovascular and respiratory systems that provide protection from disease, and improved psychological well-being and quality of life.
- Impaired aerobic capacity can occur as a result of primary cardiovascular and pulmonary disease, diseases of other systems that limit mobility, prolonged bed rest, aging, and a sedentary lifestyle.
- Areas of the patient/client history to which the clinician should pay special attention during the examination of individuals with impaired aerobic capacity include risk factors for cardiovascular disease, social/health habits such as smoking and physical activity, functional ability, and medication history.
- Patients/clients should be appropriately screened prior to the initiation of a cardiovascular training program to ensure safety and minimize risks, thus the clinician should be aware of general screening guidelines.
- Tests and measures used to examine patients/clients with impaired aerobic capacity include GXTs, body composition, and tests and measures of circulation such as BP.
- Exercise prescription can be based on the results of an appropriate exercise test administered before the initiation of a cardiovascular training program.
- Physical activity can be performed to produce health- or fitness-related benefits depending on the patient/client's goals and motivations. Most importantly, individuals should be regularly active, performing a minimum of 150 minutes per week of moderate- or 75 minutes per week of vigorous-intensity aerobic physical activity or an equivalent combination.
- Cardiovascular endurance training can be performed using a variety of exercise modes and training techniques.
- Exercise prescription should be based on the individual's needs and interests and should take into consideration comorbidities that may affect activity performance.
- Cardiovascular endurance training is one aspect of a well-balanced exercise program including muscle strengthening and endurance activities and flexibility exercises.
- The clinician should be aware of the signs and symptoms of exercise intolerance and should be able to identify the contraindications for GXT.
- Supervision requirements for GXT and for the performance of aerobic exercise are based on the patient/client's history, risk factors, and abilities, and the clinician should be able to appropriately determine the level of supervision required.
- Education about the specifics of the exercise prescription, including progression, and the implementation of strategies to enhance compliance will increase the likelihood of the patient/client adopting cardiovascular exercise as a lifelong habit.

CRITICAL THINKING QUESTIONS

1. Consider Case Study No. 1 in Unit 7.
    a. What activities to maintain cardiovascular endurance would you recommend for Lisa as she recovers from her ankle sprain? Be sure to consider the demands of her sport.

   b. What activities would you recommend if she were a long-distance runner? A hockey player? A wrestler?
2. Consider Case Study No. 2 in Unit 7.
   a. Assuming the patient has met the short-term goals, to plan an intervention program to achieve the long-term goals, what test and measure would you select to assess aerobic capacity? What tests and measures to assess circulation would you monitor during the test of aerobic capacity?
   b. To design a long-term aerobic exercise program for Sarah, determine the best strategies to incorporate to enhance compliance and increase the likelihood that she will adopt exercise as a lifelong habit.
3. Consider Case Study No. 3 in Unit 7.
   a. Design an intervention program to improve this journalist's cardiovascular endurance, including techniques to enhance compliance.
   b. According to the Transtheoretical Model of Behavior Change, what stage of change would you place Cathy in and what strategies are appropriate to incorporate to move her to the next stage?
4. Consider Case Study No. 8 in Unit 7.
   a. Recommend a GXT for George, considering the examination findings and his premorbid condition.
   b. Make recommendations for a cardiovascular exercise program, considering George's examination findings and his job.
   c. How would your intervention plan be different if George worked as a long-distance truck driver?

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CHAPTER

7 Impaired Range of Motion and Joint Mobility

LORI THEIN BRODY

Most patients with orthopedic conditions need mobility activities during the rehabilitation process. The clinician must provide hands-on rehabilitation techniques as well as instructions for a home exercise program. The execution of mobility activities is not as difficult as choosing the appropriate level of assistance and ensuring that the patient is performing the exercise correctly. Clear instruction and supervised practice in the clinician's presence can prevent misunderstandings about exercise performance.

Mobility exercises may be initiated early in the rehabilitation program and done throughout the rehabilitation program on a maintenance basis. Some individuals need progressive mobility exercises throughout the rehabilitation course, progressing from passive (PROM) to active assisted (AAROM) to active range of motion (AROM). The choice of mobility activities depends on the stage of healing, length of immobilization, number and kind of tissues affected, and the specific injury or surgery. Understanding of the effects of decreased mobility and remobilization is the key to making appropriate mobility exercise choices. The clinician must also realize that immobilization is relative; it can be externally imposed by a brace or cast, or the patient may "self-immobilize" by discontinuing the use of the limb.

When considering mobility, the terms *arthrokinematic* and *osteokinematic* motion must be differentiated. **Arthrokinematic motion** refers to movements of the joint surfaces. Roll, spin, and glide are terms used to describe arthrokinematic motion. Arthrokinematic motion is a necessary component of osteokinematic motion that refers to movement of the bones. **Osteokinematic motion** is described in terms of planes (e.g., elevation in the sagittal plane) or relative movements (e.g., flexion, abduction). Mobility can be impaired by alterations in arthrokinematic motion, osteokinematic motion, or both.

CONTINUUM OF MOBILITY

Although decreased mobility is the most obvious mobility impairment encountered, the concept of mobility is relative, with the degree of mobility occurring along a continuum. That continuum encompasses **hypomobility**, or decreased mobility, and **hypermobility**, or excessive mobility. Hypermobility should not be confused with instability. **Instability** is an excessive range of osteokinematic or arthrokinematic movement for which there is no protective muscular control.[1] For example, someone may have excessive arthrokinematic anterior, posterior, and inferior glide at the shoulder (i.e., hypermobility) that is asymptomatic. Loss of dynamic muscular control at the shoulder produces instability and symptoms.

At the hypomobility end of the continuum, the concepts of contracture and adaptive shortening are important for understanding hypomobility. A **contracture** is a condition of fixed high resistance to passive stretch of a tissue because of fibrosis or shortening of the soft tissues or muscles around a joint.[2] Contractures occur after injury, surgery, or immobilization and are the result of the remodeling of dense connective tissue. Immobilization of a tissue in a shortened position results in **adaptive shortening**, which is shortening of the tissue relative to its normal resting length. Adaptive shortening also can result from holding a limb in a posture that shortens the tissues on one side of the joint. For example, protracting the shoulders in a rounded posture results in adaptive shortening of the pectoral muscles. This shortening can be accompanied by **stiffness** or a resistance to passive movement.

Somewhere between the ideas of hypermobility and hypomobility lies the concept of relative flexibility. **Flexibility** is the ability to move a joint or a series of joints through a ROM. **Relative flexibility** considers the comparative mobility at adjacent joints. Movement in the human body takes the path of least resistance. If one segment of the spine is hypomobile because of injury or disease, the segment is stiffer and has more resistance to movement than adjacent joints. When flexion, extension, or rotation is necessary, the adjacent joints produce most of the movement because of the resistance to motion at the hypomobile joint. Likewise, stiffness in the hamstrings is often compensated by lumbar spine motion, placing more load on the spine. Lengthening the hamstrings minimizes the stress placed on the spine and is the basis for hamstring stretching, an approach used by some persons to remedy back pain.

Relative flexibility is not always an impairment. For example, because of its biomechanical and anatomic properties, L5 is more adapted to produce rotation than any other lumbar segment. It is *relatively more flexible* in the direction of rotation. This is a clinical problem (i.e., impairment) only if the motion becomes excessive and is not muscularly controlled. This problem may occur because of relative stiffness at other spinal segments (above or below L5) or at the hips. For example, golfing requires a significant amount of total body rotation. If the hips, knees, and feet are relatively more stiff in rotation than the spine, the discrepancy may impose excessive rotation in the spine. If the thoracic spine or upper lumbar segments are stiff in rotation, the difference may impose excessive rotation on the L5 segment. L5 is the site of relative flexibility in the direction of rotation.

MORPHOLOGY AND PHYSIOLOGY OF NORMAL MOBILITY

Normal mobility, in its broadest definition, includes:

- Osteokinematic motion (movement of bones)
- Arthrokinematic motion (roll, spin, and glide movements of the joint surfaces)
- Adequate tissue length to allow full ROM (i.e., passive mobility)
- Neuromuscular coordination and skill to accomplish purposeful movement (i.e., active mobility)

Structures involved in passive mobility include the joint's articular surfaces and interposed tissues (e.g., menisci, labrum, synovial lining), joint capsule, ligaments and tendons (including insertion sites), muscles, bursae, fascia, and skin. Mobility is maintained in most individuals by routine, daily use of their limbs and joints in normal daily activities. However, adaptive shortening can occur in those who spend long periods of time in single postures (e.g., sitting most of the day), resulting in a loss of mobility.

Normal mobility includes adequate joint ROM and muscle ROM. **Joint ROM** is the quantity of motion available at a joint or series of joints in the case of the spine. In contrast, **muscle ROM** is the functional excursion of the muscle from its fully lengthened position to its fully shortened position. Examination and treatment techniques for joint ROM impairments and muscle ROM impairments differ. Joint ROM impairments are examined using accessory or "joint play" motions (arthrokinematic motions) and are treated with joint mobilization, whereas muscle or other soft tissue ROM impairments are examined using flexibility (muscle length) tests and treated with ROM or stretching exercises.

IMMOBILITY, IMMOBILIZATION, AND REMOBILIZATION

Individuals can lose mobility at a joint for several reasons including:

- Trauma to soft tissue, bone, or other joint structures
- Surgical procedures such as total joint replacements, reconstructions, debridements, arthroplasties, osteotomies, and tendon transfers
- Surgery for nonorthopedic conditions such as mastectomy or other chest procedures
- Bed rest after cardiac, gynecologic, or other surgical procedures
- Joint disease such as osteoarthritis or rheumatoid arthritis
- Prolonged immobilization or bed rest for any reason
- Inability to move a joint because of neuromuscular disease
- Pain that inhibits movement

Immobility at a joint produces a self-perpetuating cycle that can be interrupted by several physical therapy interventions, including ROM activities, resistive exercises, or other manual therapy procedures such as joint mobilizations. Progressive adaptive shortening of the soft tissues occurs as the body responds to decreased loading. This shortening limits mobility and function, reducing the patient's ability to carry out normal activities of daily living, work, or leisure activities. The patient accommodates these limitations by substituting other joints or limbs to achieve functional goals, thereby contributing to the disuse. Pain results from disuse and progressive shortening of the joint capsule (a highly pain-sensitive structure), adding to the disuse, and perpetuating the cycle of immobility. Weakness ensues because of changes in the length–tension ratios, furthering the patient's disinclination to use the limb (**Fig. 7-1**).

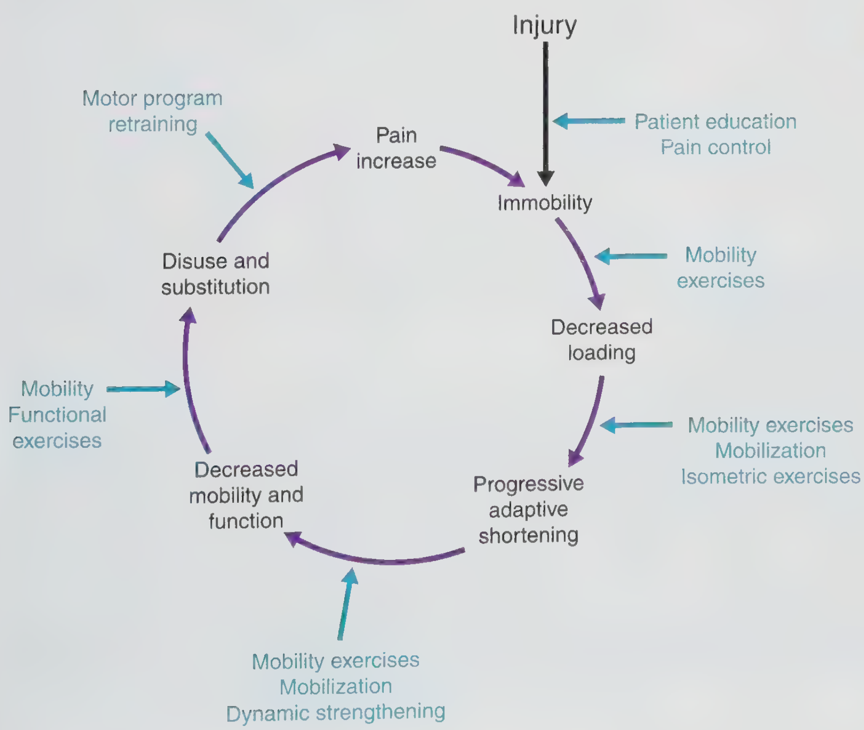

FIGURE 7-1 Self-perpetuating cycle of immobility.

TABLE 7-1

Effects of Immobilization and Remobilization on Muscle and Tendon

MUSCLE	TENDON
Position- and composition-specific muscle fiber atrophy	Decreased size and number of collagen fibers
Functional loss > muscle mass loss	Collagen fibers thinner and disorganized
Decreased electrical activity > atrophy	Decreased load tolerance
Increased connective tissue	Decreased water and GAG[a] content
Increased subcutaneous fat deposition	Increased synthesis and degradation of collagen
Remobilization: lengthy rehabilitation necessary to restore muscle performance especially with longer immobilization	Decreased tensile strength, elastic stiffness, and total tissue weight
	Remobilization: controlled mechanical stress increases tensile strength and energy absorption capacity, facilitates normal gliding and soft tissue relationships, prevents excessive scar formation

[a]GAG, glycosaminoglycan
From References found on thePoint.lww.com/BrodyHall4e.

Decreased mobility has profound effects on bone and soft tissues, reflecting the body's ability to adapt to various levels of loading. The plastic nature of these tissues works in positive and negative ways. The specific adaptation to imposed demands principle is based on Wolff's law and asserts that tissues remodel in accordance to the stresses placed on them. The effects of **overload** (tissue load greater than its normal usage), and its resulting hypertrophy, are well known, but the findings associated with underloading are less well known. Findings such as muscular atrophy and loss of joint motion are evident, but cellular changes, articular cartilage changes, and weakening of ligaments and their insertions are less obvious alterations.[3] The clinician must prevent these effects when possible and consider them when implementing a rehabilitation program.

Tables 7-1 to **7-4** summarize the consequences of immobilization or decreased mobility on various tissues.[4] Further information can be found on thePoint.lww.com/BrodyHall4e. Generally, most research has examined the effects of immobilization on healthy, uninjured tissues. This raises two important issues. First, immobilization usually is initiated in the presence of an injury (although tissue-lengthening procedures are exceptions), and the structural and mechanical properties of the injured tissues probably will be further compromised. The stages of healing can be found in Chapter 10 and should be considered in concert with the immobilization issues. Second, it is tempting to focus only on the injured tissue after immobilization. However, all surrounding tissues also are immobilized, and understanding the immobilization effects on these tissues ensures a safe and effective rehabilitation course.

Following immobilization, the patient typically goes through a course of structured remobilization.[5] The physiologic response to remobilization of previously immobilized tissues provides the scientific basis for many of the mobility interventions used. Be sure to consider the effects of remobilization on collagenous tissues prior to choosing any specific intervention techniques. The effects of remobilization on connective tissue vary with the type of connective tissue, the type of immobilization, and, most importantly, the length of immobilization. Response to remobilization interventions are not necessarily linear and excessive exercise can disrupt the healing process. How the

TABLE 7-2

Effects of Immobilization and Remobilization on Ligament and Their Insertion Sites

- Decreased total collagen mass
- Decreased strength and stiffness of ligament
- Decreased load to failure
- Shortening of ligament
- Increased stiffness of associated joint
- Disproportionate increase in young, immature collagen
- Bony resorption and weakening at insertion sites
- Increased avulsion rates
- **Remobilization:** can restore structural and mechanical properties of ligaments but takes longer than the original immobilization period

From References found on thePoint.lww.com/BrodyHall4e.

TABLE 7-3

Effects of Immobilization and Remobilization on Articular Cartilage

- Increased water content
- Decreased proteoglycan content
- Decreased chondrocyte population
- Decreased articular cartilage thickness and stiffness
- Articular cartilage softening
- Collagen fiber splitting and fibrillation
- Subchondral bone sclerosis
- Osteophyte development
- **Remobilization:** effects are time and load dependent; progressive joint deterioration may ensue with inappropriate loading postimmobilization

From References found on thePoint.lww.com/BrodyHall4e.

TABLE 7-4

Effects of Immobilization and Remobilization on Bone

- Decreased bone mass
- Decreased bone synthesis
- Decreased trabecular bone volume
- Weight-bearing bone loss exceeds nonweight-bearing bone loss
- **Remobilization:** depends upon bone quality prior to immobilization; may return to normal faster or bone changes may not be reversed

remobilization activity is dosed will impact the final quantity and quality of tissue. In-depth information on the specific tissue effects of remobilization on various tissues can be found on thePoint.lww.com/BrodyHall4e.

MOBILITY EXAMINATION AND EVALUATION

Performing a thorough examination before choosing a physical therapy intervention ensures appropriate indications and goal setting for the specific mobility technique(s) chosen. Moreover, the evaluation, including subjective examination and history taking, informs decisions about exercise dosage, activity type, and subsystems of the movement system specific to the individual.

The examination should identify the tissue(s) responsible for limited mobility. Noncontractile tissues that may limit passive mobility about a joint include the joint capsule, periarticular connective tissue, and overlying skin. Surgical incisions producing adhesions between the skin and underlying fascial layers limit their ability to glide during joint motion. Shortening, spasm, or contractures of the musculotendinous unit such as a Dupuytren's contracture can also limit the passive motion at a joint. Shortening of musculotendinous tissue should be differentiated from stiffness of other connective tissues. Stiffness in soft tissues is felt as an increased resistance to movement and can alter movement patterns passively and actively, resulting in musculoskeletal pain. Bone-on-bone approximation in the presence of degenerative joint disease, loose bodies, and pain can similarly limit passive mobility. The concepts of joint ROM and muscle ROM were clarified earlier. Examination procedures must identify the source(s) of decreased mobility to effectively direct the treatment. Joint osteokinematic motion is typically measured in cardinal planes with a goniometer, whereas joint arthrokinematic motion is evaluated with joint play assessment. Goniometric measurements are performed actively and passively, although the reliability of measurement is greater for active measures than for passive measures.[6] Isolated motions such as elbow flexion, knee extension, and ankle dorsiflexion are most commonly measured, but functional measurements with less stabilization and control can also be taken. Goniometric measurement of forward reach is a common functional assessment. Standards for normal goniometric mobility at each joint are published and provide a guideline for assessing mobility. When assessing joint ROM, the clinician must ensure proper patient positioning to avoid apparent joint motion limitations caused by poor muscle extensibility. For example, hip joint flexion ROM should be performed with the knee flexed to prevent limitations from hamstring excursion (**Fig. 7-2**).

Limitations in arthrokinematic motion decrease a patient's mobility, and increases in arthrokinematic mobility cause hypermobility. Arthrokinematic mobility is assessed through joint play maneuvers. Joint play is the movement of one articular surface on another and is not usually under voluntary control. Joint play is assessed by stabilizing one articular surface (by stabilizing the bone) and applying external pressure on the other to produce movement. Joint play assessment is typically applied in the loose packed position of the joint, which is the position where the joint is under the least amount of stress and the joint capsule has its greatest capacity. For example, applying an anteroposterior glide at the proximal interphalangeal joint of the index finger requires stabilization of the proximal phalanx while the distal phalanx is moved in an anteroposterior direction. This is performed in slight flexion, which is the loose packed position of this joint. In some cases, stabilization of one segment is provided by the surrounding bony and soft tissue structures and the supporting surface. For example, when performing posteroanterior unilateral vertebral pressure, the patient is stabilized in a prone position on the table while unilateral posteroanterior pressure is applied to the transverse process, producing rotation of the vertebral body that should be compared with the contralateral side.[1] Assessment of joint play can identify hypomobile, normal,

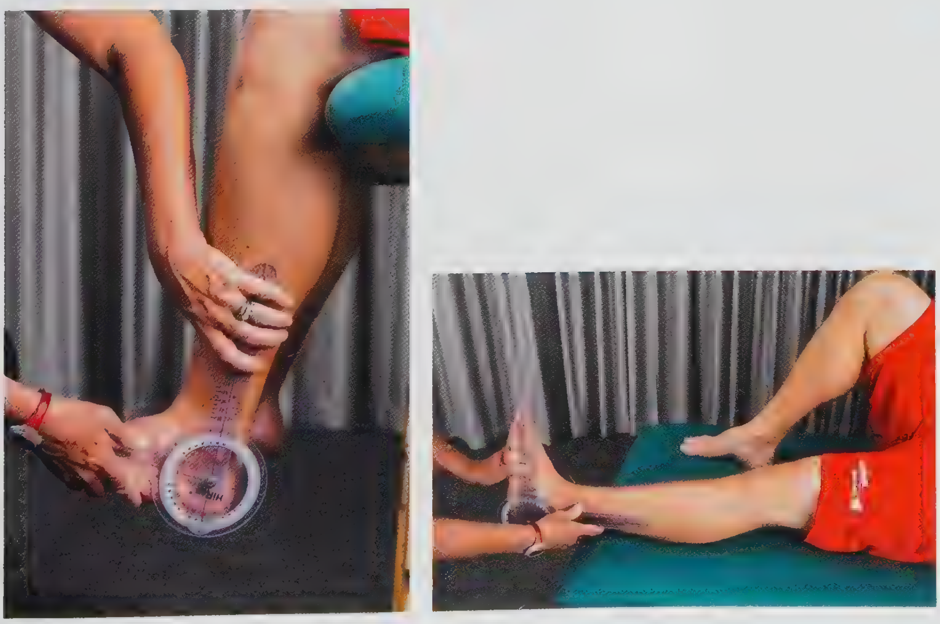

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FIGURE 7-2 **(A)** Joint ROM at the ankle. The knee is flexed to minimize effects of gastrocnemius tension. **(B)** Muscle ROM for the gastrocnemius.

FIGURE 7-3 Assessment of hip flexor muscle flexibility goniometrically using the Thomas test. The contralateral hip is flexed toward the chest to stabilize the pelvis in a neutral position. The therapist must palpate the pelvis to confirm the neutral position prior to continuing with the assessment. The affected lower extremity is slowly lowered and observed. To differentiate between 1-joint and 2-joint hip flexors (i.e., the iliopsoas and the rectus femoris/sartorius/tensor fascia lata), the therapist gradually flexes the knee until passive tension is reached. If the hip remains in the same position, regardless of knee position, the 1-joint hip flexors are at fault. If hip flexion increases with increased knee flexion, the 2-joint hip flexors are at fault.

or hypermobile conditions. These tests direct intervention for increasing capsular mobility, looking for other sources of mobility loss, or stabilization activities, respectively.

Assessment of joint ROM with a goniometer or joint play maneuvers does not identify the cause of limited motion. Joint ROM can be limited by capsular tightness, extrinsic soft tissue tightness, intrinsic joint blockage (i.e., knee meniscus tear blocking motion), or pain. Selective tissue tension testing assists the clinician in identifying the tissue at fault. Loss of joint motion in a capsular pattern or with a capsular end feel suggests that the joint capsule is the tissue at fault, and the treatment focus is joint mobilization. However, the clinician should remember that end-feel assessment is not a highly reliable measurement and that the pattern of capsular limitation does not always exist.[7]

Unidirectional loss of motion suggests some other soft tissue (muscle–tendon unit, skin, fascia, neurologic tissue) is at fault, and other ROM techniques may be employed. Muscle ROM is generally assessed using flexibility tests, a few of which are quantified. For example, hamstring extensibility can be assessed goniometrically using the 90–90 straight leg raise.[1] The Thomas test for hip flexor extensibility and the Bunnell–Littler test for hand intrinsic or joint capsule extensibility are examples of flexibility tests (**Fig. 7-3**). These tests, when performed correctly, can direct intervention for decreased musculotendinous extensibility as the cause of decreased mobility.

RANGE OF MOTION INTERVENTION FOR IMPAIRED MOBILITY

A variety of interventions are available to treat decreased mobility. After the tissues limiting mobility have been identified, appropriate ROM, stretching, or joint mobilization techniques should be applied. Adjunctive agents enhance the effectiveness of exercise interventions.

Subsystems of the Movement System

Although any of the subsystems of the movement system may contribute to decreased mobility, most mobility problems arise from passive system elements such as the neuromyofascia, capsuloligamentous, bony, and joint-related tissues. For example, loss of normal hip extension ROM may contribute to low back pain by transferring the extension mobility requirement from the hip to the low back (i.e., relative flexibility). In this case, impaired mobility in the hip contributes to low back pain impairment. The pain arises from compression of the posterior elements of the spine and subsequent inflammation around the nerve roots (i.e., pathology) and an inability to sit for long periods (i.e., activity limitation). If left untreated, this condition may lead to participation restrictions such as the inability to work at a desk, participate in recreational activities, or sit in a car (**Fig. 7-4**).

In this example, the passive subsystem elements are the shortened hip flexors and hip joint capsule pulling the pelvis into anterior tilt in addition to the weak (active subsystem) abdominal muscles that are unable to provide sufficient counterforce. The biomechanical elements are the increased anterior pelvic tilt and increased lumbar lordosis contributing to posterior element compression in the spine. The active element is an inability to recruit the abdominal muscles to improve the biomechanical elements. The cognitive/emotional element is depression related to chronic low back pain.

The subsystems of the movement system involved must be prioritized and those subsystems amenable to physical

FIGURE 7-4 Lumbar extension compensating for limited hip flexor mobility during a volleyball serve.

therapy intervention determined. In this situation, intervention to increase the length of the hip flexors, decrease stiffness in the hip joint capsule, and improve the neuromuscular firing and muscular endurance of the abdominal muscles should be instituted.

Considerations in Choosing Mobility Activities

When choosing from the wide variety of mobility interventions available (i.e., joint mobilization, ROM exercises, neuromobilization, soft tissue mobilization, stretching) be sure to consider the availability of sufficient arthrokinematic motion, the hyper-/hypomobility continuum, and the prognosis. Arthrokinematic roll, spin, and glide are necessary prerequisites for normal osteokinematic mobility. Attempting to perform ROM activities in the absence of normal arthrokinematic motion at the joint surface does not improve the impaired mobility and may increase the patient's symptoms. Therapist applied or self-mobilization activities such as inferior glide or lateral distraction at the glenohumeral joint or long-axis traction at the hip, if indicated, should precede ROM exercises (**Fig. 7-5**).

When applying interventions to increase mobility, consider the continuum of hypomobility to hypermobility and the concept of relative flexibility. Hypomobility can be mistreated if the possibility of adjacent hypermobility is ignored. For example, if a stiff segment exists at L4–L5 and treatment is directed at decreasing stiffness there without stabilizing interventions directed at hypermobile segments above and below, symptoms of instability at these segments may increase. Treatment must include a comprehensive program to *improve the mobility at the relatively more stiff segments* or regions and to *increase the stiffness at the relatively more mobile segments*. Because motion always occurs along the path of least resistance, mobility occurs naturally at the stiff segment only if it is of equal mobility or more mobile than other segments. It is important to increase the stiffness at the site of relative flexibility. This is done by improving neuromuscular control, muscle performance capability, and length–tension relationships of the stabilizing muscles around the site of relative flexibility. These techniques are coupled with patient education, postural training, and movement patterns that improve the distribution of mobility.

Also consider the cause of decreased mobility and the prognosis for resolution of the mobility impairment. In some cases, such as idiopathic shoulder adhesive capsulitis, the specific cause of the problem is unknown, whereas the prognosis and final outcome are mixed. In this case, mobility interventions that the patient can perform independently will be an important component of the treatment program.[8,9]

Range of Motion

ROM activities at a joint or series of joints and articulations are commonly used to offset some of the deleterious effects of immobilization. Movement about a joint, whether passive, active assisted, or active, produces a load in the soft tissues; this loading can maintain the integrity of the tendon, ligament and bony attachments, articular cartilage, and muscle. The magnitude of the benefit is determined by the exercise and immobilization parameters and by the status of the tissues before immobilization. Mobility activities are specific exercises or functional activities performed to improve functional ROM about a joint. Mobility activities usually are performed through a joint ROM and can be performed in cardinal planes and multiple planes or using functional movement patterns (e.g., reaching, squatting). These activities can be performed actively, passively, or with active assistance. Fundamental ROM considerations can be found in **Display 7-1**.

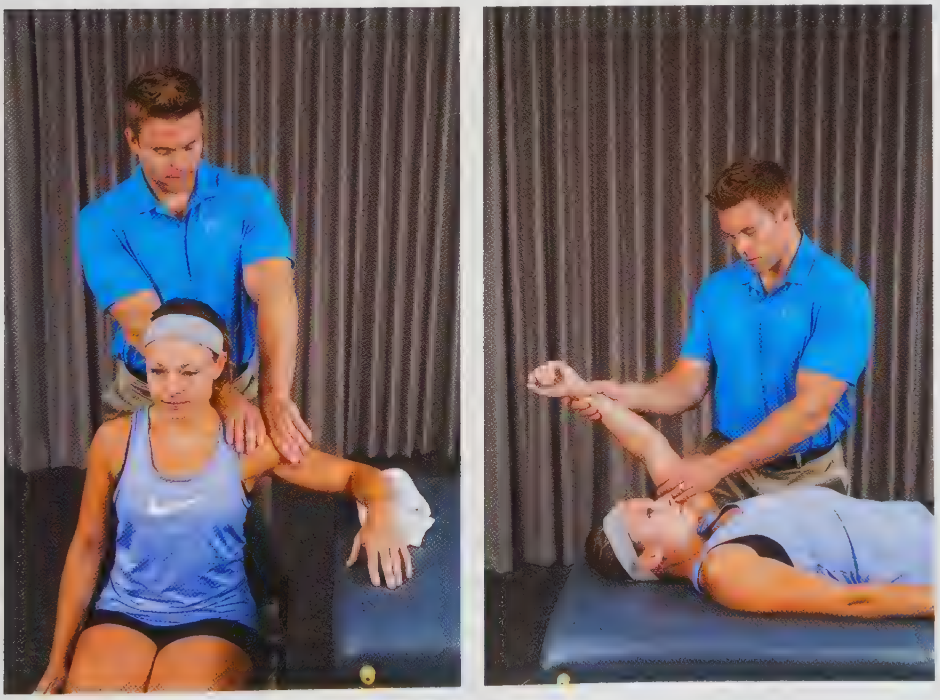

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FIGURE 7-5 **(A)** Therapist performing inferior glenohumeral mobilization. **(B)** Therapist assists shoulder flexion following joint mobilization.

DISPLAY 7-1

Considerations When Performing ROM

- Ensure patient comfort and safety
- Ensure clinician safety by using good body mechanics
- Support any areas at risk of injury resulting from hypermobility, fracture, etc.
- Perform ROM slowly and rhythmically
- Move through as full a range as possible
- Use handling and cradling techniques that increase therapist contact with the patient to enhance relaxation (especially when performing PROM)
- Use cardinal plane motions, combined motions, or functional movement patterns

Passive Range of Motion

PROM exercises are mobility activities performed without any muscular activation (**Fig. 7-6**). These exercises are performed within the available ROM. Any overpressure at the end of the range would be categorized as stretching, not PROM. PROM and stretching can be combined to increase the ROM around a joint.[10]

Indications PROM is used when:

- Active movement may disrupt the healing process.
- The patient is physically or cognitively unable to move actively.
- Active movement is too painful to perform.
- Teaching active or resistive exercises.
- Relaxation is the goal.

Goals related to the prescription of PROM depend on the patient and the setting. In an orthopedic setting, PROM is often used to prevent the deleterious effects of immobilization after an injury or surgery. Prevention of joint contractures and soft-tissue stiffness or adaptive shortening, maintenance of the normal mobile relationships between soft tissue layers, decreased pain, and enhancement of vascular dynamics and synovial diffusion are goals of PROM.[10] These goals are difficult to measure and to document. The clinician must rely on his or her understanding of the pathologic process to provide the rationale for this intervention. Measurable outcomes related to PROM as prevention intervention may include decreased pain, expeditious restoration of motion and strength, and earlier return to function after activity is allowed (see **Self-Management 7-1**).

SELF-MANAGEMENT 7-1

Ankle Passive Range of Motion

Purpose: To increase ankle motion in all directions

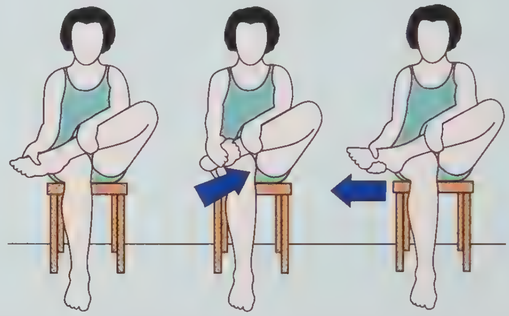
Position: In a sitting position with the ankle crossed across the knee, with a comfortable grip at the forefoot.

Movement Technique: Move the ankle in upward and downward directions. Move the ankle in and out. Stay in a comfortable ROM. Hold briefly at the end of the range in each direction.

Dosage:

Repetitions: ____________________

Frequency: ____________________



When the patient is comatose, paralyzed, on complete bed rest, nonambulatory, or cognitively unable to maintain joint ROM, PROM is used to achieve the same goals as the orthopedic setting. Because of the long-standing nature of these problems and the profound effects of long-term immobility, prevention assumes even greater importance. The patient usually requires PROM exercise two or more times each day, necessitating provision of services by family members or other assistive personnel.

Modes The exercise chosen should allow full available excursion. Several modes are available for performing PROM or stretching. Use pulleys, continuous passive motion devices, family members, or various household objects such as the floor,

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FIGURE 7-6 **(A)** Self-ROM for wrist flexion. **(B)** Self-ROM for wrist extension.

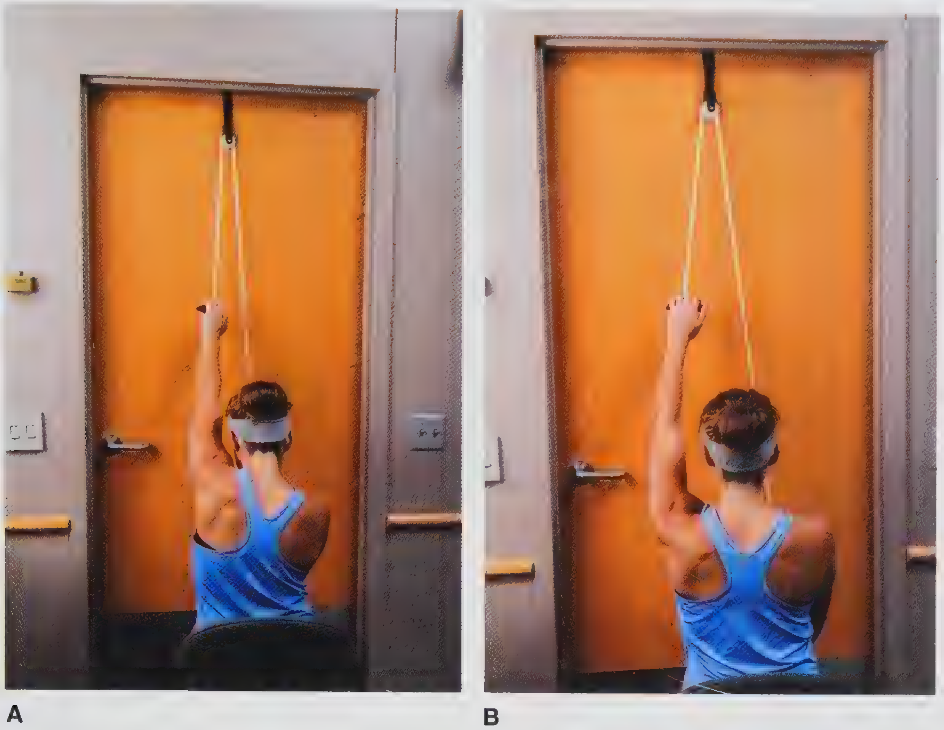

FIGURE 7-7 **(A)** Incorrect performance of shoulder flexion using pulleys. **(B)** Correct performance using proper posture and movement kinematics.

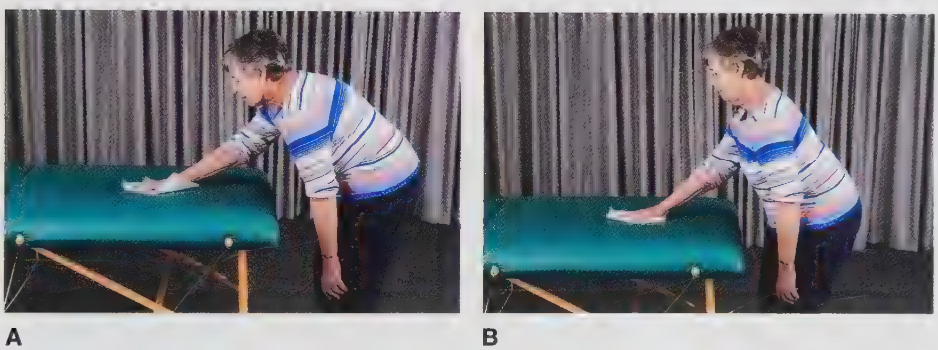

FIGURE 7-8 **(A)** Incorrect performance of passive shoulder flexion on a countertop. **(B)** Correct performance using proper posture and movement.

counters, or chairs to perform PROM. Holding the position at end range adds a stretching component to the PROM activity. Using pulleys to gain shoulder flexion can be helpful if performed properly without scapular or spinal substitution patterns (**Fig. 7-7**). The same can be said for self-mobilization activities such as stretching the arm forward on a counter (**Fig. 7-8**). Passive knee flexion can be easily performed using a towel and a smooth floor, by sitting on a chair, or while in a pool (see the section on ROM Self-Management).

Techniques and Dosage The clinician's skill in performing PROM can significantly alter the response. Handling techniques can affect the patient's comfort and ability to relax during treatment. When active muscle contraction is contraindicated, positioning and handling should allow the patient to fully relax. Any apprehension could result in protective muscle contraction and possible injury. Proper positioning allows adequate stabilization while the clinician's hand control provides stabilization and command of the affected limb. Effective PROM technique includes:

- Using a grip that provides control but considers the patient's condition.
- Avoiding painful areas or excessively tight grips that produce discomfort
- Performing PROM at a smooth and steady pace, avoiding abrupt movements or excessive speed that may cause protective muscle contraction.
- Monitoring the patient's response and being flexible enough to modify the technique when necessary.
- Tailoring the hand position, ROM, and speed for each patient.

The exercise dosage will vary with the purpose of the exercise. In general, the volume of exercise should be sufficient to achieve the physical therapy goals without overloading the tissues, particularly when performed during the healing process. It is best to perform fewer repetitions of an exercise, and return to that exercise performing additional set(s) of the exercise if the patient tolerates. For example, following cast removal for a Colles fracture, the therapist might perform 5 to 10 repetitions of wrist flexion and extension, followed by a finger activity. If tolerated, add an additional set or two of the flexion/extension activity, with alternate activities between sets.

SELF-MANAGEMENT 7-2
Knee-to-Chest Stretching

Purpose: To increase the mobility of the lumbar spine and hips into flexion

Position: Lying on your back, with your knees bent and feet flat on the floor

Movement Technique: Slowly bring one knee to your chest while grasping behind your knee. Bring the second knee to your chest. Hold for 15 to 30 seconds. Slowly lower one leg to the starting position, followed by the other leg

Dosage:

Repetitions: ____________________

Frequency: ____________________

Active Assisted Range of Motion

AAROM can be defined as mobility activities in which some muscle activation takes place. In this situation, the patient is unable or not allowed to fully activate the muscle. AAROM is used when some muscle activation through the ROM is allowed or desired, but the patient requires some assistance to complete the ROM. AAROM is frequently used to initiate gentle muscle activity after musculotendinous surgical procedures such as rotator cuff or Achilles tendon repairs. The amount of assistance throughout the ROM may vary. Some individuals may require assistance throughout the entire range, but others may require minimal or no assistance in some ranges but nearly maximal assistance in other ranges. This variation may result from a painful arc, limitations imposed by the disease or injury, changing length–tension ratios, or synergist action.

Active assisted exercise is indicated for patients who are unable to complete the ROM actively because of weakness resulting from trauma, neurologic injury, muscular or neuromuscular disease, or pain. In addition, the weight of the limb may impede active movement using proper mechanics, and assistance may be provided to ensure proper exercise performance. Lastly, some injuries or operations necessitate limitations in active muscle contraction in the early phase of healing (see **Self-Management 7-2**).

The expected goals with AAROM intervention are the same as those accomplished with PROM but extend beyond to include the benefits of muscle activation. These goals might include:

- Prevention of the negative effects of immobilization
- Prevention of joint contractures and soft tissue tightness
- Decreased pain
- Enhanced vascular dynamics and synovial diffusion[11]
- A stimulus for bone activity from the pull of the muscle on the bony attachment
- Muscle activity
- Enhanced proprioception and kinesthesia

Muscle contraction in this situation has little impact on true strength gains in most patients, but it teaches the patient how to actively fire the muscle. For example, individuals with rotator cuff injuries require assistance to activate these muscles after injury or surgery (**Fig. 7-9**). Moreover, active assisted exercise involves the patient in the rehabilitation process, rather than being a passive recipient of an intervention.

Hand placement and cueing during AAROM are important for optimal patient participation. When possible, tactile cueing should be on one side of the joint rather than using a grip on the flexor and extensor surfaces. This action cues the patient for the direction of assistance or resistance. This is particularly important when performing a technique such as AAROM when some ranges are assisted but others are not.

Active Range of Motion

AROM is defined as mobility activities performed by active muscle contraction. These activities can be performed against gravity or

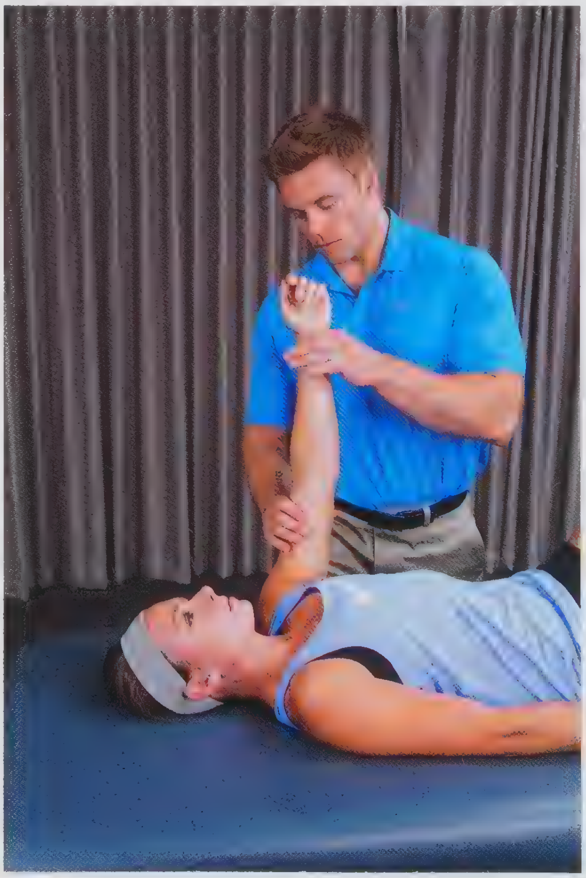

FIGURE 7-9 Active assisted shoulder flexion can be accomplished with assistance from the therapist.

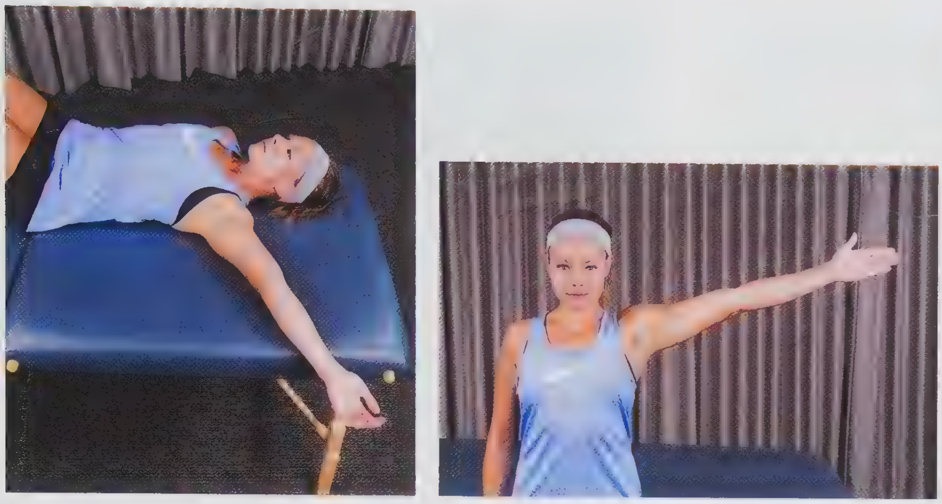

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FIGURE 7-10 **(A)** Active shoulder abduction in a gravity-minimized position. **(B)** Active shoulder abduction against gravity.

in a gravity-minimized position, depending on the individual's strength and the physical therapy goals (**Fig. 7-10**). Motions in cardinal planes, combination movement patterns, or functional activities such as reaching or combing one's hair are all examples of AROM. The expected goals or outcomes associated with AROM intervention include those associated with PROM plus the benefits of muscle contraction. These goals parallel those of AAROM, although the results are greater. In addition to the greater strength requirements, active exercise requires more muscle coordination because of the lack of assistance or guidance through the ROM. As with active assisted exercise, the strength gains are minimal in many patients. Only those with fair (3/5) strength or less can be expected to have their strength challenged. However, many patients can expect to be challenged proprioceptively and kinesthetically. For example, after knee injury or surgery, many individuals have difficulty activating the quadriceps femoris. Quadriceps setting exercises show patients how to activate the quadriceps, a prerequisite for functional activities. Although little or no tibiofemoral movement occurs, patellofemoral AROM occurs, with superior glide of the patella on the femur. An additional benefit of active exercise is independence in the rehabilitation program. Active exercise enhances the vascular benefits of ROM, with activities such as ankle pumps (i.e., repetitive dorsiflexion and plantarflexion) used postoperatively to prevent deep vein thromboses.

Indications As with AAROM, active exercise is indicated when active muscle contraction is desired. Many exercise programs begin with a regimen of active exercise to ensure proper exercise performance before the addition of resistance. In some situations, the weight of the limb alone produces optimal loading and makes a good starting point for the rehabilitation program. After learning the correct exercise technique, the patient can perform that exercise in a variety of modes that suit his or her preferences (see **Selected Intervention 7-1**).

Active mobility can be limited by the same noncontractile and contractile tissues that limit passive mobility. Shortening, stiffness, spasm, or contracture limit the joint's ability to move through a ROM. The strength and endurance of the muscle or muscle group can limit active motion. Strength below a fair (3/5) muscle grade implies an inability to complete the ROM against gravity. Poor neuromuscular coordination and balance, such as the inability to stand on a single leg, may limit active

SELECTED INTERVENTION 7-1

Active Range of Motion to Improve Mobility

See Case Study No. 4

ACTIVITY: Wand elevation exercise in the pool

PURPOSE: To increase shoulder mobility in abduction, scaption, and flexion

RISK FACTORS: Ensure appropriate stabilization and arthrokinematic motion to prevent substitution

MOVEMENT SUBSYSTEM: Active subsystem

STAGE OF MOTOR CONTROL: Mobility

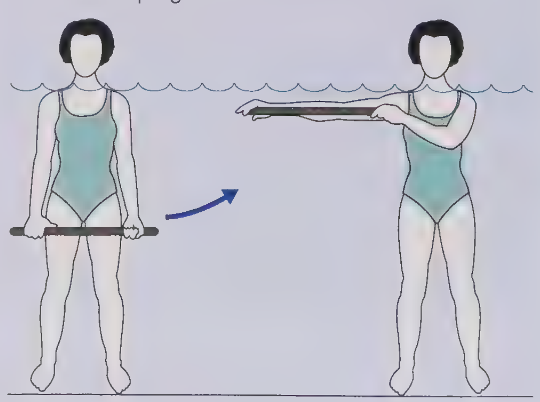
POSTURE: The patient is standing in chest-deep water, with a wand in the hands.

MOVEMENT: The patient allows the buoyancy of the water and the assistance of the uninvolved arm to lift the arm in the frontal, scapular, or sagittal plane. Relaxation of the shoulder muscles allows passive stretch into abduction, scaption, or flexion.

DOSAGE: Sets of three to five repetitions with 30-second holding at the end of the range.

RATIONALE FOR EXERCISE CHOICE: This exercise passively assists motion into a functional, frequently limited range. The intensity of stretch is easily modified by changing water depth.

EXERCISE GRADATION: The patient should discontinue use of wand and progress to active then resisted movements.



Wand shoulder abduction

mobility. Strength in an agonist may be adequate to complete the ROM, but antagonist firing because of neurologic pathology or faulty neuromuscular control patterns may limit motion. The patient may lack adequate speed of movement or agonist or synergist coordination to achieve purposeful movement. Cardiovascular endurance limitations in patients with chronic obstructive pulmonary disease, emphysema, or other cardiovascular conditions can hinder the performance of active exercise. All these situations may necessitate AROM as a therapeutic intervention (see **Building Block 7-1**).

BUILDING BLOCK 7-1

A 56-year-old man with a 6-year history of multiple sclerosis comes to physical therapy with complaints of poor left leg control and left leg fatigue with walking >¼ mile. Isolated hip flexor muscle and quadriceps muscle strength tests are 3+/5, but repeated testing reveals strength decrements after 10 repetitions, with the patient unable to complete the ROM. Describe a few simple exercises he might begin at home.

Technique Prior to performing AROM, ensure that muscle activation is warranted and determine any precautions. Examples of precautions might be working only through a portion of the ROM, performing ROM in a gravity-minimized position only, or modifying because of cardiac conditions. Once these are identified and the patient informed of these parameters, the therapist should demonstrate the exercise to be performed. Perform the exercise and then have the patient mirror the exercise, or using rhythmic initiation, the therapist may take the patient passively through the ROM and ask the patient to repeat this movement. Exercises can be performed through cardinal planes, diagonals, or functional movements. The speed, ROM, posture, and other important aspects of exercise performance should be monitored and explained to the patient. Mirrors are useful so the patient receives both verbal and visual feedback about performance.

Dosage Dosage for AROM depends upon the purpose of the activity. When using AROM to increase mobility, the exercise is typically dosed by the goal (i.e., continue repetitions until a ROM goal is achieved) or by the volume (i.e., number of repetitions × number of sets). For example, following shoulder surgery the patient might perform active shoulder flexion in side-lying until 100-degree flexion is achieved. Following knee surgery, the patient may be asked to perform 15 quadriceps set exercises every waking hour. When performing AROM as part of a strengthening routine, typical strengthening dosages should be implemented. The patient typically performs AROM exercise to fatigue, takes a rest interval, and performs additional sets. Patients performing AROM for position and kinesthetic sense should perform repetitions until form fatigue or muscle substitution. Again, this is followed by a rest interval and the exercise repeated or a different exercise initiated.

Active exercise should follow any passive technique to reinforce proper movement patterns and to overcome maladaptions to tissue stiffness. As new mobility is achieved, active exercise ensures the ability to use the new range effectively. For example, as hip flexion ROM improves from joint mobilization and stretching techniques, hand-knee rocking can be used to facilitate hip flexion ROM (see Fig. 17-26). As shoulder flexion mobility increases after stretching exercises, initiate active shoulder flexion exercises. Similarly, as knee flexion ROM increases after stretching, active knee flexion should follow (see **Self-Managements 7-3** and **7-4**). A few repetitions to reinforce the new ROM and movement pattern are generally sufficient.

SELF-MANAGEMENT 7-3
Active Range of Motion for Shoulder Flexion

Purpose: To increase active mobility in a forward and overhead direction

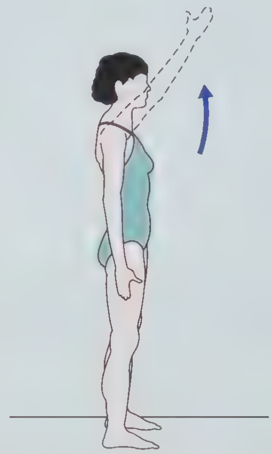
Position: In a sitting or standing position keeping your trunk in good alignment

Movement Technique: Reach your arm forward and up overhead. Reach as far overhead as is comfortable

Dosage:

Repetitions: ______________________

Frequency: ______________________



Independent PROM, AAROM, and AROM Activities

Most mobility conditions necessitating ROM intervention need these exercises daily. Therefore some exercises must be performed independently either by the patient or by a caregiver. For exercises provided by a caregiver, the therapist should instruct this individual in correct performance following the same guidelines utilized by the physical therapist. However, for the patient performing independent ROM activities, the therapist must provide tools, devices, or techniques that allow the patient to perform the ROM activity safely and effectively.

Pulleys ROM exercises can be implemented using a variety of different tools. Pulleys are one of the more common modes used for performing ROM exercises, particularly for the upper extremity. Pulleys are easily adjusted to increased shoulder ROM into cardinal planes such as flexion, abduction, and internal and external rotation (**Fig. 7-11A** and **B**). They can also be

SELF-MANAGEMENT 7-4
Active Knee Flexion

Purpose: To increase active range of knee flexion and to initiate muscle activity

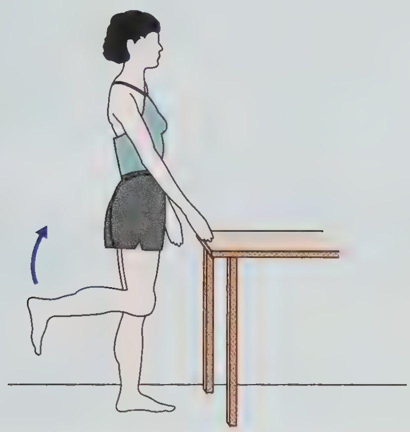
Position: Standing on your uninvolved leg on the floor or on a small step, with your involved leg hanging down next to the step, hold onto a stable object for support

Movement Technique: Slowly bend your involved knee up behind you, then lower it slowly and in a controlled fashion. Be sure to keep your knees in line with one another

Dosage:

Repetitions: ____________________

Frequency: ____________________



adjusted to increase mobility in diagonal or functional patterns (**Fig. 7-12** on page 152). Pulleys are simple as long as the patient is able to grasp the pulley handle. For those lacking hand strength or control, mitts or other assistive devices are available.

ROM exercises using pulleys can be passive or active assisted, and can incorporate stretching at the end of the ROM. Some combination of these activities is also possible. For example, the patient might begin by performing PROM and progress (either in the same exercise session or over time as healing permits) to AAROM. As tolerated, the patient might include stretching at the end of the ROM. Dosage is typically the same as if the exercise were applied manually by a physical therapist (see **Building Block 7-2**).

BUILDING BLOCK 7-2

A patient with adhesive capsulitis has been performing a home exercise program of pulleys working to increase independent active elevation of the shoulder. However, the patient is still unable to lift the arm against gravity above 90 degrees without scapular substitution. What are some changes to the exercise program that might make forward elevation easier?

A

B

FIGURE 7-11 **(A)** Pulleys used for increasing shoulder flexion mobility. **(B)** Pulleys used to increase shoulder extension and internal rotation mobility.

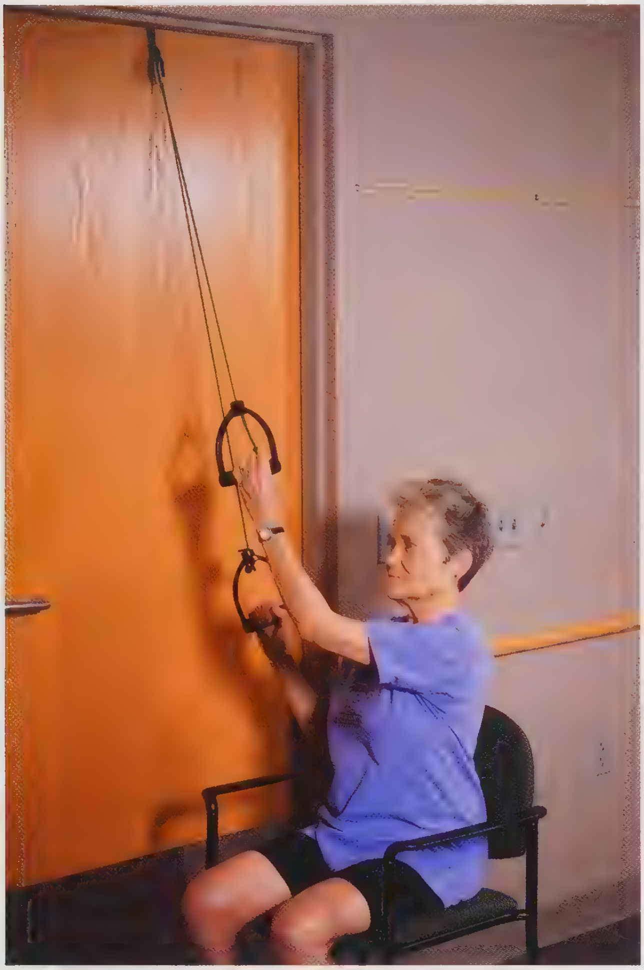


FIGURE 7-12 Pulleys to increase shoulder mobility in a functional diagonal pattern.

A

B

FIGURE 7-13 Cane exercise for shoulder: **(A)** external rotation and **(B)** abduction.

When using pulleys, instruct the patient to position themselves so that the pulley is directly in line with the axis of the joint being exercised. This facilitates normal biomechanics. If alignment is not correct, altered joint mechanics follows and may produce pain. Monitor the patient closely for proper mechanics, avoiding excessive scapular elevation as substitution for glenohumeral motion. Educate the patient on the importance of proper mechanics and supervise the patient performing the exercise independently prior to initiating this exercise.

Cane Exercises A cane, t-bar, dowel rod, or other similar device can be used to assist ROM exercises. Most of these exercises would be considered active assisted as most of these exercises require muscle activation to complete the ROM or to return to the starting position. Depending upon how the exercise is performed, these devices can be used effectively for stretching as well. Cane exercises are most frequently used for upper extremity ROM activities. In some cases, the uninvolved extremity guides the involved extremity while both are performing the same movement. Shoulder flexion and elbow flexion are good examples of this type of movement. In other cases, the uninvolved extremity guides the involved extremity in a unilateral movement pattern. Examples of this include shoulder external rotation and shoulder abduction (**Fig. 7-13A** and **B**). Combination activities such as extension and internal rotation can also be performed by grasping the end of the cane with the involved extremity while the uninvolved arm passively moves the arm into further internal rotation (**Fig. 7-14**).

Choosing cane exercises requires a good understanding of the limits of healing and confidence that the patient can perform the exercise competently without disrupting the healing

FIGURE 7-14 Cane used to increase shoulder extension and internal rotation mobility.

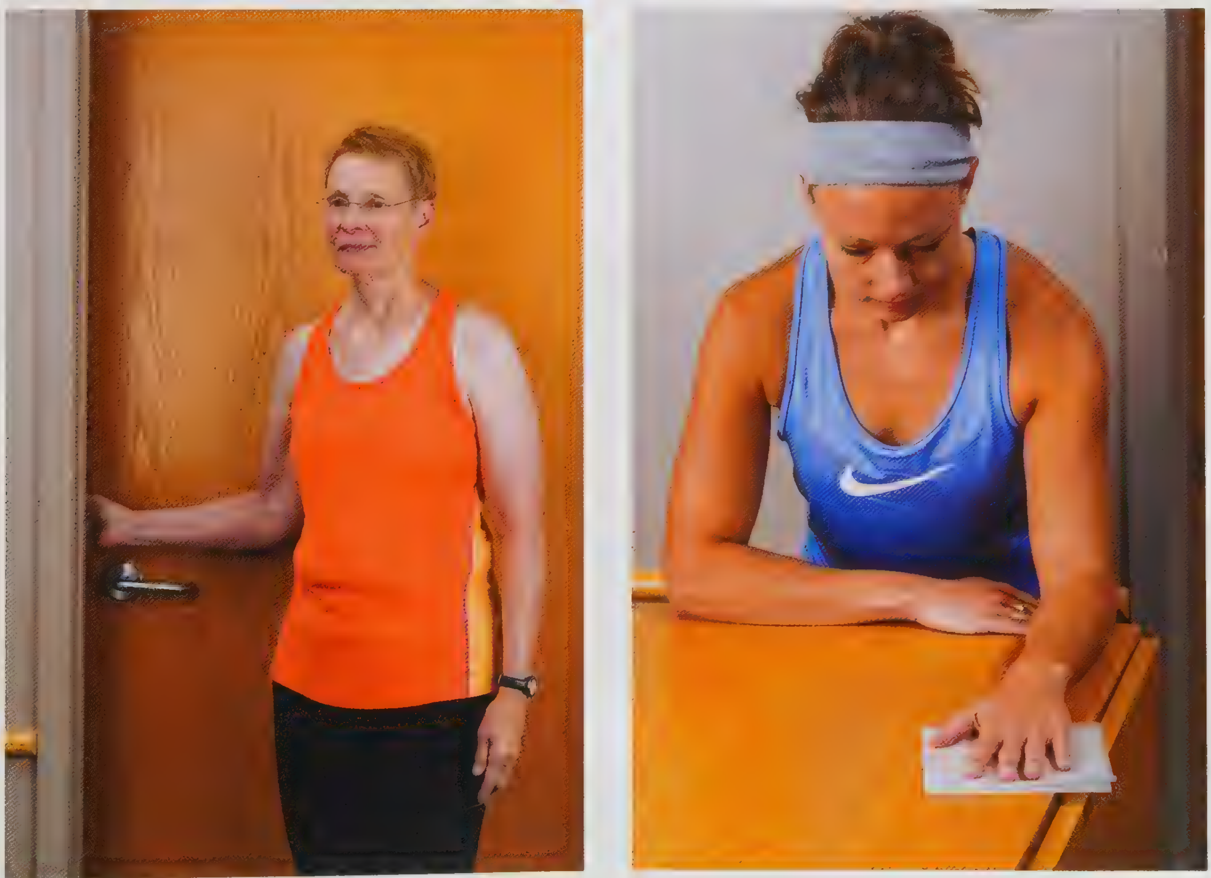
process. Although the cane is held in both hands, patients sometimes mistakenly believe that the involved extremity is not working during the activity. In many cases, the muscles are actively working and the exercise more closely resembles a guided AROM activity than a PROM or AAROM activity. If the exercise is truly passive, ensure that the patient understands the ROM limits for the exercise. When starting the exercise program, demonstrate and then guide the patient through the exercise performance. Dose the exercise the same as if the activity was being performed manually. Be sure to allow sufficient rest periods between exercise sets or sessions.

Horizontal and Vertical Surfaces Horizontal surfaces such as tabletops, desktops, floors and beds, and vertical surfaces such as walls, doors, and doorways provide ample opportunities for ROM exercises. Surfaces that allow the limb to slide easily (akin to a powder board or slide board) work best, although surface friction can be reduced by the addition of a towel, pillowcase, mitten, wax paper, or other similar material. Shoulder ROM in elevation can be performed by "walking" the fingers up a wall or doorway, or by walking the fingers out on a countertop, then forward bending at the hips to enhance the ROM (**Fig 7-15A** and **B**). Similarly, sitting at a desk, the patient can reach the arm forward on the desktop, and then slide the chair back to achieve greater overhead elevation. External rotation ROM can be performed by placing the hand in a doorway and turning away from the involved shoulder.

Use the floor or a bed to increase hip and knee flexion ROM. Either sitting or supine on the floor, slide the heel toward the buttocks to perform AROM. Pull a pillowcase or towel placed under the foot to perform PROM or AAROM (**Fig. 7-16**). Knee flexion ROM and ankle dorsiflexion ROM are easily performed sitting on a chair and sliding the foot back under the chair. A sock, pillowcase, or wax paper will decrease friction between the foot and the floor. Similarly, these activities can be performed in supine with one foot on the wall. Slide the foot down the wall to increase hip, knee, and ankle flexion. Crossing one ankle over the opposite knee and then sliding the foot down the wall will increase hip external rotation ROM.

These are only a few of the numerous examples of how horizontal and vertical surfaces can be used to perform self-ROM. When choosing an exercise, determine the amount of muscle activation allowed to ensure picking an exercise that can be done safely. Then query the patient about surfaces available at home and at work. Design a program that will be easy to perform in their living and working environments to increase program adherence. As best as possible, observe the patient performing the exercises. Dose the exercises the same as if they were being carried manually by the physical therapist (see **Building Block 7-3** on page 154).

Self-Range of Motion In the absence of tools, equipment, or other means of independent ROM, the patient can use the arms or uninvolved upper extremity to perform self-ROM



A

B

FIGURE 7-15 **(A)** Passive doorway stretch for shoulder external rotation. **(B)** Shoulder rotation using wax paper on counter.

FIGURE 7-16 Heel slides using a towel.

BUILDING BLOCK 7-3

The patient is a third-grade teacher who was recently out of a cast following a left wrist Colles fracture. He needs to increase his wrist AROM and PROM. Describe some activities he might do during his work day to increase ROM.

exercises. Self-ROM requires a baseline level of strength and coordination on the part of the patient, so the therapist should match patients with the appropriate level of activity. For example, a patient who has limited strength and mobility following a stroke may have insufficient strength or control to perform ROM on the involved arm or leg. Patients with multiple joint osteoarthritis or rheumatoid arthritis may not be able to use their arms to move other extremities because of pain.

Self-ROM can be performed in a variety of positions. The position chosen should consider the patient's strength and control, the desired working range, joint biomechanics (i.e., shoulder instability following a stroke, or hypomobility with impingement considerations), and the patient's ability to assume the preferred position(s). Modify the exercise as necessary to help the patient accomplish the activity. For example, when performing shoulder flexion ROM in supine, it may be necessary to flex the involved elbow to overcome gravity and lift the arm to the 90-degree position where gravity can begin to assist the exercise as the arm goes overhead.

In the upper extremities, the supine position allows the final range of shoulder elevation to be assisted by gravity. If this same exercise were performed in sitting or standing, the biomechanics of the exercise would increase the physical challenge of achieving the full overhead position. In contrast, the same exercise performed in supine allows gravity to assist at the end of the ROM (**Fig. 7-17A** and **B**). Upper extremity ROM activities that work well in supine are shoulder elevation, horizontal abduction and adduction, and rotation. Elbow flexion and extension and forearm pronation and supination are performed either in supine or sitting. In sitting, these activities are performed with the arm supported on the tabletop. Wrist and hand activities can be performed in supine but may work better in a sitting position with the arm resting on a tabletop. This position allows easier visualization of the activity being performed. Finger activities can be performed in nearly any position as long as visualization and stabilization are sufficient. In any case, be sure to observe the patient performing these exercises in the clinic to ensure proper performance. The patient may begin ROM exercises in one position and progress to an alternative position as improvement is made.

A B

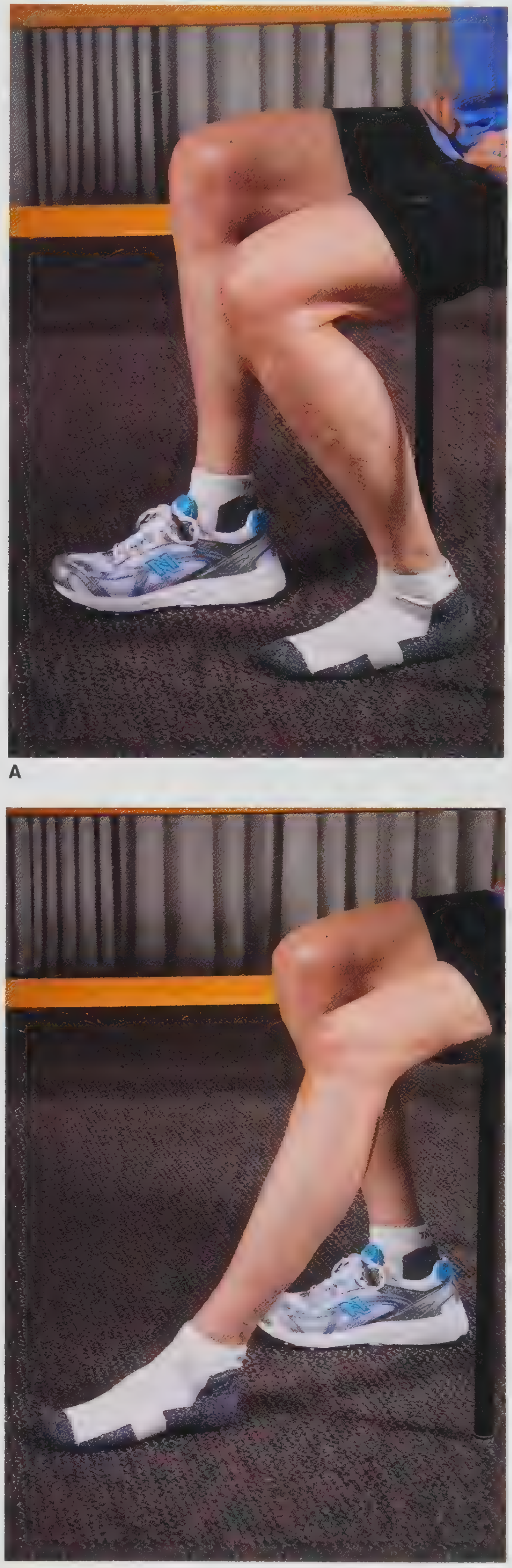
FIGURE 7-17 **(A)** Shoulder flexion in supine. Note that the moment arm length approaches zero at 90 degrees of forward flexion and further flexion becomes assisted by gravity. **(B)** Shoulder flexion in standing. The resistance because of gravity increases as the arm approaches 90 degrees flexion and continues to be resisted by gravity.

Like the upper extremities, lower extremity ROM can be performed in supine or sitting. In supine, hip and knee flexion can be performed by grasping behind the thigh with a towel or hands and pulling the knee toward the chest. This exercise requires abdominal strength to initiate the lift, and arm strength to pull the thigh toward the chest. Hip abduction and adduction can also be performed in supine, sliding the leg in and out, whereas hip internal and external rotation is performed in the same position, rolling the leg in and out. Rolling the leg internally and externally on a bed is relatively easy, whereas sliding the leg in abduction and adduction can be challenging against the friction of the bed. Some alterations can make this exercise simpler. First, if sufficient strength and control exist, the patient can slide the uninvolved ankle under the involved ankle and use the uninvolved leg to assist the activity. Also, lower friction surfaces can be used. A powder board or slide board under the involved leg can decrease friction. Lastly, wearing clothing and utilizing bedding of fabric that is "more slippery" than higher friction materials such as flannel will improve the ease of this exercise. If the patient is able to safely get down and back up off the floor and has tile, hardwood floors, or linoleum, the patient may lay supine on that surface with fabric that has higher friction and successfully perform the exercises on the floor.

Knee joint ROM exercises can be performed in supine by sliding the heel toward the buttocks, or in sitting. Sitting on the bed or floor, the patient slides the heel toward the buttocks. If ROM is to be passive, a pillowcase or towel under the foot can be pulled by the arms. In a chair, the patient can slide the foot forward and back, extending and flexing the knee, or if passive is preferred, the foot remains fixed on the floor and the patient slides his or her body forward and back over the fixed foot. Ankle PROM is easily performed passively by crossing the ankle over the opposite knee. Like the knee, PROM can also be performed with the foot fixed on the ground and moving the body anteriorly and posteriorly over it (**Fig. 7-18A** and **B**). Ankle AROM can be performed in nearly any position or posture. The same is true of the toes.

Trunk ROM exercises are more challenging because of the size and weight of the trunk. AROM exercises are performed in standing or sitting and involve trunk movements in cardinal, diagonal, or functional movement patterns. When performing PROM on land, it is usually performed in prone or supine, with the exception of side bending which is difficult to do passively independently. Passive extension is accomplished by a prone press-up, whereas flexion is performed in supine in a knee-to-chest exercise. Passive trunk rotation can be performed in hook lying, rolling the knees from one side to the other. However, on land, the effects of gravity may make these exercises uncomfortable. Many of these exercises are more comfortable in an aquatic environment.

Aquatic Environment The pool is an ideal place to perform ROM exercises. The water's buoyancy makes performance of any upward movement easier than on land. The effects of gravity resisting elevation are minimized and the water's buoyancy assists movement. Thus, many ROM activities requiring upward movement become AAROM exercises. This attribute of buoyancy is particularly useful for movements such as shoulder and arm elevation and hip flexion with knee extension during gait. The pool is particularly useful for individuals who lack the ability to perform self-ROM exercises on land. A few of the possible



A

B

FIGURE 7-18 **(A)** Passive ankle dorsiflexion by moving chair forward. **(B)** Passive ankle plantarflexion by moving chair backward.

FIGURE 7-19 Knee lift, moving the lower extremities on a fixed trunk in the pool.

reasons for this include multiple joint involvement, generalized weakness, paraparesis, or poor coordination.

Useful upper extremity movement patterns include cardinal plane flexion, extension, rotation, scaption, and abduction in a standing position. Combination patterns include functional diagonals, reaching and grasping, and pushing and pulling. Many of these combination patterns utilize all the joints throughout the upper quarter. Reaching behind the back also facilitates combination movements. These movements are generally supported or assisted by buoyancy.

Trunk movements are also easily performed in the water. Trunk rotation occurs passively by alternately flexing and extending the shoulder or actively by simply rotating the trunk. Side bending and flexion and extension can be performed by actively moving the trunk on fixed lower extremities, or by moving the lower extremities on a fixed trunk, such as when performing a knee lift (**Fig. 7-19**). Normal walking or exaggerated walking facilitates trunk rotation as a component of normal gait. Open chain hip abduction facilities trunk side bending.

Lower extremity movements are readily performed in isolation or in combination. Active hip flexion either with a straight leg or with a bent knee is assisted by buoyancy. Similarly, active hip abduction is assisted by buoyancy. Marching in place or across the pool is a functional ROM activity facilitating hip flexion motion. Sidestepping facilitates hip abduction ROM. Lunging, lunge walking, and squatting require multijoint movement in a functional pattern. Lifting the leg into hip flexion, abduction, and external rotation (i.e., figure 4 lifts) facilitates the functional movement of crossing one ankle over the knee to don socks and shoes. Nearly any joint motion of the lower extremity can be performed actively or with assistance in the pool. See Chapter 16 for more aquatic physical therapy suggestions.

STRETCHING

Stretching is one of the most common therapeutic exercise interventions applied by physical therapists. Although it is commonly prescribed and frequently utilized by rehabilitation experts, fitness experts, and the general public, proper applications and techniques are still not well understood. New information about the indications, effects, and optimal dosage of therapeutic stretching is published regularly.[12–15] The therapist must stay abreast of new information regarding stretching intervention as it becomes available.

Indications

Stretching techniques are used to increase the extensibility of the muscle tendon unit and the periarticular connective tissue. Stretching is used to increase flexibility, which depends on joint ROM and soft tissue extensibility. Stretching techniques fall into four broad categories: static stretching, ballistic stretching, dynamic stretching, and proprioceptive neuromuscular facilitation (PNF) stretching. Specific stretching exercises and methods within these broad categories can increase muscle and connective tissue extensibility and joint ROM.[16–28] The clinician must determine which stretching methods, in what sequence, and at what dosage can best resolve the impairments and activity limitations of each patient.

Stretching can be used to increase the length and to decrease the resistance to elongation (decrease stiffness) in a muscle-tendon unit or other connective tissue. However, there are some cases where stiffness and resistance to elongation might be preferred. For example, patients with paralysis or paresis because of spinal cord injury might rely on stiffness to provide stability in various postures or tasks. Similarly, patients with joint instability need some tissue stiffness around the joint to provide stability. Functionally, athletes involved in jumping sports need a combination of flexibility and stiffness to maximize performance.[13] However, in many cases, patients need increased extensibility of soft tissues because of existing hypomobility. Tissues with poor flexibility can produce pain locally in the inflexible tissue, in adjacent joints because of faulty biomechanics, or in opposing soft tissues as they become overworked attempting to overcome the resistance of the stiff or shortened tissue.

Other tissues besides the musculotendinous unit may require stretching. Loose areolar tissue, joint capsule, and supportive connective tissues may all benefit from stretching. Stretching can be combined with ROM exercises to maximize the impact of mobility activities. For example, a patient might perform ankle dorsiflexor and plantarflexor AROM followed by stretching of the Achilles tendon. Similarly, a patient might perform shoulder flexion PROM with a pulley followed by a prolonged stretch at end ROM.

Principles and Considerations in Stretching

Posture is a key aspect of any stretching activity performed. The starting and ending positions and the proper posture of associated joints are based on physiologic and kinesiologic factors. Physiologic factors such as the stage of healing affect the starting and ending positions for ROM and the position for stretching. For example, if a patient has just sustained an acute musculotendinous injury, the ending ROM avoids the extreme position of the muscle range that would place too much stretch on the injured tissue.

Kinesiologic factors include the normal osteokinematics and arthrokinematics at the joint. For example, proper performance of shoulder flexion requires normal arthrokinematic motion at the glenohumeral, sternoclavicular, and acromioclavicular joints and requires normal osteokinematic motion and associated

A B

FIGURE 7-20 **(A)** Seated hamstring stretch without appropriate lumbar stabilization stresses the lumbar spine because of lack of fixation. **(B)** Correct performance allows proper hamstring stretching.

arthrokinematic motion at the scapulothoracic articulation and thoracic spine. If motion is limited at any of these locations, substitution and faulty movement patterns occur. If an individual lacks glenohumeral arthrokinematic motion that limits glenohumeral flexion, scapulothoracic elevation or lumbar spine extension may substitute. Attempts to stretch the shoulder into further flexion can impinge subacromial soft tissues, cause substitution by adjacent joints, or both. The patient can learn an effective substitution pattern that prohibits normalization of movement patterns and the eventual progression to normal arthrokinematic and osteokinematic motion. Be sure to use joint mobilization techniques in this situation prior to performing stretching.

Another important kinesiologic factor is the stabilization of one attachment site of the muscle (usually proximal) or limb during stretching. For example, appropriately stretching the hamstring muscles requires proximal stabilization through proper lumbar and pelvic positions. Failure to stabilize proximally results in lumbar spine flexion, posterior pelvic tilt, and movement of the hamstring origin closer to the insertion, thereby minimizing the stretch (**Fig. 7-20A** and **B**). Maintaining correct posture that appropriately stabilizes is essential for effective stretching.

General procedures for stretching include a thorough examination to ensure stretching is indicated. Prior to stretching, the patient should perform a general warm-up to increase local blood flow and warm the tissue to be stretched. Active exercise for warm-up is preferable to local heat application, but hot packs can be used before stretching to warm local tissues. Use any relaxation technique necessary to enhance the stretching procedure. As with ROM techniques, use a grip technique that is comfortable for the patient or use family members or equipment such as pulleys, towels, or bands, or the pool for stretching. Stretching can be performed using equipment or steps, walls, or bars in the pool (**Fig. 7-21**). The buoyant atmosphere and water's warmth often make stretching more comfortable (see Chapter 16). As always, listen to the patient and modify techniques as necessary to ensure optimal outcomes. Ensure that the patient is feeling a stretching sensation and not pain or any other sensation. The patient should not stretch too aggressively. As a rule of thumb, the stretch should be mild and the stretching sensation should stop as soon as the stretch is released.

Neurophysiology of Stretching

In addition to the mechanical factors affecting stretching, the neurophysiology of the gamma system must be considered in exercise prescription. The muscle spindle and Golgi tendon organ (GTO) play important roles in the modulation of stretching. The muscle spindle is a specialized sensory organ comprised of intrafusal (nuclear bag and nuclear chain fibers) muscle fibers that lie in parallel with the extrafusal muscle fibers. Because they lie in parallel, stretching the extrafusal muscle fiber stretches and activates the intrafusal muscle fiber. The muscle spindle is sensitive to both changes in length and the velocity of these changes in the extrafusal muscle fiber. Type Ia and II afferent nerve fibers arise from the intrafusal fibers. The primary afferent nerve fiber from the nuclear bag intrafusal muscle fiber is principally sensitive to the rate of change of stretch.[29] If a muscle is stretched quickly, the type Ia fiber will facilitate contraction of the muscle being stretched as a protective mechanism to avoid injury. The type Ia receptor from the nuclear chain intrafusal muscle fiber responds to a maintained stretch and produces a maintained contraction. It is primarily affected by changes in muscle length, rather than velocity. Stimulation of type Ia fibers facilitates activation of the muscle being stretched. As with the type Ia fibers arising from the nuclear chain fibers, type II endings also arise primarily from the nuclear chain fibers and respond to maintained stretch with a maintained contraction.

FIGURE 7-21 Knee flexion stretching performed in the pool using buoyant equipment.

The GTO (type Ib fiber) attaches to the muscle tendon in series with the extrafusal muscle fibers and is sensitive to tension in the muscle caused either by stretching or by active muscle contraction.[29] Its function is protective, to prevent overstretching or excessive contraction of the muscle. When stimulated, the GTO inhibits its own muscle and facilitates its antagonist. This decreases the tension in the muscle being stretched. Thus the GTO can override the stimulus from the muscle spindle, facilitating relaxation of the muscle being stretched rather than contraction. The GTO is primarily responsible for the autogenic inhibition mechanism.

Static Stretching

DeVries[18–20] is credited with the initial research on the use and efficacy of static stretching and ballistic stretching. Static stretching is a method of stretching in which the muscles and connective tissue being stretched are held in a stationary position at their greatest possible length for some time period. Static stretching offers advantages of:

- Using less overall force
- Decreasing the danger of exceeding the tissue extensibility limits
- Lower energy requirements
- A lower likelihood of muscle soreness[19]
- Having less effect on type Ia and II spindle afferent fibers than ballistic stretching

When performing static stretching, position the patient to allow complete relaxation of the muscle to be stretched. This position requires a comfortable, supportive surface, or other external stabilization. Take the limb to the point at which a gentle stretching sensation is felt, and hold the stretch for 15 to 60 seconds (**Evidence and Research 7-1**). Relax the stretch and then repeat. Proper limb alignment ensures that the proper tissues are being stretched without causing injury to adjacent structures (see **Self-Management 7-5**).

SELF-MANAGEMENT 7-5
Hip Stretching

Purpose: To increase the flexibility of the lateral hip and thigh muscles

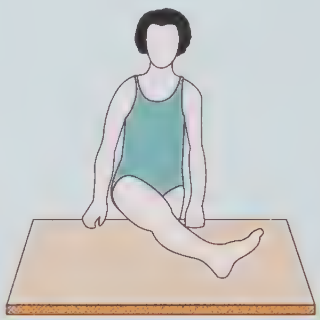
Position: Standing with the involved leg out on the surface (e.g., table, step) in front of you

Movement Technique: Keeping your hips square (do not rotate your hips), bring your leg across in front of you a few inches; next, roll your entire leg in the same direction (across your body). Hold 15 to 60 seconds or as directed by your physical therapist.

Dosage:

Repetitions: ______________________

Frequency: ______________________



EVIDENCE and RESEARCH 7-1

Patients always want to know how long to hold a stretch. In a group of subjects aged 21 to 39 years who stretched 5 days per week for 6 weeks, Bandy et al.[30] found that no increase in flexibility was found when the duration increased from 30 to 60 seconds or when the frequency increased from one to three times per day. Similarly, Ayala et al.[31] found no difference in 12 × 15-, 6 × 30-, and 4 × 45-second stretches when performed 3 days per week for 12 weeks. Note that the total stretching dosage was equal in all groups. This is in agreement with Cipriani et al.[32] and Johnson et al.[33] who suggested that the total stretch time per day was more important than any single stretch duration time. However, these studies were performed in young individuals. Feland et al.[34] found that subjects over 65 years of age demonstrated greater and longer lasting ROM improvements with 60-second stretch duration compared with 15- or 30-second durations.

Ballistic Stretching

Ballistic stretching uses quick movements that impose a rapid change in the length of muscle or connective tissue. Ballistic stretching takes the muscle to the end of its range and applies a rapid oscillating or "ballistic" stretch at end range.[35,36] Greater peak tension and greater energy absorption have been found with faster stretch rates, which is often the case with ballistic stretching.[37] Although ballistic stretching has been effective for increasing flexibility in athletes, there may be a greater chance of muscle soreness and injury.[19] Injury may result from excessive uncontrolled forces during ballistic stretching and proposed neurologic inhibitory influences (activation of type Ia afferent fibers) associated with rapid-type stretching.[22,38–43] For these reasons, ballistic stretching should be used only with selected patients, such as individuals preparing for active, dynamic, athletic, or plyometric activities. Research comparing ballistic stretching with static stretching has shown the two stretching techniques to produce different effects in the tissues.[44] Static stretching has been shown to decrease the passive resistive torque of the plantar flexors but having no effect on the Achilles tendon stiffness.[44,45] In contrast, ballistic stretching had no significant effect on the plantarflexor passive resistive torque, but decreased the Achilles tendon stiffness.[44]

The patient performing ballistic stretching should be well stabilized and comfortable. Move the limb until a gentle stretch is felt, and then gently "bounce" at the end range. Ballistic stretching is typically dosed as a number of repetitions or "bounces" for a certain time period. Ballistic stretching is often preferred over static stretching prior to many athletic activities (see "Stretching and Muscle Performance").

Proprioceptive Neuromuscular Facilitation Stretching

PNF stretching techniques are widely used by the physical therapy community. These techniques seek to capitalize on the use of the neurophysiologic concept of stretch activation. PNF stretching techniques use a contract-relax (CR) sequence, an agonist contraction (AC), or a contract-relax–agonist contraction (CRAC) sequence.[46] It has been suggested that PNF stretching techniques increase muscle ROM by using reciprocal and autogenic inhibition to induce relaxation.[47–49] Others add that increases in mobility following PNF techniques may arise from an increased tolerance to stretch, or by changes to the viscoelastic properties of the stretched muscle.[47,50] This type of stretching has been shown to increase ROM, maximal isometric strength, rate of force development, and musculotendinous stiffness.[48,51] The ability to increase ROM while concurrently increasing stiffness would be a great benefit to athletes, particularly those in jumping sports.

CR stretching utilizes autogenic inhibition. The therapist supports the patient's limb and brings it to the end ROM until gentle stretching is felt. At that point, ask for and resist an isometric contraction of the muscle being stretched for approximately 2 to 5 seconds and then ask the patient to relax the muscle. The therapist then passively increases the stretch. This procedure is repeated two to four times. Research has shown no difference in outcomes when the isometric hold duration was 3, 6, or 10 seconds.[52]

AC stretching uses the principle of reciprocal inhibition. Take the limb to the position of gentle stretch and ask for a contraction of the muscle opposite the muscle being stretched (the antagonist). This facilitates the stretch and inhibits the muscle undergoing stretch. For example, when stretching the hamstring muscles, a simultaneous contraction of the quadriceps muscles can facilitate the stretch. Hold the muscle contraction for 2 to 5 seconds and repeat the technique two to four times.

CRAC is a technique that combines CR and AC stretches. Take the limb to the point of gentle stretch, and perform a CR sequence (i.e., resistance applied against the muscle being stretched). After contracting the muscle being stretched, ask the patient to relax this muscle while contracting the opposing muscle group, thus facilitating the stretch. For example, when stretching the hamstring muscles, they are brought to a position of stretch. The hamstring muscles are contracted against resistance and then relaxed, and the quadriceps are contracted.

PNF stretching is indicated when muscle contraction in addition to stretching is appropriate. This type of stretching helps to improve strength and may help the patient better understand the continuum of contraction and relaxation. Some patients may find it easier to relax when contrasted with a muscle contraction. Each of these stretching techniques requires constant communication with the patient to ensure that neither overstretching nor excessive resistance produce muscle injury. These techniques can be performed independently with a family member or alone using a towel or other simple objects to provide resistance or assistance. Research shows both static and PNF stretching to be effective at increasing muscle ROM when dosage is equivalent.[53–56]

Dynamic Stretching

Dynamic stretching is a type of flexibility exercise where the limb is repeatedly taken through a ROM actively by the participant. The individual performs movements where the primary mover takes the limb through a ROM while the antagonist muscle relaxes and elongates.[57] For example, a reciprocal, dynamic knee extension with the hip at 90-degree flexion would be a dynamic flexibility stretch for the hamstring muscles (**Fig. 7-22**). The terms "dynamic stretching" and "dynamic warm-up" are often used interchangeably, as the term "stretching" typically implies taking a structure to its end range and holding it for some period. Typically dynamic stretching takes the structure to the limits of the range but does not hold this position. Other examples of dynamic stretching include lunge walking forward and back, lunges or squats up to a toe raise, hamstring curls, hip extensions, walking with hip rotations, and trunk activities. For those who cannot tolerate holding a static stretch, or who will be participating in activities requiring power or explosive speed, dynamic stretching is a good alternative to a traditional static stretching program (see **Building Block 7-4**).

BUILDING BLOCK 7-4

Denise is a 37-year-old mother of two who injured her right leg and hip in a motor vehicle accident (MVA) when she placed her foot against the floor of the car and sustained an impact injury up to her hip. She now has residual hip pain and limited mobility. She needs to increase hip external rotation ROM and hip strength. She is unable to tolerate a static stretch into hip external rotation. Please suggest alternatives.

A

FIGURE 7-22 **(A** and **B)** Dynamic knee extension as a warm-up activity for the hamstring muscles.

(Continued on next page)

B

FIGURE 7-22 (continued)

Measures of performance are better following dynamic stretching compared with static stretching[58–60] (**Evidence and Research 7-2**). Tendon stiffness and performance measures favor a dynamic warm-up compared with static or ballistic stretching prior to athletic activity.[62] Therefore, the type of stretching technique chosen should be specific to the patient and the purpose (i.e., increase flexibility, prepare for activity, etc.)

EVIDENCE and RESEARCH 7-2

A 4-week dynamic stretching warm-up resulted in increases in quadriceps peak torque, broad jump, underhand medicine ball throw, sit-ups, and push-ups compared with static stretching.[58] Similarly, performances in the T-shuttle run, underhand medicine ball throw, and the 5-step jump were improved immediately following a dynamic warm-up compared with a static warm-up.[59] Performance of high-speed motor skills such as the 10-m sprint also improved following dynamic warm-up compared with static stretching.[60] Gains in jump power poststretch were found in a group performing dynamic stretching prior to vertical jump.[61]

Effects of Stretching

Stretching is one of the most accepted interventions in rehabilitation. Different stretching techniques and dosage have been studied.[63,64] The effects of stretching are divided into acute effects and chronic effects. Acute effects are the immediate, short-term results of stretching and are the result of elongating the elastic component of the musculotendinous unit (see Figs. 11-2 through 11-4). Chronic effects are the long-term results of prolonged stretching and are the result of adding sarcomeres (usually because of immobilization in a lengthened position).[65] Different stretching techniques should be chosen based upon the immediate goal; a patient may use static stretching at times for the chronic effects, whereas using dynamic stretching for the acute effects at other times.

Chronic Stretching and Flexibility

The category of "chronic effects of stretching" has not been well defined. In general, chronic effects are the result of any regular ongoing stretching program of undefined dosage, and are contrasted with acute effects, which are the immediate, poststretching temporary changes. It appears that chronic stretching can improve flexibility, muscle performance, and functional performance.[64,66–70] Research has shown 30 minutes of daily stretching to increase the number of sarcomeres in series.[71] A study of immobilized soleus muscles found a 5% increase in length and a 4% increase in sarcomeres in series following a stretching dosage of 40 minutes per day, 3 days per week for 3 weeks.[72] Although regular stretching appears to increase flexibility, the research is not consistent about the dosage necessary to achieve these increases.[12,63,66,67,73,74] Differences in results may be because of the subjects under study, or research design issues (**Evidence and Research 7-3**).

EVIDENCE and RESEARCH 7-3

A large body of research supports increased flexibility outcomes following a regular stretching routine, typically ranging from 3 to 5 days per week, with a variety of stretching techniques (static, dynamic, ballistic, PNF) and stretching durations. Stretching hip flexor muscles for 1 to 2 minutes daily for 6 weeks resulted in significant ROM gains.[32] A 4-week program of stretching hamstrings found equal improvements in those who stretched daily compared with those who stretched three times per week provided they stretched at least two times per day.[75] Both static and dynamic hamstring stretching performed for 30 seconds three times per week for 4 weeks produced significant increases in hamstring length.[76] Sainz de Baranda[77] examined the American College of Sports Medicine's guidelines for stretching in a 12-week program with seven groups examining type of stretch and stretch dosage. All stretching groups improved flexibility compared with the control group, with no clear advantage for any stretch technique or stretch duration.

Research has shown that an 8-week program of regular stretching can increase active and passive flexibility and maximum torque and work.[49] Stretching using variable techniques (static, dynamic, PNF), with or without a partner and at varying dosages, has consistently shown increases in muscle flexibility[78,79] (**Evidence and Research 7-4**). Most research has been done on young healthy individuals, some active and some inactive. The differences in outcomes in some research may be because of the relative age, activity level, and baseline fitness of the population being studied. The effects of different stretching techniques in patient populations are relatively lacking. Therefore, it is essential that the limitations of the evidence and the appropriateness of application in any patient situation be thoroughly considered prior to implementing a program.

EVIDENCE and RESEARCH 7-4

Zebas and Rivera[28] demonstrated retention of gains from 2 to 4 weeks after the cessation of a 6-week stretching program. Research with inactive college students found improvements in hamstring flexibility following a 5-day per week × 4-week stretching program. These gains were subsequently lost during a 6-week no stretching period and then regained when the original stretching program was restarted. Flexibility gains in the second 4-week session were equivalent to the original flexibility gains.[80] Feland et al.[34] found retention of gains 4 weeks after cessation of a five times per week, 60-second hamstring stretching program in elderly individuals. Rancour et al. [81] found that stretching two to three times per week following a 4-week daily stretching program was sufficient to maintain gains made.

Regardless of the type of stretching method used, *chronic* stretching flexibility gains made may be retained even after the individual has stopped stretching for some time (**Evidence and Research 7-5**). For individuals with significant flexibility deficits, stretching should be part of their daily routine. After the goal is achieved, stretching one to three times each week may be sufficient to maintain gains.

EVIDENCE and RESEARCH 7-5

A study of an intense stretching program (40 minutes per day; 3 days per week × 10 weeks) resulted in significant improvements in flexibility, standing long jump, vertical jump, 20-m sprint, knee flexion 1 repetition maximum (RM), knee extension 1 RM, knee flexion endurance, and knee extension endurance.[67] However, other research has found no improvement in ROM, sprint time, or vertical jump following a 6-week stretching program.[66] These differing results highlight the important issues in determining the efficacy of chronic stretching. Significant effects on performance were found when the subjects were inactive or only recreationally active and the stretching was intense (15 stretches per session).[67] No improvement in performance was found when the subjects were collegiate track athletes who performed only four stretches.[66]

Chronic Stretching and Muscle Performance

Stretching has also been shown to improve muscle performance.[67] Increased hamstring torque production, bench press performance, trunk strength, power performance, and knee flexor and extensor strength and power have been demonstrated following stretching.[67,82–84] The mechanism of improved muscle performance with stretching is unclear. However, research has shown stretching to induce myoblast proliferation, increased muscle mass, and increased muscle fiber area.[65,85] A large body of animal research has shown less atrophy and improved muscle weight in soleus muscles that were stretched during immobilization compared with muscles that were immobilized only.[65,86,87] In some studies utilizing PNF stretching, the muscle contraction component may be responsible for increases in strength. Muscle activation in the contralateral leg working to stabilize the body while stretching has been suggested as another possible mechanism.[67] Regardless, a regular stretching program can improve muscle performance. There are limitations to the research and it is not being suggested that stretching can substitute for a well-designed resistive exercise program. For example, chronic stretching in collegiate track and field athletes demonstrated no improvement in flexibility, or sprint and vertical jump performances.[66] However, in situations where resistive exercise is contraindicated or the patient is unable to perform these activities, a stretching program has been shown to provide strength benefits.

Acute Stretching and Flexibility

The effects of routine stretching exercises are acute in nature. Most research has been done on the acute effects of stretching.[49] It is clear that acute stretching can increase the ROM and mobility of the connective tissue. Research has consistently found increases in flexibility immediately following stretching.[63,71]

The mechanism for short-term gains in flexibility after stretching techniques is unclear. Also, tissue compliance at rest is not necessarily related to tissue compliance during activity. It has been suggested that flexibility increases are not because of increased length or flexibility of the muscle, but rather because of an increased tolerance to the stretch.[88] Magnusson et al.[89] found that static and cyclic stretches both produce decreases in resistance to stretch, and that the increases in ROM were because of increased tolerance to the stretch, not to changes in the viscoelastic properties of the muscle. When comparing flexible versus inflexible individuals, the authors found that flexible subjects attained a greater angle of stretch with greater tensile stress and energy than inflexible individuals, apparently because of greater tolerance to the stretching sensation.[90] Additionally, strengthening exercises increased muscle stiffness that was unaltered by daily stretching.[91]

There is no agreement about which stretching technique is best.[16,17,21–25,27,28] According to some researchers, PNF techniques may be better than static or ballistic techniques for producing acute, short-term improvements in ROM.[92] These short-term improvements may result from contraction of antagonistic muscles while performing CRAC stretching, which is based on the principle of reciprocal inhibition.[38–42] Moreover, PNF techniques have been suggested to increase muscle performance as well, likely because of the isometric contraction component of the stretch.[67] Muscle stiffness has been decreased by performing a conditioning isometric or eccentric muscle action.[93] This muscle contraction causes a change in viscosity and resistance to molecular deformation, decreasing stiffness and resistance to stretch. Prestretch conditioning through active or passive movements (i.e., passive oscillations or active repetitive eccentric actions) may loosen actin–myosin bonds and increase stretching effectiveness.[46]

However, in the absence of continued activity, the short-term gains in flexibility may be lost. DePino et al.[94] found that improvements following four consecutive 30-second hamstring stretches were lost within 6 minutes of completing the last stretch. Following an *acute* stretching activity, hamstring flexibility returned to baseline levels within 3 minutes of concluding the stretch, although these subjects were resting quietly on a table with the hip and knee flexed between measurements.[94] In contrast, Ford et al.[63] found improvements that were retained for 25 minutes following the stretching session.

Acute Stretching and Muscle Performance

The impact of stretching on muscle and functional performance has been the subject of ongoing research. The conventional wisdom that stretching is necessary prior to an activity has been refuted. Importantly, the therapist must consider the population under study prior to drawing any definitive conclusions about the relative merits of any particular stretching regimen. In many cases, this research is done on healthy athletes who have no impairments. Thus, the applicability of this research to those patients with impairments or activity limitations because of hypomobility is limited.

In contrast to chronic stretching, acute static stretching of some lower extremity muscle groups has been shown to decrease muscle performance immediately after stretching.[57,95] Stretching, particularly slow static stretching, has been shown to reduce maximum strength, rate of force development, power, and explosive performance.[96] This appears to be true regardless of the type of stretch (static or CR).[97] A bout of three 45-second stretches with 15-second rest periods to the hamstrings, quadriceps, and plantar flexors resulted in a decrease in balance scores, and in reaction and movement time.[98] Stretches held for as little as 15 seconds still produced declines in muscle performance immediately following stretching.[99] Passive static and ballistic stretching prior to resistance training decreased the subsequent maximum repetition performance, suggesting impairments at the isolated muscle level.[62] Muscle groups involved in performing a functional countermovement vertical jump (i.e., hamstrings, gluteals, trunk extensors, quadriceps, and hip flexors) have been found to have decreased muscle performance immediately following static stretching.[95] A general warm-up plus static stretching resulted in significantly lower gains in vertical jump height compared with a warm-up alone or a warm-up plus dynamic stretching.[57] The static stretching appeared to negate the positive effects of the warm-up. The magnitude of inhibitory effects following an acute bout of stretching seems to be affected by stretching duration. A study of isokinetic strength following a 30- or 60-second bout of quadriceps stretching found that peak torque decrements were greater with the 60-second stretch compared with the 30-second stretch.[95] This finding is consistent with work showing that 60-second (8 minutes total) stretch of the calf, hamstring, gluteus maximum, and quadriceps muscles impaired a countermovement jump performance while the short-duration (30 second; 4 minutes) static stretch had minimal effects.[100] In general, if the individual is participating in a sport that requires explosive power, a dynamic warm-up is preferable to static stretching to sufficiently warm the tissue without compromising explosive power[101–103] (see **Patient-Related Instruction 7-1**).

Stretching and Joint Contractures

Joint contractures can occur following prolonged immobilization or surgery.[104] A joint contracture is an adaptive shortening of the connective tissue crossing and/or surrounding a joint that limits the ROM about that joint. The shortened tissues may be primarily the muscle–tendon unit or joint capsule.[104] However, following loss of joint ROM because of the primary soft tissue, other tissues secondarily shorten, lengthen, or are otherwise negatively affected. Depending upon the patient's history and the time interval between injury and physical therapy evaluation, it may be difficult to determine which tissue(s) are primarily at fault and which have secondarily adapted.

For those with joint contractures following prolonged immobilization, simple return to activity is insufficient in restoring joint ROM.[104] Stretching to the soft tissues and joint mobilization to the joint capsule are often employed to restore ROM.[105] Basic science research has shown that the tensile force produced by stretching, particularly long duration stretching, results in fibroblast proliferation.[106,107] Low-torque, long-duration stretching produced better outcomes than short-duration, high-torque activities.[108] This type of stretching can be applied manually but can prove tiring when applied by a therapist or a family member. Other tools or devices can be utilized to provide this stretch. For some, just the weight of the limb is sufficient to provide this stretch. For example, a prone hang with or without an ankle weight will provide a prolonged stretch for someone with a knee flexion contracture (**Fig. 7-23**). A similar stretch can be performed in long sitting with distal traction provided by a weight stack or resistive band. This can be combined with weights on the top of the knee to provide additional force into extension (**Fig. 7-24**).

External devices are also useful for providing prolonged stretch.[109] A drop-out cast can be used to increase knee extension ROM. A study of four patients with knee flexion contractures found that this intervention can increase knee extension ROM without compromising knee flexion ROM.[110] Serial casting can be used to provide a low load long duration stretch. The limb is casted in a position that provides a slight stretch to the

Patient-Related Instruction 7-1: Key Points About Stretching

Stretching to Improve Flexibility	Stretching Prior to Performance
1. Discuss the appropriate stretching technique and dosage with your physical therapist or health care provider 2. Stretching 3 to 5 days per week for 4 weeks or more should produce measurable gains in flexibility 3. Thereafter flexibility can be maintained with stretching at least two times per week 4. Precede stretching with a general warm-up to increase muscle temperature and local blood flow 5. Stretch only to the point of a medium stretching sensation	1. Discuss the appropriate stretching technique and dosage with your physical therapist or health care provider 2. The type of stretching recommended will vary with any injury or pathology and the type of activity you are performing 3. Stretching prior to explosive, jumping, or high-speed activities should be dynamic; any static stretching prior to this type of activity should be of short duration (<30 seconds) 4. Utilize static stretching for postactivity cool down

FIGURE 7-23 Prone hang to increase knee extension ROM.

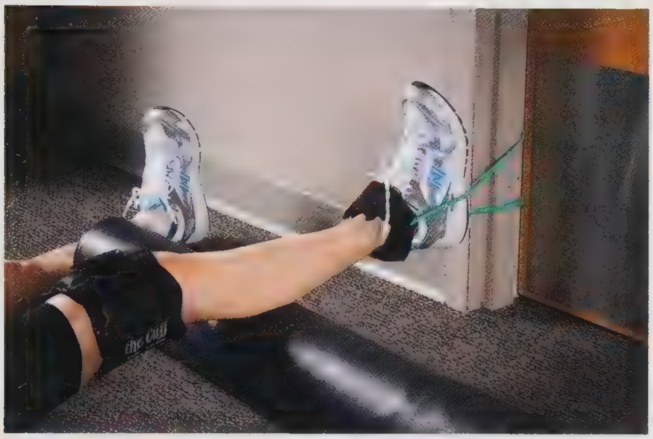


FIGURE 7-24 Prolonged passive knee extension with distal traction.

tissue. Once the tissue has accommodated to the new length, the cast is removed and a new cast applied, again, moving the limb into further stretch. Serial casting has the disadvantages associated with continuous immobilization. Significant atrophy and joint deterioration can occur from decreased loads on the tissues during immobilization. Because the immobilization is continuous, there is no opportunity for using the new range as it is acquired. Additionally, there is no opportunity to view the limb during immobilization. Atrophy, skin breakdown, or other complications can arise without the patient or clinician's ability to visualize the problem. Any suspected problem requires cast removal. Casting is also contraindicated in many patients because of such potential problems. Patients with diabetes, skin breakdown, hyperhidrosis, vascular disease, or sensory impairments are not candidates for serial casting.

Commercial dynamic splinting systems such as Dynasplint (Severna Park, MD) are available to provide low load long duration stretching (**Fig. 7-25A** and **B**). These systems can be rented or purchased for home use by the patient. A variety of commercial systems exist (i.e., Dynasplint, Ultraflex, LMB Pro-glide, EMPI Advance, and SaeboFlex), and each has its own design and specifications. Most provide a three- or four-point tension to distribute loads across a larger surface area, decreasing the high-stress region. Most importantly, these systems are designed to be used for only 6 to 8 hours per day.

A B

FIGURE 7-25 **(A)** Dynasplint used to increase upper extremity mobility. **(B)** Dynasplint used to increase lower extremity mobility.

This allows visualization of the limb both during and following the stretching session. It also allows use of the limb between stretching sessions, negating many of the problems associated with prolonged immobilization.

These commercial systems are available for many different joints including the shoulder, elbow, forearm, wrist and hand, jaw, as well as the knee, ankle, and foot.[111] The splints are applied by a therapist, and the patient or family member can learn how to don and doff the splint. The initial tension is set by the therapist and the patient is instructed in appropriate progression. Some splints, like the Dynasplint, have a preset load that remains constant during the stretching session. The tension should be at a low level that can be maintained for 6 to 8 hours without pain. Other splints, like the Joint Active System, allow the patient to set the tension at the beginning of the stretching session. The stretch is increased every few minutes throughout the 30-minute session. The sessions are repeated throughout the day. The commercial systems are typically available for either rental or purchase. These systems are an adjunctive treatment to therapeutic exercise and have shown good results for improving joint ROM.[112,113]

JOINT MOBILIZATION TO INCREASE MOBILITY

Manual therapy techniques such as joint mobilization are used to improve the mobility of joints. The *Guide to Physical Therapist Practice*[114] defines mobilization/manipulation as a "continuum of skilled passive movements to the joints and/or related soft tissues that are applied at varying speeds and amplitudes, including small-amplitude/high velocity therapeutic movement." Manipulation is a type of mobilization that is generally performed at a high velocity through a small amplitude. Various models of manual therapy exist, each with its own definitions and classification of mobilization/manipulation. For example, Maitland[115] describes five levels of mobilization, whereas Kaltenborn[116] specifies only three (**Fig. 7-26**). Regardless of the classification system, these schools of thought all focus on increasing joint mobility by increasing the joint play, or motion between the joint surfaces. Use of mobilization/manipulation techniques requires an understanding of the normal joint architecture, arthrokinematics, and the specific pathology to determine which interventions are appropriate (**Evidence and Research 7-6**).

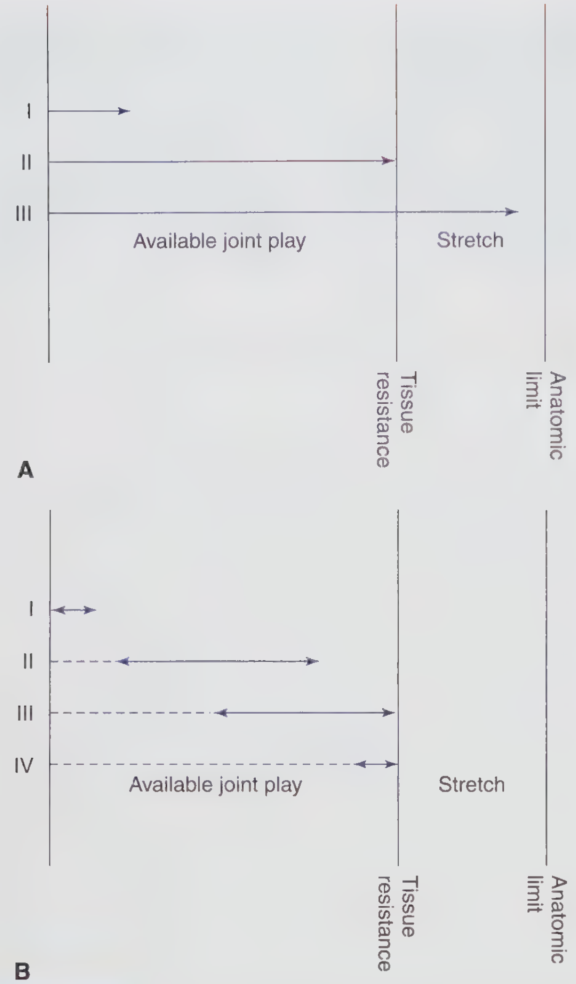


FIGURE 7-26 **(A)** Kaltenborn grades of mobilization. **(B)** Maitland grades of mobilization.

EVIDENCE and RESEARCH 7-6

Researchers have examined the ability of joint mobilization techniques to increase joint ROM.[117,118] Hsu et al.[117] examined the effects of anterior and posterior translational mobilization performed in the resting (loose packed) position and at end-range abduction on shoulder rotation and abduction ROM in cadaver specimens. Both anterior and posterior glides at end range increased abduction ROM, whereas these same glides performed in the resting position were less effective. Small increases in lateral rotation were found after anterior glides in the resting position and in medial rotation after posterior glides at end range.

Roubal et al.[118] found that inferior and posterior mobilizations after a brachial plexus block in patients with adhesive capsulitis increased motion in flexion, abduction, internal rotation, and external rotation. Range increased in all four directions despite no anterior mobilization treatment, suggesting that mobility was limited more by capsular tension than joint geometry. In a series of case studies, Vermeulen et al.[119] found increased ROM in all directions, increased joint capsule volume, and increased function in a group of patients with adhesive capsulitis treated with end-range joint mobilization.

Biomechanics of Joint Mobilization

Movement occurs at a joint when one joint surface moves on another relatively fixed joint surface. Roll, spin, and glide (also called slide) are the major categories of arthrokinematic motion found in human joints.

- Roll occurs when new points on one joint surface meet new points on the opposing joint surface.
- Spin is a pure rotational movement in which rotation occurs about a fixed axis. Motion of the radial head during pronation and supination is an example of spinning.
- Gliding or sliding occurs when one point on a moving surface continually comes in contact with new points on the opposing surface. Gliding is the predominant motion used in joint mobilization techniques.

In addition to roll, spin, and glide, compression and distraction of the joint can occur. Compression techniques are often used to facilitate muscular cocontraction and joint stabilization, whereas distraction is used in conjunction with joint mobilization to increase joint mobility or decrease pain. In most arthrokinematic motion, a combination of these movements occurs.

Some joint play must exist for arthrokinematic motion to proceed normally as the limb moves through the ROM (osteokinematic motion). The type and direction of arthrokinematic motion is determined in part by the relative shape of the joint surfaces. Most joint surfaces are classified as either ovoid or sellar. In an ovoid joint, one joint surface is concave, whereas the other is convex. For example, at the glenohumeral joint, the glenoid fossa is concave, whereas the humeral head is convex. In a sellar joint, both surfaces are both concave and convex. The carpometacarpal joint of the thumb is an example of such a joint. The convex–concave rule dictates the direction of gliding of one joint surface on the other and forms the basis for joint mobilization techniques. When a convex surface is moving on a fixed concave surface (such as the humeral head moving on the stationary glenoid during glenohumeraql abduction) the movement of the convex bone is in the direction opposite the convex articulating surface. In this case, the convex humeral head glides inferiorly as the humeral shaft moves superiorly. The opposite is true when a concave surface moves on a stationary convex surface. For example, movement of the concave tibial joint surface on the stationary concave femoral condyles is in the same direction as the tibial movement. Thus the tibial joint surface will move posteriorly as the tibia moves into flexion.

However, the human body does not always follow our rules, and the convex–concave rule is one of these. Following this rule at the shoulder would suggest that an anterior glide is used to increase mobility in external rotation, horizontal abduction, and extension, whereas a posterior glide is used to increase motion into internal rotation, horizontal adduction, and flexion. A study by Howell et al.[120] found that when the arm was placed in a maximally cocked position (abduction, extension, and lateral rotation) the humeral head was actually resting approximately 4 mm posteriorly. Additionally, Harryman et al.[121] found anterior humeral head translation with glenohumeral flexion and horizontal adduction and posterior translation with extension and lateral rotation. These apparent violations of the convex–concave rule may be the result of joint capsule tightening during rotation that is unique to the glenohumeral joint. Thus applying a single rule to all joints may mislead the clinician.

The primary indication for joint mobilization is a joint restriction resulting in a limitation in AROM and PROM at the joint. This is especially true in the case of a capsular end feel and loss of ROM in a capsular pattern. Remember that a number of structures can limit ROM at a joint; joint mobilization is most effective when the tissue limiting ROM is the joint capsule. This is generally assessed via joint play.

Joint mobilization is contraindicated in the case of joint infection, neoplasm, acute inflammation, or recent fracture. Caution must be used in cases of connective tissue disease, osteoporosis, hypermobility, or edema.

Mobilization Grades

Manual therapists use different mobilization grades depending upon their background and training. The two most commonly used grading systems are those developed by Kaltenborn and Maitland.[115,116] They are distinguished by the number of grades and the criteria for each grade. Kaltenborn[116] defines three grades of mobilization by the amount of force applied, whereas Maitland[115] describes his grades by the amplitude and position in the range. Kaltenborn techniques are a sustained translation, whereas Maitland's are an oscillation. Kaltenborn[116] grades are:

- Grade I: A low-level distraction force
- Grade II: A greater force that takes up the available joint play
- Grade III: A force that stretches the joint tissue after the available joint play has been taken up.

Maitland[115] grades are as follows:

- Grade 1: Small amplitude rhythmic movements near the beginning of the ROM
- Grade 2: Large amplitude rhythmic oscillations performed within the available range, but not reaching the limit
- Grade 3: Large amplitude rhythmic oscillations performed to the limit of the range and into the tissue resistance
- Grade 4: Small amplitude rhythmic movements performed at the limit of the range and into the tissue resistance
- Grade 5: Small amplitude, high-velocity thrust techniques performed at the end of the ROM for the purpose of breaking adhesions

Maitland[115] emphasizes not only the amplitude of the oscillations, but also the rhythm and amount of pressure. He suggests that grade I oscillations for pain must be extremely gentle using a very light touch. These oscillations stimulate joint receptors and decrease the perception of pain by the central nervous system. The rhythm of oscillations can be varied from quick staccato movements into a stiff range, to smooth, rhythmic oscillations into and out of the painful or stiff region. When using grade II oscillations, the greater the pain, the slower and smoother should be the oscillations. Note that Maitland grades I and II joint mobilizations do not stretch the capsule to the barrier; as such, they most likely do not increase mobility at the joint, but rather, are effected in controlling pain via the gate theory.

Joint traction or distraction is used to relieve the compression of painful joint surfaces and is used along with most mobilization techniques to separate joint surfaces during the mobilization procedure.

General Procedures

Be sure your patient is relaxed and positioned comfortably on the treatment table. Muscle guarding resulting from discomfort or apprehension will interfere with the treatment and place undue stress on both the patient and the therapist. Position yourself to optimize body mechanics, making use of body weight and leverage to minimize your energy expenditure. Use external devices such as the table, positioning, belts, and wedges to stabilize the patient and minimize therapist efforts. Be sure your grip is firm, using as large and wide a portion of your hand as possible. This will minimize painful pinching or a painful localized force application. Grasp as close to the joint line as possible with both the mobilizing and the stabilizing hand. Provide gentle traction to the joint while performing mobilizations. Understand the joint anatomy and arthrokinematics to minimize chances of painful joint compression forces. Oscillations are performed at a rate of 2 to 3 per second for approximately 1 minute. Reevaluate the joint and repeat, or choose another grade or direction as necessary.

Most joint mobilizations are initiated in the loose packed position of the joint. As stated earlier, this is the position where the joint capsule has its greatest capacity. The loose packed positions of most joints of the body have been identified and are listed elsewhere. As each person is unique, variations in the loose packed position (sometimes called the resting position) do exist. Kaltenborn[116] suggests finding the resting position by trying gentle traction in a variety of positions. This position with the most movement is the resting position. Kaltenborn suggests commencing mobilization in this position. If the purpose of the mobilization is to stretch the tissue, then perform the mobilization nearer the limit of mobility, closer to the barrier. Performing the mobilization closer to the end range has proven more effective in increasing motion than performing mobilizations in mid-range.

Applications to Specific Joints

Selected mobilization techniques for the spine and extremities will be described. Realize that this is only an overview of techniques and is not comprehensive. Additionally, many modifications are available, and the specific positioning will vary with available resources and patient and therapist preferences. The descriptions can be found in **Displays 7-2** to **7-8** and **Figures 7-27** to **7-44**.

NEURAL MOBILITY

Pain perceived in various regions of the upper quarter (neck, upper back, chest, shoulder, and arm) or the lower quarter (low back, buttocks, hips, and legs) can be the result of pathology in the spine and associated tissues, or from local structures. Neural tissues can be the source of pain, and vigorous stretching can exacerbate pain arising from these tissues.[122,123] A hallmark of neural tissue involvement in a pain syndrome is the response to provocation tests. Provocation tests are those examination procedures that selectively stress different neural tissues with functional positions.[122] These positions tension the neural tissues, and the area of tension or pathology can be identified by the results of these testing positions. For example, adding ankle

DISPLAY 7-2

Shoulder Joint Mobilization

Glenohumeral Anterior Glide

Purpose: To increase shoulder external rotation and extension
Position: Patient is prone with shoulder at edge of table and abducted to 90 degrees in scaption, elbow flexed to 90 degrees; mobilizing hand on posterior humeral head while stabilizing hand holds mid-humerus. Forearm on the patient can rest on a rolling stool for comfort and to encourage the patient to relax
Mobilization: Anterior force applied by mobilizing hand to humeral head while stabilizing hand applies gentle traction. The direction of mobilization is parallel to the plane of the joint; in this case the mobilization is from posterior and lateral to anterior and medial.
Glenohumeral Posterior Glide
Purpose: To increase shoulder flexion and internal rotation
Position: Patient is supine with the shoulder at the edge of the table, scapula stabilized by the table or towel roll; abducted to 45 degrees and elbow slightly flexed; mobilizing hand on anterior humeral head and stabilizing hand supporting elbow
Mobilization: Posterior force applied by mobilizing hand to humeral head while stabilizing hand applies gentle traction. The force is parallel to the plane of the joint

Glenohumeral Inferior Glide

Purpose: To increase shoulder abduction and flexion
Position: Patient is supine with the arm in 30- to 45-degree abduction; stabilizing hand supports scapula in axilla while mobilizing hand grasps distal humerus
Mobilization: Inferior force applied by mobilizing hand while stabilizing hand holds scapula steady, if necessary
Acromioclavicular Joint Anterior Glide
Purpose: To increase joint mobility
Position: Patient is positioned sitting; stabilize the scapula with thumb along the scapular spine and fingers along acromion; mobilizing hand placed on posterior clavicle near joint line
Mobilization: Mobilizing hand imposes an anterior force on the clavicle

Sternoclavicular Joint Superior/Inferior and Anterior/Posterior Glides

Purpose: Superior glide increases depression, whereas inferior glide increases elevation; anterior glide increases protraction, whereas posterior glide increases retraction
Position: Patient is supine with the stabilizing hand on the sternum and the mobilizing thumb or thumb and index finger on the proximal clavicle; alternatively both thumbs can be stacked one of top of each other on the proximal clavicle
Mobilization: Superior glide—the index finger applies a superior force to clavicle; inferior glide—thumb applies an inferior force to clavicle; anterior glide—thumb and index finger lift the clavicle; posterior glide—thumb applies a posterior force to clavicle

Scapular Mobilization

Purpose: To increase mobility at the scapulothoracic articulation
Position: Patient is in prone or side-lying; superior hand is along scapular spine while inferior hand grasps inferior angle of the scapula
Mobilization: Mobilize the scapula in elevation, depression, adduction, abduction, or rotation by pushing the appropriate direction

DISPLAY 7-3

Elbow Joint Mobilization

Elbow Humeroulnar Distraction

Purpose: To increase elbow joint mobility in flexion or extension
Position: Patient is supine with the elbow flexed to approximately 70 degrees, wrist resting on the therapist's shoulder; both hands grasp proximal ulna, humerus is strapped to the table OR one hand on humerus and one hand on ulna.
Mobilization: A distal force applied against the proximal ulna

Elbow Humeroradial Anterior or Posterior Glide

Purpose: Anterior glide to increase flexion, posterior glide to increase extension
Position: Supine with the elbow extended and supinated as far as possible; stabilizing hand grasping the medial distal humerus; proximal palm of stabilizing hand on anterior radial head with fingers on the posterior aspect
Mobilization: A posterior glide force provided by the palmar aspect of the hand, or an anterior force provided by the fingers

Elbow Radioulnar Anterior and Posterior Glide

Purpose: Anterior glide to increase supination, posterior glide to increase pronation
Position: Patient sitting or supine with the elbow extended and supinated as far as possible for posterior glide or extended and pronated as far as possible for anterior glide; stabilizing hand grasps proximal ulna with thenar eminence on anterior aspect and fingers on posterior aspect; mobilizing hand is in same position over the proximal radius
Mobilization: Posterior force on radial head for posterior glide; anterior force on radial head for anterior glide, both while stabilizing hand holds ulna steady

DISPLAY 7-4
Wrist and Hand Mobilization

Interphalangeal or Metacarpal Palmar and Dorsal Glide

Purpose: Palmar glide to increase flexion, dorsal glide to increase extension
Position: Patient's palm faces down with joint in resting position; stabilizing hand holds proximal bony segment while mobilizing hand grasps distal bony segment
Mobilization: With mobilizing hand, move distal segment toward the palm to increase flexion or toward dorsum to increase extension while applying gentle traction

Thumb Metacarpal–Carpal Radial and Ulnar Glides

Purpose: Ulnar glide to increase flexion; radial glide to increase extension
Position: Patient's hand is positioned with the ulnar side down, joint in a resting position; stabilizing hand grasps distal forearm with grip around trapezium while mobilizing hand grasps first metacarpal
Mobilization: With mobilizing hand, glide metacarpal toward radius to increase extension, or toward ulna to increase flexion while applying gentle traction

Thumb Metacarpal–Carpal Dorsal and Palmar Glides

Purpose: Palmar glide to increase adduction; dorsal glide to increase abduction
Position: Patient's hand is positioned with the palm either up or down, joint in a resting position; stabilizing hand grasps distal forearm with grip around trapezium while mobilizing hand grasps first metacarpal
Mobilization: With mobilizing hand, glide metacarpal toward palm to increase adduction, or toward dorsum to increase abduction while applying gentle traction

Wrist Palmar and Dorsal Glides

Purpose: Palmar glide to increase extension, dorsal glide to increase flexion
Position: Patient's forearm rests on table or wedge with the carpal joint at the edge; forearm is pronated for palmar glide and supinated for dorsal glide; stabilizing hand steadies the distal forearm against the table or wedge; mobilizing hand grasps the distal wrist
Mobilization: Apply a downward force with mobilizing hand while applying gentle traction

DISPLAY 7-5
Hip Joint Mobilization

Hip Distraction/Distal Traction

Purpose: Pain relief and general mobility
Position: Patient is supine or prone on the table, with the pelvis stabilized with a belt; therapist grasps either the distal thigh or the distal calf, depending upon whether or not you want distraction through the knee joint; a belt can be used around your waist and hands to reinforce the grip and allow use of body weight
Mobilization: A distal traction force is applied to the leg by shifting your body weight backward

Hip Lateral Traction

Purpose: Pain relief and general hypomobility
Position: Patient is supine with pelvis stabilized with a belt; the hip may be in any degree of flexion to extension depending upon the direction of hypomobility; mobilizing belt is placed around your pelvis and the patient's proximal thigh
Mobilization: Lean backward to apply a lateral traction force to the hip

Hip Anterior Glide

Purpose: Increase extension and external rotation
Position: Patient is prone with knee flexed to 90 degrees and a firm wedge or towel roll placed under the anterior pelvis; mobilizing hand just distal to posterior hip, and stabilizing hand grasps ankle to stabilize leg
Mobilization: Anteriorly directed force through mobilizing hand via forward weight shift

Hip Posterior Glide

Purpose: Increase flexion and internal rotation
Position: Supine with hip near full flexion, knee flexed, pelvis stabilized on table or with additional wedges or support; mobilizing hands on patient's knee
Mobilization: A posteriorly directed force through the long axis of the femur

DISPLAY 7-6

Knee Joint Mobilization

Tibiofemoral Anterior Glide

Purpose: Increase extension
Position: Patient is prone with the knee at the edge of the table; mobilizing hand is just distal to knee joint and stabilizing hand supports anterior ankle
Mobilization: Anteriorly directed force downward through mobilizing hand while stabilizing hand applies gentle distal traction

Tibiofemoral Posterior Glide

Purpose: Increase flexion
Position: Patient is supine or sitting with the knee at the edge of the table; mobilizing hand is just distal to the knee joint and stabilizing hand supports posterior ankle
Mobilization: A posteriorly directed force through mobilizing hand while the stabilizing hand applies gentle distal traction

Patellofemoral Joint Mobilization

Purpose: Increased general patellar mobility; and superior glide for increased extension, inferior glide for increased flexion
Position: Supine with knee supported by table, wedge, or towel roll; mobilizing thumb and index finger placed along patellar border oriented to direction of mobilization
Mobilization: Apply a medially, laterally, superiorly, or inferiorly directed force to the patella

DISPLAY 7-7

Foot and Ankle Mobilization

Ankle Anterior Glide

Purpose: Increase plantarflexion
Position: Prone with foot hanging just over the edge of the table; stabilizing hand under the anterior distal tibiofibular joint; mobilizing hand on the posterior calcaneus, just distal to joint line
Mobilization: Apply a downward, anteriorly directed force to the calcaneus while applying gentle traction

Ankle Posterior Glide

Purpose: Increase dorsiflexion
Position: Supine with foot just over the edge of the table; stabilizing hand under the posterior distal tibiofibular joint; mobilizing hand grasps anterior ankle just distal to joint line
Mobilization: Apply a downward, posteriorly directed force to the ankle while applying gentle traction

Ankle Traction

Purpose: Pain relief and general mobility
Position: Supine with leg stabilized by a strap and foot just over the edge of the table; both hands grasp the foot, one posterior on the calcaneus and the other anteriorly over the midfoot
Mobilization: Lean backward to produce a distal traction to the talocrural joint

Metatarsal and Phalanges Glide

Purpose: Increase mobility of toes
Position: Supine with foot over the edge of the table; stabilizing hand grasps metatarsal while mobilizing hand grasps phalanges
Mobilization: Apply dorsal and ventral mobilizations while applying gentle traction

DISPLAY 7-8

Spine Mobilization

Cervical and Thoracic Spine Posterior to Anterior Glide

Purpose: Increase segmental mobility and pain relief
Position: Patient is prone with towel under forehead or on mobilization table; therapist's thumbs placed one on top of the other, directly over the spinous process to be treated; spread hands over the adjacent neck or back area, keeping shoulders directly above treatment area
Mobilization: Apply a direct posterior to anterior force to the spinous process; this technique can also be performed with thumbs on the transverse processes unilaterally or bilaterally

Cervical and Thoracic Spine Lateral Glide

Purpose: Increase general mobility and unilateral pain relief
Position: Patient is prone; therapist's thumbs placed one on top of the other, directly over the lateral side (right or left) of the transverse. Process to be treated; spread hands over the adjacent neck or back area
Mobilization: Apply gentle pressure to lateral border of transverse process

Lumbar Spine Posterior to Anterior Glide

Purpose: Increase segmental mobility and pain relief
Position: Patient is prone; therapist's ulnar border of the hand over the spinous process to be treated; the other hand reinforces the mobilizing hand by resting on top of it and grasping the radial border of the wrist with the fingers; keep your shoulders directly over your hands; this technique can be modified to provide unilateral pressure to the transverse process using your thumbs adjacent to one another
Mobilization: A gentle rocking motion provides an anteriorly directed force over the spinous process

Lumbar Lateral Glide

Purpose: Increase segmental mobility and pain relief
Position: Patient is prone with the therapist's thumbs (one on top of the other) on the lateral side of the transverse process to be mobilized
Mobilization: Apply a horizontal pressure to the lateral border of the transverse process

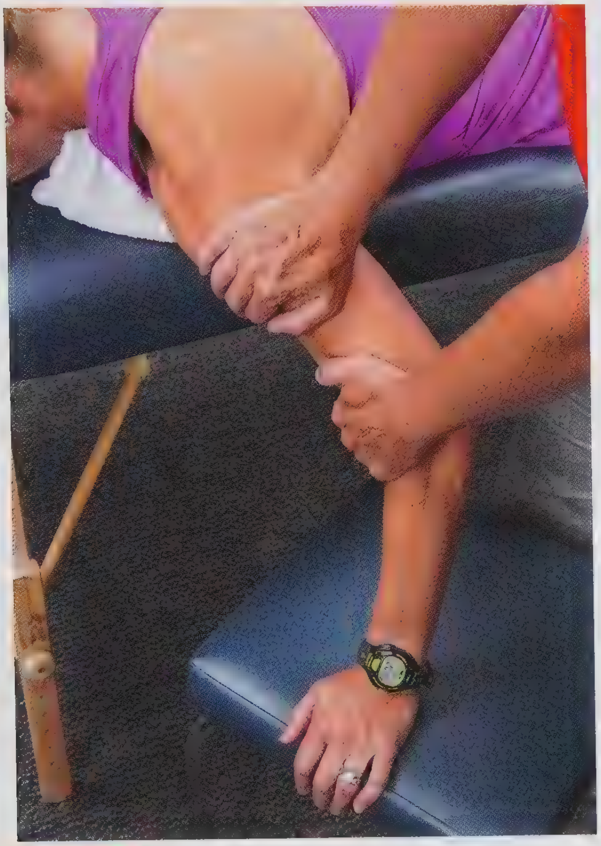


FIGURE 7-27 Glenohumeral anterior glide.

FIGURE 7-28 Glenohumeral posterior glide.

FIGURE 7-29 Scapular mobilization.

FIGURE 7-30 Humeroradial anterior glide.

FIGURE 7-31 Radioulnar posterior glide.

FIGURE 7-32 Interphalangeal palmar glide.

FIGURE 7-33 Thumb metacarpal–carpal dorsal glide.

FIGURE 7-34 Wrist dorsal glide.

FIGURE 7-35 Hip distraction.

FIGURE 7-36 Hip anterior glide.

FIGURE 7-37 Tibiofemoral anterior glide.

FIGURE 7-38 Tibiofemoral posterior glide.

FIGURE 7-39 Anterior glide of the talus.

FIGURE 7-40 Posterior glide of the talus.

FIGURE 7-41 Metatarsal glide.

FIGURE 7-42 Cervical spine posterior to anterior glide.

FIGURE 7-43 Thoracic spine lateral glide.

FIGURE 7-44 Lumbar spine posterior to anterior glide

dorsiflexion to a straight leg raise (SLR) maneuver increases the tension in the nervous system up to the cerebellum.[123] Adding hip movements to the SLR can help differentiate ankle symptoms arising from the neural structures versus local ankle structures.[124] In the upper extremity, components of shoulder abduction and lateral rotation, wrist and finger extension, forearm supination, elbow extension, and cervical lateral flexion can be used to determine involvement of median nerve structures.[124]

Mobilization of neural tissues is one part of an overall management strategy for patients with pain arising from these tissues. Mobilization can be passive, active, or some combination of both. Passive mobilization is rarely a treatment provided in isolation, but is generally combined with active movements, exercise, lifestyle modification, and education.[125] When performing direct nerve mobilization, Butler[124] recommends starting the movements farther from the presumed site of pathology, and beginning with the rest of the body "unloaded" where there is less tension throughout the connective tissue system. If the patient has a number of positive tension tests, consider starting with the least provocative of these positions and examine the response to treatment before moving to the more acute or sensitive positions. With a successful response to the passive mobilization, the intervention can be progressed by:

- Adding active movements
- Adding more components
- Increasing the repetitions
- Increasing the intensity of the technique
- Moving techniques closer toward the presumed site of pathology

For example, when tensioning an SLR, the patient can flex the cervical spine at the same time as dorsiflexing the ankle, thereby providing tension both from the proximal and distal ends.

Specific mobilization techniques have been described for problems in the extremities and trunk.[123,124] Mobilization begins with determining the starting position based upon examination results. Once a successful clinical program has been established, home exercises are incorporated to replicate the techniques used in the clinic (**Fig. 7-45A** and **B**). Further information on specific techniques can be found in Butler.[123,124]

Active movements following passive mobilizations should be functional. For example, when mobilizing the tissues associated

A

B

FIGURE 7-45 **(A)** Upper limb tension test 3 position. **(B)** Slump sit with ankle dorsiflexion.

with the median nerve, movements that place the wrist in extension with elbow extension are useful. A wall push-up, a chest pass with a ball, or reaching overhead with the wrist extended are all examples of active movements that replicate the passive mobilization techniques. Once active movements are initiated and tolerated, progress the patient through AROM to resistive ROM following previously described guidelines.

A number of precautions and contraindications should be considered when examining and treating patients with mobilization directed at neural structures. These can be found in **Table 7-5**.

SELF-MOBILIZATION

Mobilization techniques performed only in the clinic may be of insufficient frequency to produce a significant change. Therefore, adding self-mobilization to therapist-provided interventions may provide a therapeutic dosage resulting in significant improvements. Mobilizations can be in the form of joint mobilizations performed with the use of assistive objects, or they can be soft-tissue mobilizations or neural mobilizations designed to lengthen or relax associated soft tissues (**Fig. 7-46**).

Spine self-mobilization can be performed with the support of a chair or other rigid device that stabilizes the spine at a specific

TABLE 7-5

Precautions and Contraindications to Mobilizing Neural Tissues

PRECAUTIONS	CONTRAINDICATIONS
Potential of injury to other structures loaded during testing or treatment	Recent onset of or worsening neurological symptoms; acute, unstable symptoms
Tissue irritability	Cauda equina lesions
Worsening symptoms, especially if a rapid worsening	Injury to the spinal cord
Unstable neurological signs or signs indicative of active disease process	
General health problems, especially those that involve connective or neural tissue	
Dizziness or circulatory problems	
Frank spinal cord injury with a minor secondary cord problem potentially amenable to treatment	

From Butler DS. Mobilisation of the Nervous System. St. Louis, MO: Churchill Livingstone, 1999

FIGURE 7-46 Neural flossing using a lateral hip stretch position with hip internal rotation.

level. The patient can then extend or extend and rotate over the fixed chair (**Fig. 7-47**). This is most effectively done for the thoracic or lumbar spine. Alternatively, spine self-mobilization can be done using foam rollers or similar equipment. Foam rollers can be used in a variety of ways to provide mobilization. Half-foam rollers can be placed flat side down with the patient lying on the curved part to mobilize the spine. Place a hypomobile segment at the end of the roll and relax the body over the edge to mobilize the segment (**Fig. 7-48**). The full foam roll can be used to mobilize soft tissue by rolling the stiff or shortened area over the roll (**Fig. 7-49**). Alternately, if a full foam roller is not available, in some situations, a 2-L bottle of water placed in the freezer and frozen can be substituted. Tennis balls taped together work well to mobilize soft tissues adjacent to the spine. Place the balls on either side of the spine while leaning against a wall. Slide up and down the wall to provide pressure and mobilization (**Fig. 7-50**).

Body rolling using a 6- to 10-in diameter hollow ball provides additional opportunities for home programs utilizing mobilization techniques (**Fig. 7-51**).[125] Techniques to mobilize,

FIGURE 7-47 Thoracic spine mobilization using a chair.

FIGURE 7-48 Half foam roll mobilization for the spine.

FIGURE 7-49 Foam roll for soft tissue mobilization of the iliotibial band

FIGURE 7-50 Soft-tissue mobilization of spine using tennis balls

A

B

FIGURE 7-51 (A and B) Body rolling.

stretch, and lengthen hypomobile tissues throughout the body are available for patients who have good general mobility. Many of these techniques require the ability to get up and down off the floor, to position the body, and to move over the ball. This is not possible for some individuals with multiple joint involvement. However, for those who are mobile enough to utilize these techniques, self-mobilization with these assistive devices can be useful.

MOBILITY EXERCISE DOSAGE

The stage of healing (see Chapter 11) and the tissue response to loading relative to the patient's examination findings determine the dosage of mobility exercises. Each patient should be considered on an individual basis, with the dosage matched to the patient's needs. These needs extend beyond the physical impairments to include psychosocial and lifestyle issues.

Sequence

Mobility activities can be performed as part of warm-up exercises before aerobic or strengthening activities or as independent rehabilitative exercises. Use PROM or AAROM to teach AROM exercises, and use AROM as a teaching tool for resistive exercise. The sequence of exercise depends on the purpose of the ROM activity. ROM exercise as preparation for more difficult exercise should occur before that activity. When mobility exercises are being performed for the benefit of ROM increases, they should be performed in a sequence of easier to more difficult.

Most exercises performed passively can also be performed actively or with active assistance. This makes an easy progressive sequence for the patient to follow. For example, a single knee flexion exercise can be easily progressed by changing instructions. Progress knee flexion with a towel to active assisted by using some muscle activity and some passive assistance from the towel (**Fig. 7-52A** and **B**). As the patient improves, the same exercise can be performed without assistance. The same is true for shoulder flexion exercises with a pulley or counter; the exercise can be performed with some level of assistance or completely actively.

The concept of active stretching is important when sequencing mobility activities. **Active stretching** is the use of active movement to stretch the antagonist or to use the agonist in its new range. Stretching a short muscle should always be complemented with active stretching by strengthening the opposing muscle in the shortened range. Based on scientific studies of length–tension properties of skeletal muscle, it is hypothesized that a stiff or short soft tissue structure cannot remain lengthened until opposing soft tissue structures shorten.[126] The opposing muscle must be strengthened because its length–tension properties have been disrupted because the short muscle is in need of stretch. It cannot generate sufficient tension in the short range to oppose the pull of the short muscle. By strengthening the lengthened muscle, particularly in the short range, its length–tension properties can improve, and it can provide a counterbalancing force to the short muscle. Therefore, stretching a shortened muscle without strengthening the lengthened muscle (preferably in a shortened range) may render stretching ineffective. Stretching a short muscle can be done passively through a self-stretch or manual stretch, but it should always be accompanied with active stretching through strengthening the opposing muscle in the shortened range (**Building Block 7-5**).

BUILDING BLOCK 7-5

A 48-year-old woman with rounded shoulders and kyphotic posture complains of neck and mid-back pain after 2 hours at her computer workstation. Describe a sequence of mobility and active contraction exercises she might use to address these postural impairments.

FIGURE 7-52 **(A)** AAROM using a towel followed by **(B)** AROM at the knee using muscle activation to slide the towel.

Active contraction of the antagonist in a shortened position is used to strengthen this muscle while simultaneously actively stretching the agonist. For example, after static stretching of the hamstrings, the patient can extend the knee in a sitting position while the paraspinal muscles stabilize the spine to prevent lumbar flexion. The quadriceps actively stretches the hamstrings into the new range. This repeated activity enhances mobility in the new range. This same sequence concept can be applied throughout the body, as in the treatment of low back and pelvic muscle imbalance. After static stretching of short hip flexor muscles, the patient should extend the hip in a walk stance position while the abdominal muscles stabilize the spine and pelvis (see **Self-Management 7-6**).

Frequency, Intensity, and Duration

As with resistive exercise, stretching dosage can be considered in terms of frequency, intensity, and duration. Frequency is how often the stretch is performed, while duration is how long the stretch is held, and intensity is how far into the end of the ROM the stretch is applied. ROM activities, because of their purpose and goals, are generally a lower intensity exercise performed for a shorter duration. These exercises can be performed more frequently and usually take place in the home or work environment. Choose exercises that can easily and effectively be performed independently by the patient or with the assistance of a family member.

The exercise frequency is related to the purpose of the exercise, which can be considered relative to physiologic, kinesiologic, or learning factors.

- Physiologic purposes are those that enhance fluid dynamics, support articular cartilage nutrition, and maintain the integrity of the periarticular connective tissues.
- Kinesiologic purposes include establishing normal arthrokinematic motion and are closely tied to learning factors or choosing the correct motor program.

Learning purposes include exercises to teach postural set, appropriate sequencing, and patterning of muscle contraction or to teach a complex motor skill. Exercises performed for physiologic or kinesiologic purposes are performed two to five or more times each day. The number of times depends on the environment and availability of exercise within that environment. If it is nearly impossible for an individual to perform exercises during the workday, asking him or her to carry out an exercise program five times each day is unreasonable. Similarly, if the ROM activities require the assistance of another, availability of that help dictates the frequency of the exercise program. As discussed in Chapter 3, an exercise prescription should fit within the context of the individual's day.

SELF-MANAGEMENT 7-6
Active Stretch for the Hip Flexor Muscles

Purpose: To stretch and use hip flexor muscles in the new range. This activity should follow hip-stretching exercises.

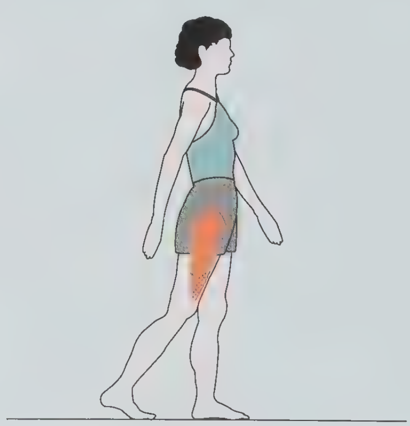
Position: In a stride position, with the leg to be stretched behind and with the opposite foot forward as in taking a step. Be sure to keep the back straight and abdominal muscles tightened.

Movement Technique: Shift your weight forward onto your front foot while maintaining proper hip and back position. Hold 30 to 60 seconds. Be sure that the hip of your back leg is being stretched as shown by the highlighted area in the illustration below.

Dosage:

Repetitions: ____________________

Frequency: ____________________



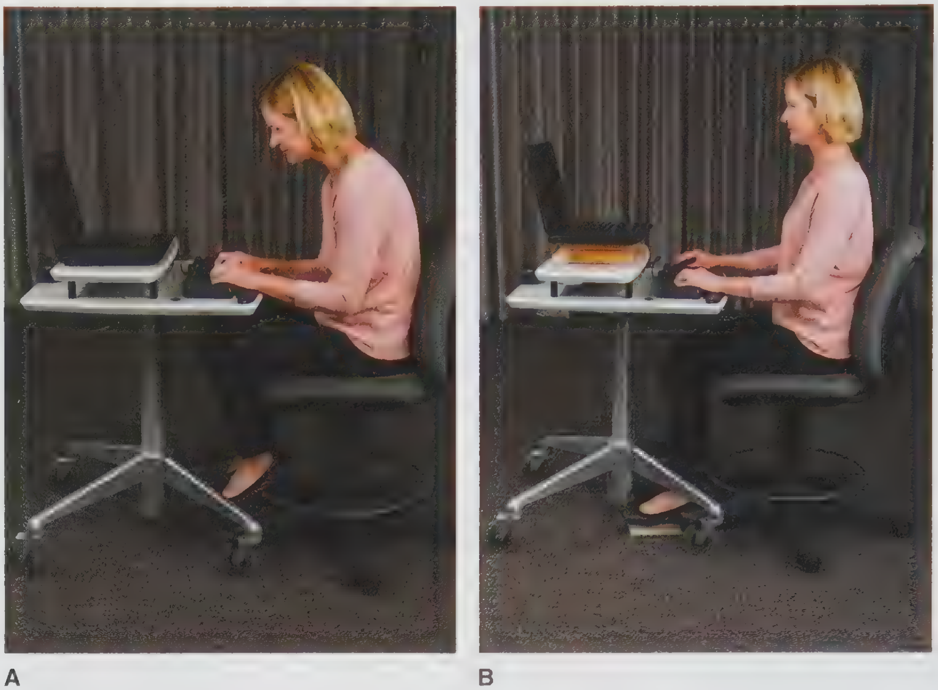


FIGURE 7-53 **(A)** Poor posture at desk can be retrained using postural retraining. **(B)** Good posture with proper pelvic posture and chin tucks.

Exercises performed as learning tools are usually performed more frequently during the day. Examples of these exercises are postural reeducation activities such as scapular retraction and depression, chin tucks while sitting at a desk, and knee extension while driving without posterior pelvic tilt or lumbar flexion (**Fig. 7-53A** and **B**). These kinds of exercises are often put "on cue" so that a specific stimulus can elicit the postural response, such as performing postural exercises every time the phone rings, every time a new page is started on a computer document, or every time an instructor poses a question. This type of programming places the exercise in the appropriate functional context, within the environment or situation where the exercise most needs to be performed. With time and repetition, individuals should find that when the stimulus elicits the response, they are already in the appropriate posture. The intensity of this type of exercise is low, and the frequency is therefore increased.

The number of sets and repetitions depends on the frequency and the number of exercises performed. When several exercises are being performed to maintain ROM during a period of bed rest or in the early healing stages of an injury, the sets and repetitions may be fewer as multiple components of the joint and periarticular connective tissues are being mobilized. Conversely, when only a few exercises can be performed because of healing constraints or other medical conditions, more sets and repetitions of those exercises can be performed. When exercises are being performed frequently throughout the day, fewer sets and repetitions are performed during each session. When active exercise is being used to increase endurance, more repetitions and longer duration rather than greater frequency is the rule. The guiding principle in ROM prescription is understanding the physiologic, kinesiologic, and learning factors associated with each exercise in relation to the patient and exercise goals.

The length of time a stretch must be held to facilitate an increase in muscle flexibility remains a point of disagreement among clinicians. The clinical literature states that stretches should be held for a minimum of 30 seconds in young individuals and 60 seconds in older individuals. There does not appear to be any advantage to holding a stretch longer than those periods.[127–129] A study of individuals aged 65 and older found that holding stretches for 60 seconds produced greater ROM gains that persisted longer than the gains for stretches held for 15 or 30 seconds.[34] A study of younger individuals found that holding stretches for 30 or 60 seconds produced greater benefits than stretches held 15 seconds, but there was no difference between the 30- and 60-second stretches.[127] Research into the viscoelastic tissue responses to stretching has shown little change after four repetitions of stretching, suggesting that only a few repetitions are necessary to produce most of the elongation.[37] Other research suggests that it is the total time per day that the stretch is performed that is significant. A study comparing 10-second stretches with 30-second stretches performed for a total of 2 minutes per day found equivalent increases in hamstring flexibility.[32] If a patient is unable to hold a stretch for 30 seconds, then a shorter duration but higher repetition dosage may be equally effective.

However, the time that a patient or an athlete wants to hold a stretch may be based on the individual's perceived need or comfort level. The intensity of stretching should be low to medium to prevent reflexive contraction. This contraction occurs in response to discomfort during stretching. The stretch should be comfortable enough to be easily held for 30 seconds.

HYPOMOBILITY EXERCISE PRECAUTIONS AND CONTRAINDICATIONS

PROM and stretching are not benign processes and are contraindicated when motion could disrupt the healing process. For example, passive motion into full shoulder external rotation may disrupt the healing process after a capsular shift procedure. Passive motion into hip adduction, flexion past 90 degrees, and internal rotation past neutral may result in dislocation of a recent total hip arthroplasty. Use caution to ensure that the activity is passive when active muscle contraction is contraindicated, such as after a tendon transfer procedure. Ensure that the activity is producing *joint* ROM in the case of PROM and *muscle* ROM in the case of stretching. Moreover, control the speed and patient comfort to prevent inadvertent muscle contraction to oppose the passive exercise. Active muscle contraction in response to fear or pain could disrupt the healing process. Be aware of local anatomy, arthrokinematics, and the effects of PROM on these tissues. For example, passive shoulder ROM into full overhead flexion without adequate humeral head depression may compress a recent rotator cuff repair under the coracoacromial arch, producing pain and disrupting the healing process.

As with PROM, AAROM is contraindicated when motion or contraction may disrupt the healing process or affect the individual's health status. For example, individuals with unstable cardiac conditions are not candidates for active assisted exercise. When performing exercise with an active component, ensure that the type of muscle contraction performed (e.g., concentric, eccentric, isometric) is indicated and that the amount of tension generated is appropriate. The indications and contraindications for these contraction types are described in Chapter 5. Emphasize the importance of muscle relaxation between exercise repetitions to ensure adequate blood flow to the working muscles.

Contraindications and precautions for AROM are the same as those for active assisted exercise. Muscle contraction that may disrupt the healing process or affect the individual's health status are contraindications to AROM. The type of muscle contractions being performed should be safe for the specific situation, and the clinician should allow muscle relaxation between repetitions.

Stretching is contraindicated in the case of acute inflammation or infection in the tissues being stretched. Signs of inflammation or infection include increased warmth, tenderness, redness, or localized swelling. When stretching inflamed tissues, the patient will often report a sensation of pain prior to any sensation of stretching. This is an important reason to ask patients *what* they are feeling, not just *if* they are "feeling" the stretch. Some patients will assume that it is okay to feel pain. Use caution in patients with recent fracture, particularly if the fracture has been immobilized for some time, as the associated soft tissues will have weakened simultaneously. Additionally, the fracture site should be stabilized manually or by a supportive surface and the stretch should be designed to avoid torque directly over the fracture site.

Patient's osteoporosis should approach stretching cautiously as a quick muscle contraction in response to discomfort, as well as the force across the bone can produce a fracture. Similarly, the elderly are at risk of stretching injuries because of increased soft tissue stiffness. Those who have been in prolonged immobilization or those with very weak muscles will be at risk of stretch-related injuries or may lack sufficient strength to oppose a stretch applied too vigorously.

CAUSES AND EFFECTS OF HYPERMOBILITY

Although most clinicians are familiar with the treatment of persons with decreased mobility, many patients have problems related to excessive mobility. Most individuals do not seek medical attention primarily for possessing excessive mobility about a joint or throughout the body. More frequently, patients seek medical attention for pain, fatigue, or tendinitis. These pathologies, impairments, and activity limitations often result from the hypermobility.

Hypermobility should be differentiated from instability. Hypermobility is excessive laxity or length of a tissue, and instability is an excessive range of movement, osteokinematic, or arthrokinematic, for which there is no protective muscular control. Despite hypermobility, the individual may experience no symptoms of instability. For example, individuals with anterior cruciate ligament–deficient knees may have measurable anterior laxity (i.e., hypermobility) at the tibiofemoral joint with no symptoms of instability. Conversely, individuals may have complaints of instability or "giving way" with no measurable laxity.

Hypermobility can be broadly categorized as excessive joint mobility resulting from trauma or a genetic predisposition (i.e., Ehlers–Danlos Syndrome, Hypermobility Syndrome) or as excessive tissue length. Patients with traumatic or atraumatic hypermobility may seek medical attention for a number of complaints, which may or may not include frank instability. Systemic hypermobility is often rated according to the Beighton Score (**Display 7-9**).

Hypermobility at a joint caused by traumatic injury can lead to true instability, particularly at the glenohumeral joint, where a traumatic anterior inferior dislocation can result in recurrent dislocation. Similarly, sprains to the lateral ankle ligaments or medial knee ligaments can result in hypermobility and instability.

DISPLAY 7-9
Beighton Hypermobility Score

Beighton Score*	
Examination Finding	**Score**
1. Passive dorsiflexion and hyperextension of the fifth MCP joint beyond 90 degrees **2.** Passive apposition of the thumb to the flexor aspect of the forearm **3.** Passive hyperextension of the elbow beyond 10 degrees **4.** Passive hyperextension of the knee beyond 10 degrees **5.** Active forward flexion of the trunk with the knees fully extended so that the palms of the hands rest flat on the floor	
Total	/9

**Score one point for each side (left and right) if able to perform 1 to 4. Trunk flexion is 1 point for 9 total possible points.*

Atraumatic hypermobility is common at the glenohumeral joint; persons with multidirectional instability often seek medical attention for symptoms of rotator cuff tendinitis. At the knee, hypermobility can result in secondary patellofemoral pain.

Hypermobility can develop in response to a relatively less mobile segment or region. In a multijoint system with common movement directions (e.g., spine), movement occurs at the segments providing the least resistance. Abnormal or excessive movement is imposed on segments with the least amount of stiffness. With repeated movements over time, the least stiff segments increase in mobility, and the stiffer segments decrease in mobility. A thorough examination, seeking to understand the impairment contributing to the hypermobility, is necessary.

THERAPEUTIC EXERCISE INTERVENTION FOR HYPERMOBILITY

Treatment techniques for hypermobility should be directed at the related impairments and activity limitations and at the underlying causes of hypermobility. For example, a patient with hypermobility at the spinal level probably has pain and decreased mobility at adjacent segments. These impairments must be treated along with the underlying hypermobile segment. Although it is important to address the patient's current complaints, failure to recognize hypermobility as the underlying cause ensures the return of symptoms. Hypermobility should be treated only if it is associated with instability or is producing symptoms elsewhere (i.e., hypomobile segment) because of relative flexibility.

Stabilization Exercises

The concept of stabilization exercises gained popularity in the treatment of conditions of the spine. Stabilization exercises are dynamic activities that attempt to limit and control excessive movement. These exercises do not imply a static position, but rather describe a range of movement (i.e., the neutral range) in which hypermobility is controlled. Stabilization activities include:

- Mobility exercises for stiff or hypomobile segments
- Strengthening exercises in the shortened range for hypermobile segments
- Postural training to ensure movement through a controlled range
- Patient education

Supportive devices such as taping or bracing may be necessary initially to keep movement within a range where stability can be maintained. This range is different for every patient and condition. Patient education focuses on helping the patient find the limits of stability and work within those limits.

As mobility exercises to decrease hypomobility and stabilization exercises to increase stiffness improve symptoms, the stability limits increase, allowing the patient to work through a larger ROM. For example, a patient with an L4 spondylolysis may have short hip flexor and lumbar paraspinal muscles in combination with a hypermobile L4 segment. Stabilization focuses on increasing the length of the short muscles through static stretching, followed by active stretching through contraction of the abdominal muscles in a walk stance position. Initially, a stabilization brace may be used during exercise. As mobility of the short muscles and stiffness at the L4 segment improve, the brace can be discontinued and the walk stance position progressed to a lunge position.

Stabilization activities should be chosen based on the direction in which the segment is susceptible to excessive motion. In the previous example, the susceptible direction is extension; the spine tends to extend excessively, producing pain. Focus treatment on training the back to resist extension forces, rather than resisting motion in all directions. For the individual with anterior shoulder instability, the arthrokinematic motion of anterior glide is the symptom-producing hypermobility. Stabilization activities should focus on controlling anterior displacement and on treating the associated impairments.

Stabilization exercises can be performed in a variety of positions and using a range of equipment. When increasing the stability of a hypermobile segment, support (e.g., taping, bracing) and strengthening in the short range must be combined with mobility exercises for the hypomobile segment. This approach ensures balance in areas with variable relative flexibility. Gymnastic balls, foam rollers, balance boards, and proprioceptive exercises are effective ways to enhance stability.

Closed-Chain Exercise

Closed-chain exercise has been advocated for those with joint instability or hypermobility. For the lower extremity, exercises such as squats, lunges, or step-ups with the foot fixed are commonly used closed-chain activities. For the upper extremity, any weight-bearing exercise performed in the push-up or modified push-up position is considered to be closed-chain exercise. Weight bearing with the hands against the wall or on a table or countertop is also an effective closed-chain position for the upper extremity. The rationale for this exercise is muscular cocontraction, decreased shear forces, and increased joint compression, all of which offer stability to the joint. Some of this theory is supported by scientific and clinical research.[130,131] Other studies dispute some aspects of this rationale, such as muscular cocontraction with a closed-chain position.[132,133] Particularly for the lower extremity when the foot spends a lot of time in contact with the floor, using closed-chain exercise for hypermobility makes good clinical sense. However, for the upper extremity, the closed-chain position is rarely the position of function. The closed-chain position remains an effective position for upper extremity training for individuals with hypermobility, but open-chain stabilization techniques should be incorporated as well. More information on the effects of closed-chain exercise can be found in Chapter 14.

Open-Chain Stabilization

Open-chain stabilization activities are available for the lower and the upper extremities. PNF techniques such as rhythmic stabilization and alternating isometrics can be used effectively to facilitate cocontraction about a joint (see Chapter 15). These techniques are particularly effective in the latter stages of rehabilitation when performed in the position of instability, such as abduction and external rotation for treating anterior glenohumeral instability (**Fig. 7-54**).

Stabilization exercises for the spine are difficult to categorize, because the spine is often fixed at one end and open at the other end. It is not a true closed or open system. Stabilization

FIGURE 7-54 Rhythmic stabilization performed in a position of apprehension.

FIGURE 7-55 Forward flexed superman exercise is an example of an advanced spine stabilization exercise.

exercises for the spine are often initiated in a supine position with abdominal bracing exercises and progressed to sitting and standing positions. A variety of stabilization exercises can be performed on unstable surfaces such as a gymnastics ball or foam rollers to improve stability within a comfortable range. Sitting, prone, and supine activities combined with arm reaching and leg lifts can be used from early to advanced stages of stabilization training (**Fig. 7-55**). Many of these same activities can be used to improve stability throughout the upper and lower extremities.

Ballistic Exercises

Ballistic exercise has been shown to produce cocontraction about a joint through triphasic muscle activation. High-speed ballistic activities result in different patterns of agonist–antagonist muscle contractions from those of slower activities. Rapid ballistic movements result in synchronous activation of agonists and antagonists.[6,134,135] In contrast, the same movement pattern at a slow speed demonstrates only agonist muscle contraction, with braking provided by passive viscoelastic properties.[6] Although the viscoelastic properties also restrict movement at faster speeds, these properties are inadequate to halt fast movements.[134] These rapid ballistic movement patterns can be used with resistive tubing, balls, or inertial exercise equipment (**Fig. 7-56** on page 180). The amount of antagonist activity needed to halt a movement is related to the velocity of the activity, with higher velocities requiring greater muscle activation[134] (**Evidence and Research 7-7**).

Quick movements through small distances result in a large, quick antagonist burst, whereas slow movements over a long distance result in small and late antagonist bursts.[134] For example, flexing and extending the hip rapidly through a very small range elicit cocontraction of agonist and antagonist musculature, but flexing and extending slowly through a large range elicit reciprocal activation of the agonists and antagonists. If hip and pelvic stabilization is the goal, small-amplitude, fast movements are more likely to elicit cocontraction than slow, large-amplitude movements.

EVIDENCE and RESEARCH 7-7

Subjects were asked to produce fast flexion movements of the thumb and fast extension movements of the elbow over three distances and at a variety of speeds. All movements resulted in biphasic or triphasic muscle contraction. A linear relationship was found between peak velocity and the amount of antagonist activation needed to halt the movement. Movements made through large angles (i.e., large amplitude) showed less antagonist activity than those made through small angles at the same speed, and fast, small-amplitude movements demonstrated an earlier onset of antagonist activity. The distance during fast movements is controlled primarily by the first agonist muscle contraction, and increasing antagonist torque is associated with decreasing distance, ultimately controlling the movement time.[135] Producing fast movements requires large agonist torque production, followed by an equally large or larger antagonist torque.

Another factor that affects antagonist activity is the subject's knowledge of the necessity for such a contraction. On study

A B

FIGURE 7-56 Performance of rapid alternating shoulder flexion and extension at end ROM using resistive tubing.

provided a mechanical stop for preventing further movement in some elbow flexion and extension tasks.[134] When the subjects knew that the stop was in place, the antagonist burst disappeared after two or three trials. This resulted in a faster movement, suggesting that the antagonist activity brakes and slows the motion. Some cognitive control over the braking mechanism exists.

This research supports the use of rapid, alternating movements, moving quickly through a short distance. Large-amplitude movement does not produce the same muscular coactivation as small-amplitude movement.

Exercise Dosage

Dosage parameters depend on the purpose of the exercise and the patient's tolerance for the activity. Any time rapid, alternating movements are used, fatigue can alter the proper performance and thus the outcome of treatment. Watch for signs of fatigue that result in substitution patterns or loss of the desired stabilization. For rapid movements, sets for time often work better than a set number of repetitions. Patients can try to increase the number of repetitions of an exercise within the timed set.

As with all other exercise prescription, perform the exercise to fatigue without losing control or proper form. Monitor the time or number of repetitions, and, as the patient improves, change the exercise parameters to continue increasing the challenge. This may include increasing the resistance, repetitions, or speed or decreasing the rest interval.

Hypermobility Exercise Precautions and Contraindications

An important precaution when treating areas of hypermobility is to ensure that areas of relative flexibility are identified. Stretching techniques to improve mobility in a hypomobile area may increase hypermobility in an adjacent area. Reinforce correct dynamic stabilization to ensure that intervention is isolated to the correct segment. For example, failure to stabilize the pelvis during hip flexor stretching increases lumbar extension, potentially increasing hypermobility in this area.

Any time dynamic stabilization activities are being performed at the limits of stability (e.g., resisted shoulder rotation at 90-degree abduction and full external rotation in a hypermobile shoulder), be sure that the individual has adequate control to prevent instability or dislocation. Progress activities according to the patient's ability to control the limits of stability. Fatigue of dynamic stabilizing musculature places the patient at risk for injury, and the fatigue level should be monitored throughout the exercise session.

Many stabilization exercises use eccentric muscle contraction to provide stability. Eccentric contractions are associated with delayed-onset muscle soreness (see Chapter 5), fatigue, loss of control, and substitution. Consider this in the exercise dosage. Watch the patient closely for signs of fatigue and loss of control because the patient could be injured or develop excessive muscle soreness.

Any time activities are performed on a single limb, use caution to prevent falling and ensure that single-leg stance is indicated. Individuals with degenerative joint disease at the primary or adjacent joint may experience a symptom exacerbation because of excessive loads on the limb. A pool can minimize the quantity of weight bearing while performing single-leg stance activities (see Chapter 16).

LIFESPAN ISSUES

Be sure to consider that most studies on stretching and mobility exercises have been performed on young and middle-aged adults, and few have been performed on children or the elderly. However, because of the aging of the population, more and more studies are being carried out on the elderly to determine how their responses to treatment differ from that of younger individuals. As noted in the section on "Stretching," the elderly benefit from holding their stretches for a longer time than do younger individuals.

As with many adults, children exhibit variable degrees of mobility, from shortened and tight muscles to hypermobility. In general, flexibility remains relatively stable through age 8, and then declines until about the ages of 11 to 15.[136] This decline is probably because of the adolescent growth spurt. As with adults, flexibility in children can be improved by the stretching techniques outlined in this chapter. A study of elementary schoolchildren found that regular hamstring muscle stretching throughout the school year produced significant increases in SLR ROM.[137] Increases were greater for those stretching 4 days per week compared with those children stretching 2 days per week.

Joint mobilization techniques are not commonly used in children, although there may be special cases in which this technique is indicated. Joint mobilization has been considered for children with central nervous system disorders such as cerebral palsy.[138] As with adults, the primary indication for use in this population is joint hypomobility resulting from capsular tightness. However, use caution when using joint mobilization in any child. It may be contraindicated in some situations, such as Down syndrome in which joint hypermobility secondary to joint laxity is generally the case. Additionally, in any child with open epiphyses, the potential damage to the growth plate must be balanced against the potential benefits of joint mobilization. Alternative interventions to increase mobility may be safer choices.

Other issues exist at the older end of the life span. Joint mobility and muscular flexibility decline with aging.[34] Connective tissue changes occurring with aging impact the use of joint mobilization and stretching exercises. Aging muscle increases in stiffness as measured by passive length–tension plots, and the amount of muscle area occupied by connective tissue also increases.[139] Feland et al.[34] suggest using static stretching over PNF stretching because the muscles of the elderly are more susceptible to contraction-induced injury and have decreased capacity to recover from such injury. Older individuals have demonstrated greater muscle stiffness and a lower tolerance for stretching.[91]

Additionally, joint ROM decreases with aging. Declines of 20% in hip rotation and 10% in wrist and shoulder motion have been reported.[140] Walker et al.[141] showed declines in the lower extremity joint ROM of up to 57%. A 25% decrease in trunk-side bending between the ages of 20 and 60 have also been reported.[140] Before performing joint mobilization in the elderly population, consider their decreased joint capsule tensile strength, diminished articular cartilage water content, and increased bone fragility. Joint mobilization should be approached cautiously because of all these connective tissue changes.

ADJUNCTIVE AGENTS

Clinicians often use various treatments or techniques to enhance the effects of another treatment. Forms of tissue heating are the most common adjunctive agents used in combination with ROM exercises to increase mobility. The ability of collagen to be easily and safely deformed or stretched is enhanced by increasing the temperature of the collagen. Because muscle is primarily composed of collagen, the ability of the muscle to be stretched may be enhanced by increasing the temperature of the muscle.[142] The critical temperature for beneficial effects appears to be approximately 39°C or 103°F.[10,142–145]

Intramuscular temperature may be increased by heating modalities or through exercise. The therapeutic temperature required may be efficiently achieved for the time necessary to complete a flexibility program using a deep-heating modality such as ultrasound.[146,147] Physiologically, the easiest and most appropriate way to increase intramuscular temperature is through the use of exercise. Active, submaximal resistive exercise of the muscle groups to be stretched should be performed before stretching. This type of exercise is capable of producing temperature increases to approximately 39°C after 10 to 15 minutes.

Heating techniques may prepare the tissue for mobility activities by increasing the tissue temperature, promoting relaxation and pain reduction, and increasing the local circulation. Forms of heat other than exercise can be categorized broadly as superficial-heating and deep-heating agents. Although heat can increase local circulation and temperature, it is not a substitute for warm-up exercises before a planned activity. A warm-up exercise such as walking, bicycling, upper body ergometry, or AROM exercise should take place before any therapeutic ROM activities. This approach increases core temperature and prepares surrounding tissues for the forthcoming activity. More information on Superficial Heat and Deep Heat can be found on thePoint.lww.com/BrodyHall4e.

KEY POINTS

- The effects of immobilization on the injured and uninjured soft tissues are profound. All tissues are affected, including insertion sites and bone.
- These effects are the result of the specific adaptations to imposed demands principle; tissue responds to loads placed on them. When underloaded, the tissue weakens.
- The period needed to restore normal structural and mechanical properties to immobilized tissue can be two or more times the length of the immobilization period.
- Joint ROM should be differentiated from muscle ROM. The specific goal dictates the type of mobility activity prescribed.
- A variety of contractile and noncontractile tissues can limit mobility at a joint.
- PROM exercise is a mobility activity performed without muscle contraction. AAROM is a mobility activity in which some muscle activity takes place, and AROM exercise uses active muscle contraction to perform the exercise.
- To increase flexibility, static, ballistic, and PNF stretching techniques can be used. The type of stretch chosen depends on the individual's impairments and lifestyle. All techniques have been shown to increase short- and long-term flexibility.
- Joint mobilization is an integral component of a comprehensive mobility program when capsular restriction is a key finding.
- Pulleys, machines, the pool, or objects found in the home or office can be used to perform mobility exercises.
- Mobility exercise prescription depends on the specific goal of the activity and the environment in which it will be performed. Mobility exercises should be performed daily.

- Hypermobility can be as disabling as hypomobility. Stabilization exercises such as closed-chain and rapidly alternating movements may be incorporated.
- Adjunctive agents such as heat can be used to enhance mobility activities.

LAB ACTIVITIES

Perform the following activities with your partner. Not all positions are optimal for performing each of the exercises, but the clinician occasionally is unable to change the patient's position. If not the optimal position, which position would be better and why?

1. With your patient in supine, perform the following:
   a. PROM shoulder flexion
   b. AAROM shoulder abduction
   c. PROM shoulder internal and external rotation
   d. CR stretching for pectoralis major
   e. PROM hip and knee flexion
   f. CRAC stretching of the hamstring muscles
   g. PROM lumbar flexion
   h. PROM lumbar rotation
2. With your patient sitting, perform the following:
   a. PROM hip internal and external rotation
   b. AAROM knee extension
   c. CR stretching hip internal rotator muscles
   d. AAROM shoulder flexion
   e. AROM shoulder abduction
3. With your patient in a side-lying position, perform the following:
   a. PROM shoulder extension
   b. AAROM shoulder abduction
   c. CR stretching shoulder internal rotator muscles
   d. AROM shoulder flexion
4. With your patient in a prone position, perform the following:
   a. AAROM elbow extension
   b. PROM hip internal and external rotation
   c. AROM shoulder flexion
   d. CR stretching hip flexors
   e. CRAC stretching for gastrocnemius
   f. CRAC stretching for soleus
5. Decide how to best position your patient for the following:
   a. AROM shoulder external rotation in a gravity-minimized position
   b. AROM scapular elevation
   c. AROM wrist extension in a gravity-minimized position
   d. CR stretching of hip adductor muscles
   e. AROM shoulder abduction in a gravity-minimized position
   f. PROM cervical rotation
   g. Static stretching of the triceps muscle
6. Choose five of the previous exercises and write a description of those exercises for a patient in a home exercise program. Include a picture of the exercise.
7. Consider Case Study No. 6 from Unit 7. Instruct your patient in the first phase of the exercise program. Explain and demonstrate.
8. The clinician is treating a postal worker with rotator cuff tendinitis resulting from hypermobility. This man sorts mail all day at eye level. The rotator cuff tendinitis has resolved with intervention. Instruct this patient in an exercise program to treat the instability. Explain and demonstrate.
9. Instruct a patient in a self-stretching program for the quadriceps, hamstrings, and iliotibial band. Explain and demonstrate three different stretches for each muscle group.

CRITICAL THINKING QUESTIONS

1. Consider Case Study No. 2 in Unit 7.
   a. Although the patient needs to increase knee ROM in both flexion and extension, which direction would you emphasize first and why?
   b. Discuss the advantages and disadvantages for various exercise modes to increase this patient's active knee ROM.
2. Consider Case Study No. 4 in Unit 7.
   a. How would your treatment differ if the patient were an elderly woman with severe osteoporosis?
   b. How would your treatment differ if the patient were 25 years of age and the joint accessory motion testing result indicated hypermobility?
3. Consider Case Study No. 1. Given this patient's impairments and activity limitations, design a program to improve his hip mobility.
   a. Include in-house therapist-provided activities.
   b. Include a home exercise program including dosage parameters.
   c. What activities might you allow this patient to engage in to maintain an active lifestyle? Would any of these need to be modified in any way?

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CHAPTER

8 Impaired Balance and Mobility

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Balance is an important consideration when rehabilitating patients with a variety of conditions, and balance training is long recognized as integral to clinical practice.[1–4] Health conditions may result in or from impaired balance. For example, a patient who is status-post anterior cruciate ligament reconstruction, which was torn while playing basketball, may present with residual impairments in single-leg stance (SLS). Alternatively, a patient with impaired balance because of Parkinson's disease may fall resulting in a hip fracture and increased mobility-related disability. The rehabilitation plan of care for each of these patients should include a balance component. However, clinicians must be mindful that the skill of maintaining balance is multidimensional and impaired balance is not a simple impairment, such as impaired range of motion (ROM). Rather, impaired balance represents a super-impairment for which there are a variety of underlying body systems potentially at fault. Thus, the balance component of a plan of care will differ greatly between patients, often even between those with the same medical diagnosis.

DEFINITIONS

Balance is a multidimensional concept that involves both postural balance and locomotor stability. *Postural balance* is the ability to maintain equilibrium or the ability to maintain the center of mass (COM) relative to the base of support (BOS).[5] *Locomotor stability* is the ability to control postural balance during gait and while changing from one posture or position to another, such as going from sit-to-stand transition.[6] Stability during gait requires control of a moving COM that is not always within the BOS.

Postural sway is a component of balance and is the normal, continuous shifting of the body's COM over the BOS. Postural balance is maintained when a person is able to keep his/her postural sway within the *limits of stability* (LOS) or his/her maximum angle of displacement from vertical, before losing equilibrium. These limits represent the spatial area in which the individual can maintain equilibrium without changing his/her BOS.

A certain amount of anteroposterior and lateral sway normally occur while maintaining equilibrium. This *sway envelope* defines the LOS in anterior, posterior, and lateral directions. Normal anteroposterior sway in adults is 12 degrees from the most posterior to the most anterior position.[7] Lateral stability limits vary with foot spacing and body height. An average-height adult with 4 inches between their feet can sway approximately 16 degrees from side to side.[7] This stability limit is often characterized by a *cone of stability* (**Fig. 8-1A** and **B**). As long as an individual's sway envelope stays within the cone of stability, balance is maintained.

Individuals rely on a variety of balance *strategies* (coordinated neuromuscular synergies) to maintain postural balance. When sway approaches the LOS, a corrective strategy is necessary to maintain stability.[8] The strategies that govern postural balance without causing a change in the BOS are known as *in-place* strategies. In-place strategies include ankle and hip strategies. If sway exceeds the LOS, a corrective stepping or protective extension strategy must be employed to reestablish balance over a new BOS. These are referred to as *change-in-support strategies* and are used by the individual to establish a new BOS. Taking steps when lunging for a tennis ball or when bumped by someone are examples of change-in-support strategies.

A significant contributing factor to person's ability to manage balance within her LOS is the position of the COM relative to the BOS. If an individual's COM is aligned more anterior, posterior, or lateral than center, a smaller sway envelop is tolerated before losing balance (see **Fig. 8-1C**).[7] For example, persons with Parkinson's disease or with a significant thoracic kyphosis secondary to osteoporosis may have a static or dynamic anterior posture, decreasing tolerance for anterior sway. Alternatively, persons who are status-post right total knee arthroplasty or status-post left middle cerebral artery stroke may stand with their COM displaced toward the left. In such cases, the person may ambulate with a decreased ability to effectively load weight onto the right leg. This lateral postural displacement may increase this individual's risk for falling to the left.

Postural balance strategies result from highly coordinated balance functions. *Coordination* is defined as the ability to perform smooth, accurate, and controlled movements.[5,9] Coordination is easily recognized as necessary for the execution of fine motor skills such as writing, sewing, dressing, and the manipulation of small objects. Coordination also provides the foundation for performing gross motor skills such as walking, running, jumping, occupational tasks, and basic and instrumental activities of daily living (IADL). Coordinated movements are

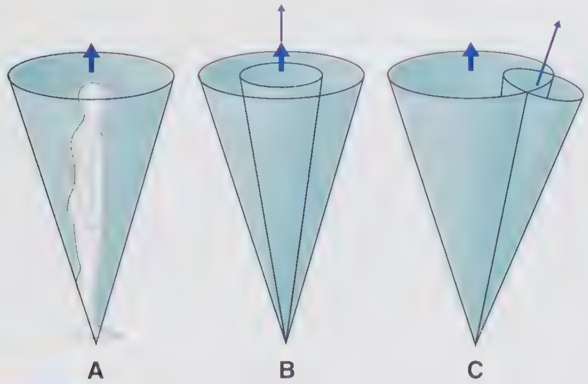


FIGURE 8-1 Relationships of the LOS, the sway envelope, and the COG alignment. **(A)** The LOS are described by a cone-shaped sway envelope. **(B)** When the COG is aligned in the center, the sway envelope remains within the LOS. **(C)** When the COG is offset, as in a forward leaning posture, the sway envelope exceeds the LOS, and a balance restoration strategy must be implemented to regain balance.

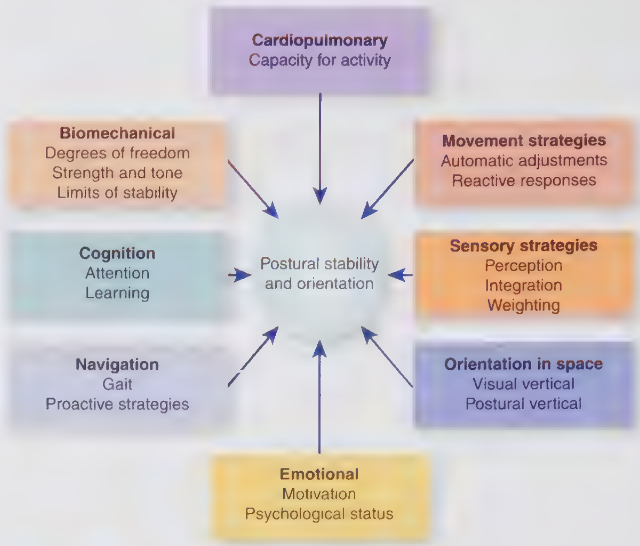


FIGURE 8-2 Systems model of postural stability and orientation.

characterized by proper sequencing and timing of synergistic and reciprocal muscle activity. In fact, skilled activities, such as throwing, kicking, hopping, and running, are not possible without appropriate balance function.[10] Thus, the concepts of coordination and balance are highly interrelated. However, despite their integrated relationship, balance and coordinated movements are felt to be controlled separately.[11] Observations of reprogramming of postural responses before measured changes in focal movement during a changing task or environmental context provide evidence of the integration of balance and coordination.[12]

Maintenance of postural balance requires that individuals have the ability to maintain a position of stability before, during, and immediately after voluntary activities, as well as the ability to react to external perturbations.[13,14] Balance functions also enable individuals to protect the body in the event of a fall[12] and allow for clear vision during head and/or body movements.

Postural balance is far more complex than a simple relationship between the COM and the BOS. Effective and efficient performance and integration of multiple body systems are required for postural balance.[15] Specifically, stability is accomplished through the interaction of biomechanical (articular and muscular), sensory feedback (somatosensory, visual, and vestibular), self-perception (orientation in space, subjective postural and visual vertical), dynamic control (control of walking and navigation), neuromuscular integration (neuromuscular synergies, and adaptive and anticipatory action), cognitive processing (multitasking, information processing), affective (motivation, preferences), and cardiopulmonary (activity tolerance) systems. **Figure 8-2** describes postural control and orientation from this perspective. Impairment in any of these systems can lead to altered balance and mobility function. A detailed examination enables the clinician to determine the system(s) at fault and to develop targeted treatment for impaired balance. Successful interventions also depend on the clinician's ability to prioritize interventions based on the relative impact of each underlying impairment in relationship to each other and the resulting activity limitations, participation restrictions, and mobility-related disability (see **Building Block 8-1**).

BUILDING BLOCK 8-1

A 75-year-old woman with multiple sclerosis (MS) presents to your clinic for evaluation and treatment of her gait instability following a recent fall. The patient fractured her right wrist as a result of the fall. The fracture was surgically repaired, and she has recently been cleared for full weight bearing through her right hand. Before the fall, the patient had been using a front-wheeled walker for several years because of decreased stability while walking. In fact, she has fallen four times in the past year. You note that she stops walking whenever she tries to converse with you on the way to the exam room. Her past medical history is significant for the additional problems of depression, an anal cyst, and hypertension. She is taking multiple medications, including disease-modifying agents, a benzodiazepine, prescription pain medication, a selective serotonin uptake inhibitor, and a calcium-channel blocker. She lives alone in the home that she bought with her husband 40 years ago. There are three steps to enter the home, which have a railing on the right side for ascending. Her three adult children live more than 2 hours away. The patient relies on volunteers for transportation because she is unable to drive. In fact, she rarely leaves her home. One of her regular companions spends 3 hours a day helping her with household chores and with completing her home exercise program for residual muscle weakness and adaptive shortening in her right wrist and hand.

Hypothesize impairments from each of the domains just discussed that you might find upon examination.

PHYSIOLOGY OF BALANCE

Identifying causes of and prescribing treatment for balance impairment requires an understanding of the various influences on balance control and their normal interactions. Again, biomechanical, sensory, self-perception, neural integrative, cognitive, and affective systems each directly influence postural balance. The individual must effectively and efficiently process contributions from these systems within the central nervous system (CNS), then choose, and execute an appropriate and integrated balance strategy. The actual movement or task performance, as well as the interaction with the environment, must then be evaluated for accuracy, and corrective action must be taken when necessary. An ecological model (**Fig. 8-3**) describes these interactions among the individual, the environment, and the functional task, with a circular network of domains demonstrating the integration of balance functions.[5,16] Any of these domains may dominate depending on the particular context.

Additionally, other individual body systems, such as the circulatory, respiratory, and integumentary systems, indirectly influence balance and mobility via the effects of disease, damage, or suboptimal function. For example, consider a patient with peripheral vascular disease who has swelling in the lower extremities and the subsequent impact of limitations in ROM on balance reactions. Alternatively, consider the impact a venous stasis ulcer on the plantar surface of the foot has on weight acceptance in a patient with diabetes mellitus. Both of these conditions will affect balance reactions.

The primary systems that influence balance and mobility are depicted in Figure 8-2. Each of these systems is considered to be within the *individual* domain. The role of the integumentary system in balance typically occurs in select situations, such as a case of a person with a burn that limits ROM or affects weight bearing. Thus, this system will not be addressed further herein. Additionally, the influence of the cardiopulmonary system will not be considered further in this chapter. Refer to Chapter 6 for further information regarding examination and treatment of impaired aerobic capacity and endurance.

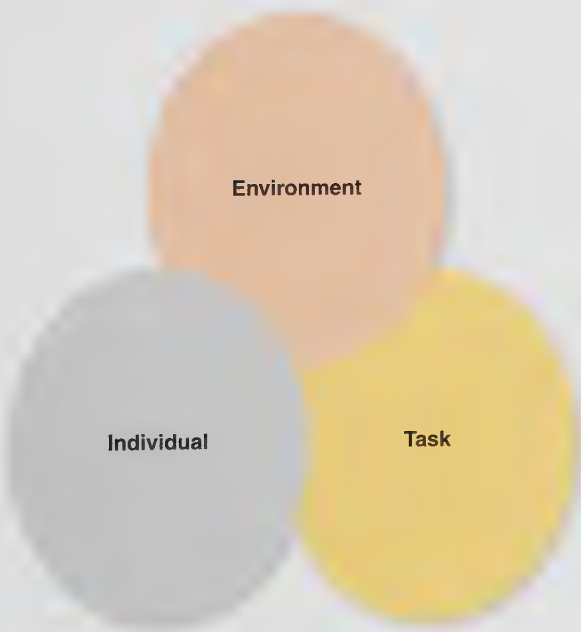


FIGURE 8-3 Ecological model of motor behavior.

Biomechanical Contributions

An individual's LOS is largely a function of the size of the BOS and any impairments in biomechanical, sensory, or neural structure or function in the lower extremities. Individuals who are prone to falling tend to have smaller LOS.[6] The most important biomechanical constraint on balance is the size and quality of the BOS, the feet.[15] Any limitation in size, strength, ROM, pain, or control of the feet will result in impaired balance.[17] Additionally, changes in lower-extremity strength, ROM, and flexibility can cause restrictions in moving the body on the BOS, which will ultimately effect balance control. As previously stated, suboptimal postural alignment also affects balance control. In addition to primary biomechanical impairments, impairments in biomechanics may develop secondary to impairments in other systems. Consider a patient with vestibular dysfunction who presents with complaints of pain and stiffness in the cervical region as a result of self-restricted head movement.

Contributions of the Sensory Systems

Three sensory systems contribute to the maintenance of upright posture and orientation: somatosensory, visual, and vestibular. These are considered to be the sensory triad of postural control (**Fig. 8-4**). No single sense directly determines the position of the body's COM; the combined feedback from each system must be integrated. The somatosensory system gathers information from the individual (e.g., position of one body segment vs. another or the position of the COM relative to the BOS), as well as the environment (e.g., various surface characteristics). The visual system provides information about task performance (e.g., orientation of the body relative to the task) and environmental cues (e.g., position relative to other objects, orientation to vertical, and environmental motion). The vestibular system provides an internal reference and final pathway, providing information about orientation of the head relative to gravity and movement of the head through space.[18]

Somatosensory Neurophysiology

The somatosensory system plays an important role in regulating posture and orientation. Information must be detected peripherally and transmitted centrally for processing. The peripheral receptors are an important source of that information. When a person steps onto a rug that slips beneath his/her foot, the

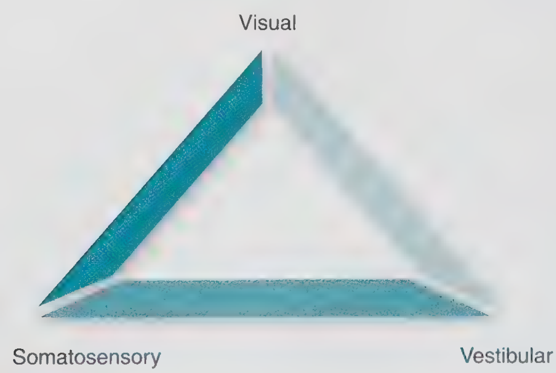


FIGURE 8-4 The triad of balance control.

acceleration of the slipping limb provides the first information to the balance system about impending peril. Information from the somatosensory system arises from the periphery. A variety of somatosensory receptors provide information about movement and joint position through the dorsal column to the medulla and brain stem.[18] This information assists in coordinating eye, head, and neck movements to stabilize the visual system and in maintaining postures and coordinated movement patterns.[19] The influence of each different form of somatosensory input varies. For example, joint afferent information does not contribute to a *conscious* sense of position.[19,20] This conclusion is based on studies in which local anesthetization of joint tissues failed to reduce joint position awareness and total joint replacement did not diminish joint position sense.[21] However, loss of proprioception function in the lower extremities has been associated with higher rates of falling.[22]

Visual Neurophysiology

The visual system contributes significant information about the body's position and movement in space. Vision plays a primary role in anticipatory postural control.[23] Incoming information from the visual system is used to pre-set the postural system for an anticipated change or perturbation.[23] The visual system provides information about the position of the head relative to the environment and orients the head to maintain level gaze. This system contributes significantly to head and neck posture.[23] The visual system also provides information about the movement of surrounding objects, thereby providing information about the speed of movement. Information entering the visual system travels through the optic nerve to the lateral geniculate nucleus (LGN) of the thalamus to the superior colliculus and inferior olivary nuclei. The LGN receives the largest projection and is the first center where information from the retina is represented.[23,24] From here, neurons project to the primary visual cortex in the occipital lobe (Brodmann's area 17). As essential as vision is to anticipatory control, clearly it is possible to balance without vision such as walking in the dark. Visual inputs can also be an inaccurate source of orientation information about self-motion, and the visual system has been shown to have difficulty distinguishing between self-motion and object motion.[23]

Vestibular Neurophysiology

The vestibular system provides information on orientation of the head in space with respect to gravity and acceleration. The vestibular system provides the gravito-inertial frame of reference for postural control.[23] Any movement of the head, including weight shifts to adjust posture, stimulate the vestibular receptors. There are two types of vestibular receptors: the semicircular canals and the otoliths of the macula. The semicircular canals function as angular accelerometers and sense angular acceleration of the head.[23] The otoliths sense linear position and linear acceleration. The semicircular canals are particularly sensitive to fast head movements, whereas the otoliths respond mostly to slow head movements, such as those movements during postural sway.[23] The vestibular nerve (a division of cranial nerve VIII) projects to the vestibular nuclei and to the cerebellum. In fact, the vestibular system is the only sensory system that has direct, monosynaptic input to the cerebellum. Two vestibulospinal tracts descend from the vestibular nuclei to the spinal cord for postural control.[24] These join several other descending pathways involved in postural control. Ascending projections include fibers to oculomotor nuclei to control eye movements and stabilize gaze via the vestibulo-ocular reflex. Ascending fibers also project via thalamic relays to the head of the caudate nucleus and to the parietal association area, where the information is integrated with other sensory information.

Interestingly, the vestibular system alone cannot provide the CNS a completely accurate picture of how the head and/or body is/are moving in space. The vestibular system is not able to distinguish between a simple head nod (head moving on a stable body) from a forward bend from the hips (head moving in concert with moving trunk).[23]

Neural Integration and Processing of Sensory Information

It is generally believed that the nervous system maintains an internal representation of the body in space. Balance control involves both postural and visual vertical orientation in space. Effective motor control depends on the accuracy of the internal maps of body and spatial orientation. Damage to the sensory systems or CNS may lead to impaired orientation in space. For example, the internal representation of visual, but not postural, vertical is tilted in individuals with unilateral vestibular loss.[25] However, the internal representation of postural, but not visual vertical, is tilted in individuals with hemi-neglect because of stroke.[25]

After information arrives from peripheral receptors, the information must be analyzed. Because no one sensory system can completely detail the body's position in space, the relative contributions from each system and integration of each system's information are critical. Integration and processing of incoming information occurs in the cerebellum, basal ganglia, and supplementary motor area.[26] The time required to process this information is important, particularly when a quick response is necessary. In adults, muscle response latencies to visual cues signaling perturbations to balance are slow, approximately 200 milliseconds, compared to somatosensory responses that are activated in 80 to 100 milliseconds.[23] Thus, the somatosensory system information is generally processed fastest, followed by the information from the visual and vestibular systems.[23,26] Researchers suggest that the nervous system preferentially relies on somatosensory inputs for controlling body sway when imbalance occurs from rapid displacement of the support surface.[23] However, balance function is also determined by the task and the context in which that task is being performed. Thus, the nervous system also needs information about the intended task and must resolve and ambiguity in sensory feedback from the environment in order to generate appropriate postural alignment, adjustments, and reactions.

Sensory organization is the process of resolving conflicting input; it is necessary because incoming information from a system may be inaccurate. For example, consider sitting stationary on a train in a station when an adjacent train begins moving forward. The visual system alone is unable to detect whether the adjacent train is moving forward or your train is moving backward. The brain must resolve inaccurate input from the visual system with the accurate information from the somatosensory and vestibular systems. However, somatosensory and visual inputs are prone to error. If an injury decreases the information processing rate, balance may be impaired. For example, individuals with sensory loss from any sensory modality are limited in their ability to reweight (adjust the emphasis) sensory information as required by changes in environmental context and, thus, are at increased risk for falling in certain situations.[6] If a single sensory system is impaired, other systems may adequately compensate for this impairment in most environmental contexts, and this concept is the basis for many treatment programs. However, balance may be significantly impaired if multiple sensory systems are damaged (see **Building Block 8-2**).

BUILDING BLOCK 8-2

Consider the impact of impairments in specific sensory systems. Patients with impairment in the somatosensory system are more likely to demonstrate imbalance in which conditions? In which environmental contexts would you anticipate persons with vestibular impairments to show the greatest instability?

Generating Motor Output—Movement Strategies

After the sensory information is transmitted centrally, the information is processed, and a response is selected, the response output must be executed. This process is referred to as *motor organization*. The process of motor response organization involves the execution of coordinated and properly scaled neuromuscular synergies[27] that must counteract either internal or external perturbations of the COM. Normal voluntary movement is dependent on complex excitation and inhibition of muscular contractions, accurately controlled in force and extent, and appropriately organized in space and time, with a number of relevant postural adjustments[28] in the head and neck, trunk, and extremities.[10] Complex movements take longer to process and program than simple tasks. Motor processes develop early in life, resembling adult performance between ages 3 and 4 years.[29]

The systems-level model of postural control proposed by Riach and Hayes[30] suggests that normal postural control is dependent on the parallel and integrated maturation of specific feedback (closed loop) and feedforward (open loop) mechanisms. The feedback mechanisms of postural control are the automatic postural responses; these involve activation of the labyrinthine righting reflex, vestibulo-collic reflex, vestibulo-spinal reflex, and functional stretch reflexes. The feedforward mechanisms involve preparatory adjustments in body position that accompany a variety of activities.

Automatic Postural Responses

Although a multitude of postural responses are available when someone is destabilized, two broad classes of *automatic* responses are common. There are four classically identified automatic postural responses:

- Ankle strategies
- Hip strategies
- Protective extension
- Stepping strategies

The ankle and hip strategies are *in-place* strategies because the BOS does not change. Alternatively, the protective extension and stepping strategies are *change-in-support* strategies. These responses are considered automatic because of their short response latencies. The earliest response latencies to surface perturbations are at 70 to 180 milliseconds, much longer than stretch reflex latencies of 40 to 50 milliseconds, but shorter than volitional reaction times of 180 to 250 milliseconds.[16] This suggests that balance is learned and therefore trainable. These pre-programmed strategies (or synergies) are the fundamental movement unit engaged when balance is disturbed.[5,14,16]

Rather than determining which muscles to activate and when, the brain only needs to recognize which synergy to engage to meet the task demands in the particular environment, when to engage it, and at what intensity to respond. This is an example of synergistic neuromuscular control. These synergies use feedforward control when the movement occurs too fast to rely solely on sensory feedback. The synergies can also function automatically using feedback control. Selection of these movement patterns is triggered initially by sensory feedback. Sensory feedback experiences throughout development help the CNS learn the rules used to engage these strategies. Treatment procedures for reactive balance control impairments focus on eliciting these pre-programmed synergies to maintain postural control. However, remember that the motor output is situation dependent. The response to a stimulus will vary depending on the environment in which it is elicited. Thus, be sure to vary the treatment environment appropriately; this allows the patient to develop movement strategies in a variety of situations.

The ankle strategy proceeds in a distal to proximal pattern and is utilized when displacements are small (**Fig. 8-5**). Posterior displacement of the COM results in activation of the anterior tibialis, quadriceps, and abdominals to counter backward movement. Conversely, anterior displacement of the COM produces activation of the gastrocnemius, hamstring, and trunk extensors to slow the forward movement.[16,26]

The hip strategy is activated when ankle motion is limited, the displacement is large, the COM is near the LOS, or the surface is unstable. In this case, a posterior displacement of the COM (i.e., anterior translation of the surface) results in a backward sway with activation of the hamstring and paraspinal muscles (**Fig. 8-6**). Anterior displacement of the COM (i.e., posterior translation of the surface) produces forward sway with

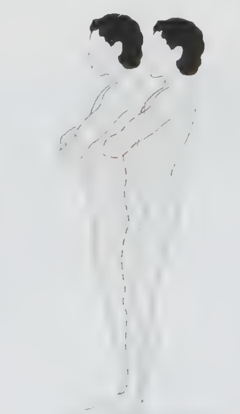


FIGURE 8-5 Ankle strategy in response to small perturbations.

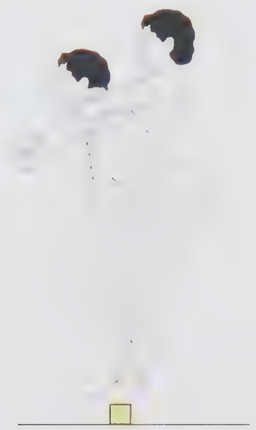


FIGURE 8-6 Hip strategy in response to larger perturbations.

contraction of the abdominal and quadriceps muscles. In each case, the muscle activation proceeds from proximal to distal in an attempt to return the COM over the BOS. Little ankle activity occurs in this synergy (**Table 8-1**).

If the displacement is great enough, the stepping strategy may be used to return the BOS under the COM. A forward, backward, or lateral step is elicited to regain postural balance in these circumstances.

Healthy individuals appropriately match the selection of a balance strategy to the demands of the situation. However, factors such as age, risk for falling, and the presence of disease significantly influence which balance strategies are activated and may result in specific types of balance impairments. For example, elderly individuals who are at increased risk for falling tend to use hip, protective extension, and stepping strategies more frequently than those who are not at increased risk.[31]

Anticipatory Postural Adjustments

Volitional movements, such as reaching, stepping, or lifting objects, cause displacements of the COM. The healthy individual is able to anticipate the postural requirements needed with these tasks and generate anticipatory movement strategies that prevent destabilization secondary to self-generated postural perturbations. These anticipatory postural adjustments are generated by feedforward mechanisms of postural balance. Feedforward control is characterized by actions that occur without sensory feedback. Research has identified numerous examples of this postural adjustment in healthy individuals (**Evidence and Research 8-1**).

EVIDENCE and RESEARCH 8-1

Examples of Feedforward Control

- Activation of the contralateral tibialis anterior before step initiation of the ipsilateral limb to pull the COM forward and over the stance limb.[32]
- Lower-extremity muscles are the first to be activated during reaching activities.[33]
- With a heel rise, the triceps surae are inhibited 150 milliseconds before lift off as the tibialis anterior pulls the COM forward over the anticipated new BOS.[34]

Persons with neurologic and orthopedic impairments may demonstrate poor feedforward postural control. Patients with Parkinson's disease often have impaired anticipatory postural adjustments and will become unstable during lifting tasks. Similarly, pain and muscle weakness may interfere with anticipatory adjustments following total joint replacement.

Additional Considerations

Some individuals, such as those with multifactorial disequilibrium, may have difficulty with both feedback and feedforward control mechanisms. It is often difficult to separate the feedforward and feedback aspects of postural control in a given task. Many tasks require both processes, and these control mechanisms operate in parallel with each other. Careful analysis of postural balance during task performance leads to a better understanding of impairments related to motor organization, and, thus, more targeted treatment interventions.

Though early research identified three fundamental movement strategies to maintain equilibrium (ankle, hip, and the stepping strategies),[16,26] more recent studies suggest that these strategies rarely occur in isolation.[15] Additionally, the selection and execution of these strategies depends on the intensity of the disruption, the relative location of the COM to the LOS, the individual's awareness, and the individual's posture at the time of perturbation.[26]

TABLE 8-1

Comparison of In-Place Strategies (Ankle and Hip)

	ANKLE STRATEGY	HIP STRATEGY
Used when. . .	Small displacement	Ankle motion is limited, the displacement is large or rapid, the COM is near the LOS, or when standing on an unstable surface
Posterior displacement of the COM	Anterior tibialis, quadriceps, and abdominals to counter backward movement	Backward sway with activation of the hamstring and paraspinal muscles
Anterior displacement of the COM	Activation of the gastrocnemius, hamstring, and trunk extensors to slow the forward movement	Forward sway with contraction of the abdominal and quadriceps muscles
Activation pattern	Distal to proximal	Proximal to distal

In addition, underlying balance impairments may vary within a specific patient population. For example, individuals with Parkinson's disease, who demonstrate poorly coordinated automatic postural reactions, show instability with external perturbations.[15] However, those with abnormalities in anticipatory postural adjustments show instability during self-initiated tasks.[15] Thus, knowledge of the individual's diagnosis is not sufficient to guide rehabilitation interventions. A careful and thorough examination encompassing each of the subsystems of balance control is needed.

Control of Walking—Navigation

Many of the concepts described thus far can also be applied to understanding adaptive control of walking. Patla[35] provides further insights into the requirements of adaptive gait. The nervous system must set up the body's initial posture and orientation necessary to initiate walking. Propulsive muscle activation patterns must be determined, executed, and coordinated. The individual must be able to initiate and terminate walking as desired. Dynamic stability must be maintained as the body encounters both expected and unexpected destabilizing forces. The individual must also be able to modulate locomotor patterns to accommodate for obstacles, changing terrain, and time constraints. The ability to navigate toward a point that is not seen is often required. Locomotor systems must also minimize fuel consumption and maximize structural integrity to promote longevity. The nervous system employs reactive, predictive, and proactive control strategies to accomplish these goals.

Reactive and predictive control of walking involves context-specific, neuromuscular synergies analogous to automatic postural responses and anticipatory postural adjustments involved during stance control. Proactive control strategies involve visually guided mechanisms used for obstacle avoidance or to alter global locomotor patterns in response to perceived or observed hazards in the environment.[35] For example, consider that walking characteristics change as one approaches a patch of ice on the sidewalk, even in advance of detecting any loss of traction under the feet.

Balance impairments related to any of the requirements for adaptive gait may arise related to a variety of health conditions. Persons with limited hip ROM secondary to osteoarthritis (OA) may have difficulty setting up the posture required to initiate walking. An individual with cerebellar ataxia may demonstrate instability in walking because of problems coordinating muscle activation patterns or may have difficulty terminating walking at the appropriate time. Consider the impact macular degeneration may have on an individual's ability to effectively recognize and avoid hazards in her path. The clinician may choose from a variety of tests developed to assist the understanding of balance impairments specific to the task of walking in order to drive clinical decision-making regarding rehabilitation of balance and mobility (see **Building Block 8-3**).

BUILDING BLOCK 8-3

The use of an assistive device, such as a front-wheeled walker, is an appropriate compensatory measure for individuals with a variety of balance impairments (e.g., ineffective use of postural reactions). Why would you prescribe exercises to facilitate appropriate postural movement strategies for an individual who will continue to use an assistive device after the conclusion of rehabilitation?

Higher-Level Influences

Information processing resources in the CNS are constrained. As a result, attention is both limited and selective. Attention has a significant influence on balance control.[36–39] The effect of attention is typically measured by the degree of interference between two tasks. The degree of interference is determined by several factors, including the *relative task difficulty*. This concept refers to the fact that specific factors, such as personal (e.g., age, pathology, medications) and environmental (e.g., noise in the treatment area), influence attention capacity in highly individual ways. For example, increased age and a high number of comorbid health conditions tend to increase relative task difficulty. Therefore, when examining the effects of attention on balance control, care must be taken with regard to the types of tasks that are chosen for a given individual.

The individual's focus of attention also plays a significant role. Consider whether the individual should be encouraged to have an internal or an external frame of reference when completing a specific task. Research has shown that having an internal focus of attention is associated with greater performance errors, whereas successful functional outcome is associated with an external focus of attention.[40] For example, asking a patient to simply focus on clearing her foot as she attempts to step over an obstacle (external focus) is more effective than instructing the patient to flex their knee 70 degrees (internal focus) as they try to clear the object.

The limbic system, emotional resources, and coping strategies also play important roles in determining balance control. Fear of falling significantly influences behavior. The selection of automatic postural responses is influenced by fear of falling.[41] Individuals make choices about the mobility based on the types of threats to postural instability encountered in their environment.[42] Confidence related to balance and perception of disability secondary to dizziness have also been shown to impact rehabilitation.[43,44]

CAUSES OF IMPAIRED BALANCE

Injury, disease, or suboptimal function of any of the major body systems can lead to impaired balance. The relationships between health, impairment, activity limitation, and participation restriction are complex and dynamic. Impairments in body structure or function alone do not result in specific activity limitations.[15] Rather, activity limitations that lead to participation restrictions depend on the individual's impairments and the mechanisms that a person uses to overcome those impairments.[15] Consider the potential impact of vestibular loss on two different people: one who works as a flight attendant, the other who is a skilled welder working on overhead scaffolding. Although both may need to work on learning how to balance on a moving surface with conflicting visual feedback, the level of challenge presented during rehabilitation, compensatory mechanisms available, and ultimately their ability to return to work may differ.

Damage to any of the sensory systems contributing to balance leads to balance impairment. Lesions produced by tumors, cerebrovascular accidents, or other insults often produce visual field losses, changing the individual's spatial orientation and altering balance responses. Loss of vision for any reason, including aging, can impair balance. Visual losses can often be compensated by input from other sensory systems. Damage to the vestibular system can also cause profound limitations. Viral infections of the vestibular nerve, the aging process, or head injury are among the possible causes of vestibular pathology. These individuals experience vertigo, or the feeling of falling or spinning even when stable.

Other lesions of the cerebellum, basal ganglia, or supplementary motor area can impair processing of the incoming information. Parkinson's disease, Huntington's disease, and cerebellar tumors affect balance and movement.[16]

Damage to proprioceptors has been implicated in balance deficits. Injury or pathology of the hip, knee, ankle, and back is associated with increased postural sway and decreased balance.[20,45–48] Numerous studies demonstrate impaired balance in patients with a variety musculoskeletal conditions (see **Evidence and Research 8-2**).

EVIDENCE and RESEARCH 8-2

Damage to proprioceptors implicated in balance deficits:

- Damage to the anterior cruciate ligament (ACL), posterior cruciate ligament, or meniscus results in altered mechanoreceptor activity and altered kinesthesia and joint position sense.[49–52]
- Sensory feedback improves after joint reconstruction, but remains abnormal.[53]
- Basketball players with a history of ankle sprain demonstrate increased mean sway and increased sway area.[54]
- Increased mediolateral postural sway in SLS on the injured side following unilateral ankle sprain persists after rehabilitation without neuromuscular reeducation.[55]
- Abnormal postural control significantly increases the risk (42% to 57%) for future ankle injuries.[56]
- Individuals who are status-post ACL reconstruction demonstrate better balance versus individuals with ACL-deficient knees, but performance remains significantly worse than healthy control subjects.[57]

Research demonstrates a relationship between balance and degenerative disease of the knee joint as patients with knee OA have significantly more postural sway than the healthy individuals.[46] Similarly, the relationships among degenerative joint disease, total joint replacement, and balance have been studied.[46,58] Significantly increased postural sway in both sagittal and frontal planes is seen status-post repair of a hip fracture.[59] Use of sensory feedback and dynamic standing balance are significantly impaired following total hip arthoplasty.[60] In fact, functional measures of balance demonstrate that postural control remains impaired at least 6 to 12 months post-surgery for hip replacement.[61,62] The unfortunate consequence is often a fall with rehospitalization. Patients show a 10% to 20% decrease in strength compared to the uninvolved hip 1 year after hip replacement.[63] Research also shows a 27% to 39% decrease in extensor and flexor torque 1 year after knee replacement[64] and decreased vertical loading on the involved side 2 years following hip replacement.[65] Thus, patients may have long-term mobility-related disability following these procedures.

Adults with low back pain demonstrate increased postural sway, increased posterior center of pressure displacement, and decreased stability in SLS.[45] Impaired sensory organization and abnormal automatic postural responses are observed in individuals status-post whiplash injuries.[66,67] Together, this collection of findings further illustrates the importance of spine and extremity function to balance control.

There are also many examples of balance impairments related to the combination of orthopedic and neurologic conditions. Consider the following examples. Exaggerated disability following stroke may occur secondary to undiagnosed arthritic hip on the less-involved side. Diagnosis of Parkinson's disease can occur after hospitalization for surgical repair of a hip fracture resulting from a fall. An elderly patient with multiple risk factors for falling, including dizziness, may present for rehabilitation of a distal radius fracture.

Age is also a primary consideration in balance impairment. Age appears to affect all aspects of the stability triad (i.e., somatosensory, visual, and vestibular) and all three stages of information processing (i.e., input from periphery, processing information, and generating motor output).[68] For example, the sensory input stage can be affected by losses in proprioception in the elderly. Barrack et al.[58] found a decline in joint proprioception as part of normal aging. This decrease, along with poor vision and impaired vestibular function, predisposes the elderly person to impaired balance and falls.[68]

Although declines in sensory input, especially declines in the acuity of sensory information, are found with aging, the primary problem appears to occur at the information-processing stage. Visually "noisy" environments with much visual stimulus from mirrors and windows can make information processing challenging.[68] Information processing can be improved by the use of high-contrast input, for which the difference between the signal and noise is clear.

After sensory information is processed and a response is selected, impaired balance can result from weakness, decreased mobility, impaired motor programming, pain, or impaired posture. The balance strategy chosen will be unsuccessful if the patient lacks the muscle strength, mobility, or motor programming to execute stabilization. Similarly, if the movement is inhibited by pain, the chances of falling are increased. If the patient has significant posture impairment such as a thoracic kyphosis, the sway envelope is decreased, and the chances of exceeding the LOS are increased.

EXAMINATION AND EVALUATION OF IMPAIRED BALANCE AND MOBILITY

Horak et al.[16] identified keys to examination and rehabilitation program design, including balance control:

- Knowledge of the systems controlling equilibrium
- Knowledge of the systems likely disordered by aging and pathology
- An understanding of the factors that are likely to influence recovery of function
- Attention to the environmental factors that influence balance and mobility
- Adherence to the concepts of motor learning that govern task development

Additionally, a clinical framework, such as the systems model set within an ecological context, can facilitate our thinking about examination and intervention.[13] Given that balance and mobility-related disability is both individually and contextually dependent, clinicians must also strive for a deep understanding of the *lived experience* of the individual. Furthermore, clinicians must thoroughly understand the myriad of tests available for examining balance and gait. Perhaps most important, the clinician must work with the patient to develop meaningful and realistic goals for rehabilitation. Basing clinical decisions on knowledge from each of these domains can enhance the clinician's ability to choose the right outcome measures for the right patient at the right time. Understanding the relative importance of specific impairments, activity limitations, and participation restrictions identified during the examination enhances the ability to prioritize the plan of care and select specific interventions.

The *Guide to Physical Therapist Practice*[69] describes three categories of balance assessments. They are:

- Balance during functional activities with or without the use of assistive, adaptive, orthotic, protective, supportive, or prosthetic devices or equipment (i.e., ADL or IADL scales, observations)
- Balance (static or dynamic) with or without the use of assistive, adaptive, orthotic, protective, supportive, or prosthetic devices or equipment (i.e., balance scales, dizziness inventories, dynamic posturography, fall scales, motor impairment tests, mobility skill profiles)
- Safety during gait, locomotion, or balance (i.e., confidence scales, diaries, fall scales, logs)

Thus, examination of balance impairment can range from simple to complex.[23,70] Simple, impairment-level clinical measures, such as the ability to maintain a SLS with the eyes closed or the Romberg test, are commonly used in clinics. Measures of activity limitations, such as the Berg Balance Scale (BBS) and Timed Up and Go (TUG) Test, are more commonly used by certified clinical specialists.[71] Additionally, computerized balance testing systems are increasingly incorporated into clinical evaluation and treatment.[72–74]

As stated, balance impairment can arise from many sources. Thus, it is critical that the examination differentiate between biomechanical, motor, sensory, and other contributing causes of imbalance. This is the hallmark of a systems approach to examination. The systems model of postural control and orientation provides the foundation for this discussion regarding examination of balance (Fig 8-2).

It is also imperative that the clinician understand what he/she is testing. Consider the example of the sternal nudge test. The clinician attempts to disturb the patient's balance by trying to push the patient with instructions such as, "don't let me push you over." The patient's response is to tighten all muscles in an attempt to resist the clinician's push. This tests the ability to tighten postural muscles, more so than balance reactions. Further, this test, like the SLS and Romberg tests, is a static test, and tells little about the individual's ability to maintain balance while moving. However, this test may be a relevant indicator of balance control in crowd situations, where a patient may get pushed. Consider what is being tested, what determines a positive test, and how this test would subsequently direct treatment. This highlights the importance of an organized, thoughtful examination process designed to sequentially and specifically test the various systems involved in balance.

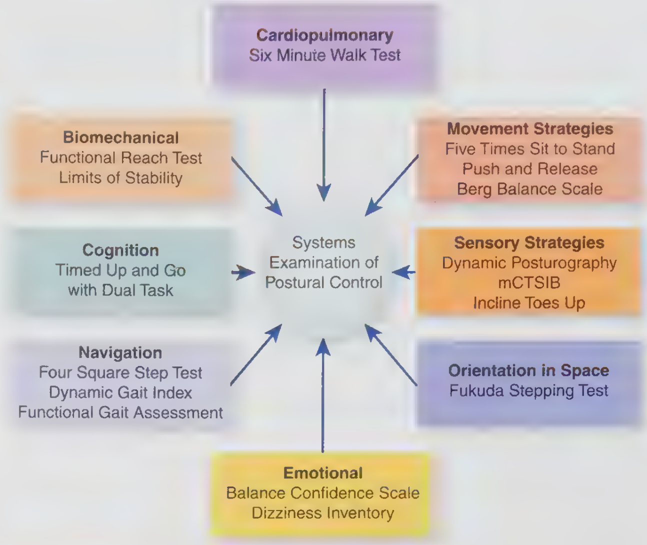


FIGURE 8-7 Examination of postural control from a systems model perspective.

Although most balance measures examine the performance of multiple body systems simultaneously, each assessment tool falls into a primary domain within the systems model (**Fig. 8-7**). The clinician should choose an evaluation battery that taps the multiple aspects of balance control, including musculoskeletal, sensory strategy, movement strategy, dynamic control, cognitive, and affective domains.

Biomechanical Domain

Evaluation of biomechanical causes of imbalance can be readily performed in the clinic. Crutchfield[5] emphasizes the importance of distinguishing among a normal neurologic system working with an abnormal musculoskeletal system, an abnormal neurologic system working with a normal musculoskeletal system, or a combination of both. Joint ROM, muscle length imbalance, impaired muscle performance, pain, or other postural abnormalities (e.g., kyphosis) can contribute to balance impairment. Loss of motion at a joint or series of joints (e.g., ankle, knee, and spine), decreased accessory motion, and muscle length imbalance alter posture and movement strategies. Likewise, muscle impairments such as weakness or loss of endurance alter movement strategies. For example, gluteus medius weakness results in a predictable alteration in gait known as trendelenburg gait. This weakness may prevent normal hip or stepping strategy use. Pain often produces changes in movement that, if continued, can produce secondary strength and mobility impairments. Limited ankle ROM prevents use of an ankle strategy, requiring the patient to use a hip strategy. This may be interpreted as faulty balance, although the hip strategy may be the best strategy available for that individual. Many of these impairments can be assessed using simple clinical measures such as goniometry and manual and functional muscle testing.

The Functional Reach Test (FRT)[75] and tests of stability limits are examples of functional balance measures that can guide clinical decision-making regarding potential biomechanical influences on postural stability. The FRT was originally developed as a performance-based assessment of unsupported dynamic standing balance. This test is performed by observing how far forward an individual can reach while standing. Population-based normative data and/or data regarding risk for falling based on FRT scores are available for the elderly[75] and children.[76] Another version of the FRT provides information regarding the ability of the patient to reach in multiple directions.[77] The FRT requires minimal equipment and time to administer. An individual's stability limits can also be quantified by performance-based scales, use of posture grids, or via computerized technologies utilizing force platforms.

Sensory Strategies Domain

Impairment of the sensory systems can result in balance impairment. Thus, each of the sensory systems contributing to balance control should be addressed. The somatosensory and visual systems may be tested directly. Basic, impairment-level tests of the lower-extremity sensations of light touch, vibration, proprioception, and kinesthesia should be considered. Screening for visual field defects, eye movement control, or sensitivity to visual motion may be pertinent depending on the specific case. The influence of the vestibular system must be tested indirectly and inferred through observing the performance of vestibular outputs, such as the vestibular-ocular reflex and postural stability in sensory-deprived conditions.

Several components of sensory organization (functional utilization of sensory feedback for postural stability) can be tested readily in the clinic; however, a full examination of sensory contributions to postural sway requires more elaborate equipment such as a visual-conflict surround and rotating platform. The Postural Dyscontrol Test or Clinical Test of Sensory Interaction in Balance (CTSIB) provides clinicians with data regarding the individual's use of visual, vestibular, and somatosensory systems in combination and isolation.[14,23] Systematically studying the contributions of each of these systems requires different testing situations, including standing with the eyes open on a fixed platform; standing blindfolded on a fixed platform; sway-referenced vision with fixed support; normal vision with sway-referenced support; absent vision with sway-referenced support; and sway-referenced vision and support[7] (**Fig. 8-8**).

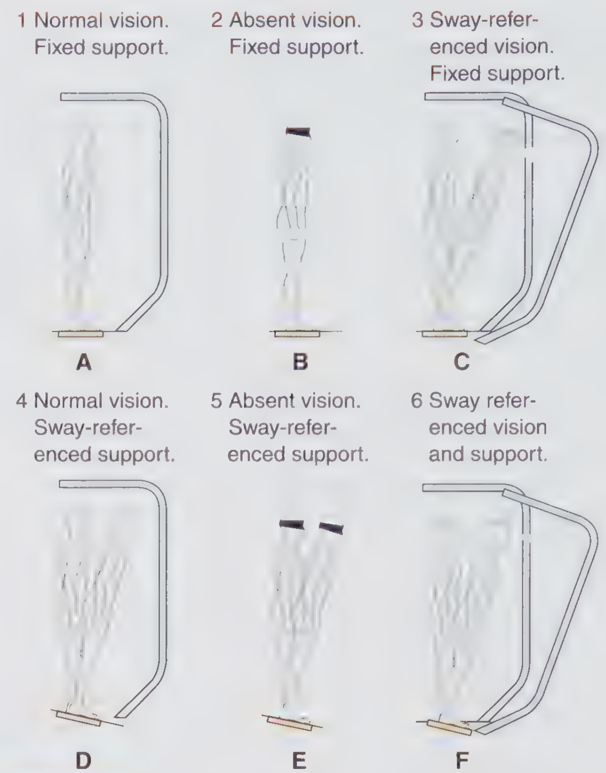


FIGURE 8-8 The six balance testing situations: **(A)** standing quietly, eyes open; **(B)** standing quietly, with eyes closed; **(C)** standing with a visual box, and eyes open; **(D)** standing, and body rotates with body sway; **(E)** standing, rotating platform, with eyes closed; **(F)** standing on a rotating platform with a visual box.

Observation of performance while standing with the eyes open on a fixed surface provides a global view of stability when all sensory modalities are potentially available. Removing vision by closing or blindfolding the eyes provides information on the contribution of the somatosensory system. In the situation with sway-referenced vision with fixed support, the visual box moved as the subject swayed, presenting a sensory conflict: movement took place, but the eyes did not register movement. Joint receptors sensed the movement, but the eyes did not. The vestibular system provided the resolving information, indicating that movement had taken place. During this testing, normal subjects sway very little. The situation of normal vision with sway-referenced support presents a different conflict. In this case, the platform rotates in conjunction with the body sway. The visual system records movement, but the joint receptors do not. Once again, the vestibular system presents the resolving information. Greater sway occurs in this situation than in the previous three situations because of differences in sensory processing times between the somatosensory and other systems. The greatest sway is observed in situations of absent vision with sway-referenced support and of sway-referenced vision and support, for which inaccurate information is furnished from more than one source. Platform rotation provides inaccurate information to the visual and kinesthetic systems in the situation of absent vision with sway-referenced support. The rotating platform and visual box provides inaccurate visual and somatosensory information in the situation of sway-referenced vision and support. These tests suggest that individuals rely primarily on the somatosensory system for orientation and postural control and that, when somatosensory and visual information are removed or inaccurate, the vestibular system is left to provide postural control.[5]

Modified CTSIB (mCTSIB) Test components	Biases which system
Eyes open, firm surface	All sensory systems available
Eyes closed, firm surface	Somatosensory (vision absent)
Eyes open, compliant surface	Vision (impaired somatosensory)
Eyes closed, compliant surface	Vestibular (impaired somatosensory, absent vision)

Cohen et al.[78] developed a streamlined version of the CTSIB. This modified version includes only the following four conditions (see table) This version has been used in adults,[78] children,[79] and patient's with vestibular disorders.[80,81] The test may be performed with or without the patient standing on a force platform. Various ways of describing performance have been proposed, such as using an ordinal scale.[14]

Movement Strategies Domain

Assessing motor organization (movement strategies) in balance control can be conducted within the context of functional task performance inside or outside the context of standardized clinical assessment tools. Simple measures that provide insight regarding use of in-place anticipatory and reactive movement strategies include the FRT (described previously) and the Five-times-sit-to-stand (5×STS) Test.[82] As a measure of upper-extremity reaching ability, the FRT also assesses postural adjustments that anticipate upper-extremity movement.[75,83] In addition to measuring functional lower-extremity strength, the 5×STS also provides a basis for evaluating balance control during transitions when moving between sitting and standing. In this test, the individual is asked to rise to standing and sit back down (without use of the hands) as quickly and safely as possible five times consecutively while being timed. Alternatively, the 30-second Chair Stand Test may be used for patients who are unable to rise from a chair without pushing off the armrests.[84]

Alternatively, the Push and Release Test (PRT) provides information about corrective stepping (change-in-support) responses.[85] As opposed to the sternal nudge or "pull test" in which the individual knows the perturbation is coming, the PRT creates instability by having the patient attempt to maintain stability after being unexpectedly released from a position of gently leaning into the examiners hands. The reliability, sensitivity, and specificity regarding detecting balance impairments with the PRT have been found to be superior to other tests of perturbed stance, such as the sternal nudge.[85] Much information regarding movement strategies can also be gleaned from observing performance on test batteries such as the BBS.[8,13] The BBS rates performance from 0 (unable to perform) to 4 (normal) for 14 different tasks. Each task is performed without using the upper extremities for assistance.

Dynamic Control Domain

None of the measures introduced thus far provide the clinician with the necessary information required to drive clinical decision-making regarding walking-related balance impairments. Insight into a patient's ability to step in multiple directions, a skill necessary for many functional tasks, including obstacle avoidance and navigation in crowded spaces, can be gleaned from the Four Square Step Test (4SST).[86] In the 4SST, the patient is asked to step over four standard canes arranged on the floor in the shape of a "plus sign." The test is timed and the patient must first step over each cane moving in a clockwise manner and then return to the starting position moving counter-clockwise. The TUG Test requires the patient to stand up from sitting in a chair, walk 3 meters, turn around, return to the chair, and sit again.[23,87] The reliability of this test is high, and it correlates well with the BBS.[88] The Dynamic Gait Index (DGI) is a measure of dynamic balance as it measures the patient's ability to modify gait in response to changing task demands.[23,89] The DGI has been shown to have good interrater and test–retest reliability.[23] Two major alternatives to the original DGI now exist. Wrisley and colleagues[90] expanded this test and created the Functional Gait Assessment (FGA) in part in an attempt to capture information regarding balance control in patients with high-level problems. Preliminary normative data for the FGA now exist.[91] Alternatively, Marchetti and Whitney[92] found that a four-item version of the DGI could provide accurate information about faller status with comparable sensitivity and specificity to the original DGI. The scoring system for the original DGI was recently expanded to account for additional factors that affect performance, such as the time required to complete tasks.[93] In order to evaluate higher-level skills, such as running, jumping, hopping, and skipping, clinician's may use the High-level Mobility Assessment Tool (HiMAT).[94,95] This tool was developed for use with patients status-post traumatic brain injury.

Cognitive Domain

The TUG Test has been modified to include the simultaneous performance of a secondary cognitive task.[39] Repeating the TUG Test in this manner allows the clinician to gather information regarding the influence of divided attention on balance control during walking. Careful consideration should be given to which secondary cognitive task the patient is asked to perform. Patients should be allowed to practice a similar cognitive task before engaging in timed walking. The details of the task, as well as the impact on walking performance and cognition should be documented clearly.

Affective Domain

Self-confidence related to balance and perception of disability secondary to dizziness represent two important affective influences on balance and mobility. The Activities-Specific Balance Confidence (ABC)Scale consists of 16 questions for which patient's are asked to rate their level of confidence that they will not lose their balance or fall while performing.[96] Average scores of less than 80% are considered abnormal and less than 50% have been correlated with a greater likelihood of being home bound.[96] The Dizziness Handicap Inventory (DHI) is an assessment tool used to gauge self-perceived disability related to dizziness.[97] The DHI consists of 25 questions divided between physical, functional, and emotional subscales. Scores range from 0 to 100, with higher scores indicating greater disability. The degree of disability has been correlated with functional balance measures[44,98] and prognosis for recovery.[43] Each of these questionnaires also provides insight into the patient's lived experience of their health condition (see **Building Block 8-4**).

BUILDING BLOCK 8-4

A 30 year-old previously healthy man is referred to physical therapy in the hospital two days after undergoing surgical resection of a vestibular schwannoma. The patient complains of vertigo, blurred vision, and feeling like he is intoxicated. He reports he has had difficulty walking to the bathroom with the nursing staff. What are the two tests of postural control that you would prioritize to be completed during the initial evaluation that could be used subsequently in the outpatient setting as outcome measures for this patient's rehabilitation? Why did you choose these tests?

Determining Risk for Falling

What is the likelihood that my patient will fall? This is one of the most important questions clinicians must answer. The ability to accurately answer this question has profound implications. Researchers and clinicians use each of the clinical tests of balance mentioned above to provide clues as to a person's risk for falling. The 5×STS Test, PRT, FRT, 4SST, BBS, Tinetti's balance and mobility assessment, TUG Test, and DGI are used frequently in the clinic to stratify risk for falling.[8,13,75,89] The cutoff score associated with falls risk may vary by age. For example, the cutoff score for the 5×STS was found to be 10 seconds for those under 60 years and 14.2 seconds for those over 60 years in a population of adults with balance disorders.[99] Cutoff scores may also vary by population. For example, a score of 15 seconds or longer on the 4SST identifies older adults with a history of multiple falls;[86] however, scores of 12 seconds or longer provide the same indication of prior falls status in persons with vestibular disorders.[100] Older adults who scored higher on the BBS were less likely to fall than those who scored below 45 out of the possible 56 points.[89,101] Different cutoff scores for the BBS are applied to individuals with Parkinson's disease[102] or those who are status-post traumatic brain injury[103] or stroke.[104] Like the BBS, the DGI can be used to determine falls status. Scores of less than 20 on the DGI indicate an increased association with previous falls, whereas scores of less than 17 are highly associated with prior falls status.[23] Likewise, individuals with vestibular disorders who score less than 19 on the DGI are 2.7 times more likely to have reported a fall in the previous 6 months.[105] Though performance indicators for the BBS and DGI have also been shown to vary by population and living arrangements, the BBS and DGI have been shown to agree 63% of the time for individuals with vestibular disorders.[83,106] It is critical that the clinician be mindful or *who* they are evaluating and *how* they are applying the information gathered. Further information regarding the psychometric properties, population-specific normative data, and/or cutoff scores related to falls risk for many of the assessment tools described in this text may be found online at thePoint.lww.com/BrodyHall4e.

Accurately diagnosing risk for falls is a complex and challenging task. This is due in part to the fact that most published indicators of falls risk only correlate with a person's recent history of falling. Predicting *future* falls requires careful analysis.[102,107,108] Currently, the best predictor of future falls is a history of previous falls.

Balance measures that look at the activity domain incorporate many of the impairment tests discussed above. The challenge for clinicians is to choose measures that will capture the difficulty and predict return to safe activities. The falls risk measures above cross multiple levels of activity. The BBS predicts fall risk as it relates to static and transitional movements. However, a ceiling effect is seen when looking at the person who needs to have dynamic balance during gait, or for the athlete who wants to return to sport. Measures such as the Star Excursion Balance Test (SEBT) have been shown to be sensitive to predict risk for injury as well as to measure recovery from injury.[109] The goal of the SEBT is to maintain single-limb balance while reaching with the contralateral limb in eight different directions.

Consider Jerry, a 19-year-old student who sustained a traumatic brain injury when he was struck by a car while riding his scooter without a helmet. In the acute hospital, while he was still confused and showing mild right hemiplegia, the BBS was useful to determine fall risk in his room. As he progressed in inpatient rehabilitation, Jerry was more mobile and ambulating with close supervision in part because he was not attending to the environment. Although he scored a 52/56 on the BBS (low risk), he only scored an 18/24 on the DGI as he tripped over objects, lost his balance when walking with head turns, and was inconsistent and tripped on the stairs. By the time Jerry reached the outpatient setting, he was walking independently on level surfaces, but movements were slow. Now the DGI score was 23/24, but his HiMAT score, a test that included running, skipping, hopping, and bounding was impaired. In addition, when the BESTest was administered, it suggested Jerry had specific balance impairments including sensory integration and dual-task activities. The acuity and setting must be considered when choosing the most appropriate balance measures.

Activity level is also important when choosing a balance measure. Remember Megan, the 12-year-old who had injured her ACL in Case Study No. 6, Unit 7. By 4 weeks post-ACL injury, she was walking independently without a device. One of her goals was to return to volleyball and tennis. In this case, the therapist used the Y-Balance Test (YBT) to look at Megan's balance. The YBT is derived from the SEBT and is a tool to test a person's risk for injury. The patient does repeated lower extremity reaching anteriorly, posterior medially, and posterior laterally with each leg. Different cut points exist for the YBT based on age, gender, and sport/activity level. In Megan's case, she had a significant 8 cm asymmetry between her involved and uninvolved leg during anterior reach, and her composite reach distance was only 84% of her limb length. These findings suggest a high risk of injury if she tried to return to sport at this time.[109] Interestingly, if the therapist had chosen the Berg, Megan would have scored 56/56, and on the DGI she would have scored a 23/24.

TREATING IMPAIRED BALANCE

Diagnosis and Prioritization

The most important factor in treating balance and mobility impairments is diagnosing the underlying cause(s) and the factors contributing to these impairments. Remember that balance problems can result from biomechanical, neuromuscular, sensory, cognitive, or affective impairments. These impairments may be considered primary (a direct result of a health condition) or secondary (occurring in response to the development of primary impairments). Matching intervention strategies to underlying impairments is critical. Impairments related to muscle performance, mobility, or pain should be addressed early in the rehabilitation process, with ongoing re-evaluation and interventions for continued balance impairment as the fundamental musculoskeletal problems resolve. Chapters 5, 7, and 10 provide specific activities to treat these impairments. If the problem involves motor learning, then it would be considered a modulator element. Modulator elements are addressed throughout the plan of care. Additional modifying factors, such as the need for psychological interventions or cardiac rehabilitation, may need to be addressed early and incorporated into the plan of care as well. For example, consider those with a primary problem of fear of falling. The impaired element of the movement system is within affective domain. A health psychologist or licensed counselor can assist the patient in developing the relaxation strategies needed in order for her to face her fear of falling and engage in the risks associated with balance rehabilitation. Often, the physical therapist works in collaboration with other professionals whose expertise would benefit the patient, but may be less familiar with balance disorders.

Customization

There is strong evidence to support prescription of an individualized intervention program for balance retraining. The treatment suggestions described below must be matched to specific underlying problems for each patient (see **Evidence and Research 8-3**).

EVIDENCE and RESEARCH 8-3

Evidence supports individualized intervention program for balance retraining:

- Rehabilitation that includes balance training results in improved balance[110] and greater success in return to play in athletes.[111]
- Customized balance rehabilitation is more effective than generic exercise programs for reducing dizziness and improving balance in individuals with vestibular disorders.[112]
- Customized, multidimensional exercise programs also improve balance and mobility and reduce falls in geriatric populations.[113]

Environmental Context

Rehabilitation takes place in an environmental context. There are three major factors to consider regarding the influence of the environment on balance rehabilitation:

- The physical location
- Appropriate safety measures
- Specific environmental features to be manipulated during task practice.

The physical location for balance training depends on the patient's situation. For the frail elderly or those with significant balance impairment, most training activities should take place in the clinic. Patients with higher baseline balance abilities and/or self-efficacy related to balance training or sufficient assistance at home will perform the majority of their training at home. Alternatively, patients who are ready to transition out of formal therapy may desire to include more challenging, balance-specific activities, such as T'ai Chi, yoga, and dance into their routine health and wellness program. Recommendations of community-based programs that are appropriate for his/her needs and abilities may be a part of a successful plan of care. For athletes or other active individuals, balance activities may be carried out independently at home, at a local health club, or in a local pool.

Safety is a key factor when making choices about the exercise environment. A stable support should always be available for regaining balance. This support should be placed such that it does not interfere with the exercise and does not cause injury during an attempt to regain balance. Be alert for correct posture, avoidance of substitution, proper performance, and safety when providing direct interventions. Foster the patient's self-awareness and error detection and correction. Simple activities such as postural awareness exercises may be performed safely at home by most patients. Realize that the clinic environment is designed for maximum patient safety and may not reflect real-world situations. Recommendations to perform exercises in a corner, narrow hallway, nearby sturdy furniture, or with various forms of assistance may be appropriate.

The environment has a significant impact on patients and the choices they make regarding mobility. Factors such as distance, temporal demands, physical load, ambient conditions, attentional demands, terrain, frequency of postural transitions, and traffic density are examples of key environmental variables.[42] Distance refers to how far the individual must walk to complete each trip outside their home. Temporal demands include factors such as crowd speed, traffic lights, and amount of vehicular traffic. Precipitation, temperature, and available light are examples of factors related to the ambient conditions. Whether or not the individual must carry a load, such as a purse or grocery bags, relates to the required additional physical demands of each trip. Relevant features of the terrain may include the presence of grades, curbs, stairs, uneven surfaces (grass), shifting surfaces (gravel), and moving surfaces (elevators and escalators). Factors such as presence of distractions or being accompanied by a spouse, partner, or friend are examples that alter the attentional demands of mobility. Even the occurrence of postural transitions such as the need to stop, start, turn, back up, and reach may influence choices about mobility. Individuals with mobility-related disability encounter fewer challenges and show avoidance behaviors with regard to temporal factors, physical load, terrain, and postural transitions.[42] The salience of these factors is unique to the individual.[114] This is another aspect of rehabilitation that should be customized for each patient.

Whether exercising indoors or outdoors, a multitude of external environmental conditions may overload the sensory systems, increasing the risk of a fall. Be sure to progress the patient to balance training in the types of environments they will encounter when they leave the clinic. This may require short "field trips" outside the clinic to reproduce these situations. If real-world experience is not possible, consider the use of photographs, video tape, virtual reality, or gaming to facilitate discussion, mental rehearsal, or simulated practice of specific functional tasks within meaningful environmental contexts.

Mode

A variety of modes, such as supportive chair, therapeutic ball, firm floor, foam roll, foam pad, balance board, or pool, may be used during treatment. The pool is a unique environment to train balance. The water's movement causes perturbations, and the water's viscosity slows balance loss, giving individuals more time to respond (see Selected Intervention 16-3 in Chapter 16). A warm water pool may be an especially good mode for rehabilitating balance in persons with severe arthritis. Balance skills learned in an aquatic environment may not readily transfer to land because of the differences in environmental conditions. Thus, land-based training should be recommended when the patient is ready. More sophisticated, computerized balance testing devices also provide unique opportunities for training. In fact, any mode used for testing balance can be used for training. One of the primary advantages of commercially available balance platforms is that they allow selective modulation of sensory systems and objective measures of progression.

Motor Learning

If a movement is performed repeatedly with sufficient sensory feedback, motor learning occurs and a pattern is formed that guides future performance of the motor program.[16,89]

Although the ankle, hip, and stepping strategies are examples of feedback control, these responses are controlled by motor programs that are pre-programmed collections of motor signals with a goal of achieving a specific task. In the case of restoring balance, sensorimotor experiences related to the goal of repeatedly aligning the COM over the BOS lead to development of pre-programmed, balance strategy, motor programs consisting of collections of motor signals with a goal of achieving a specific postural task. Each motor program contains specific information about *postural set* and the sequencing and timing of muscle activation. If a movement is performed repeatedly with sufficient sensory feedback, motor learning occurs and a pattern is formed that guides future performance of the motor program.[16,89]

Several models of motor learning exist in the literature. Fitts and Posner[115] proposed that the learner passes through three stages when mastering a new skill. Consider learning a new task such as playing the piano or learning to swim. The first phase is *cognitive*, in which full attention to instructions, the task, and performance feedback is necessary to develop gross problem-solving strategies. Performance during this phase is marked by a larger number of large errors, extreme variability, and little insight regarding how to improve.[116] The rehabilitation professional plays a critical role in this stage of learning balance control by working with the individual to select the appropriate tasks to be mastered, providing effective instruction, and guiding the individual with appropriate external feedback. The second phase is *associative*, in which further development and refinement of the movement strategies and acquisition of the ability to detect and identify one's own performance errors occur.[116] The movement patterns become more efficient, although still requiring attention to the task. The goal of training is to get the learner to the *autonomous* (third) stage so that the movement can occur with little thought. The ability to balance while coordinating other physical and cognitive activities is an example of functioning at the autonomous stage and is the penultimate goal of rehabilitation.

Factors such as the quality of instruction and practice, as well as the amount of practice, influence whether or not a person reaches the autonomous stage of motor learning. Continued practice alone may not move the patient toward this stage. The early phase of training a new skill requires feedback. Learning relies on intrinsic and extrinsic cues to refine the movement program. As the process moves toward the autonomous level, more feedback should become intrinsic. Thus, the learner should be encouraged to develop her own internal problem-solving skills. Consider learning to drive from home to work in a new city. In the early stage, concentration on the task is required, and the individual can be overwhelmed with sensory information (e.g., other cars, signal lights, and commercial signs). As driving this path is repeated, less attention to the task is required, until the drive eventually becomes automatic. Extraneous sensory information can be filtered out and only pertinent information processed. In most situations, repeating the pattern facilitates progression to the automatic stage. However, the patient must continue to learn and adapt to new situations. Continued exposure to new situations such as driving in unfamiliar areas teaches the nervous system how to learn or adapt quickly and effectively to new stimuli and situations.

The same learning process is applied to balance activities. As balancing on a single leg or on a balance board becomes easy, less attention is necessary, and the task becomes automatic. The nervous system must be challenged at a new level. This can be done by changing the surface, BOS, external perturbation, or visual or vestibular input (see Self-Management 21-1 in Chapter 21). Continued practice at grossly similar but continuously changing tasks can enhance the patient's ability to adapt to new situations. Exactly which tasks are practiced and which treatment variables are manipulated by the clinician depend on the unique balance impairments of the individual, as they relate to her function in daily life (see **Building Block 8-5**).

BUILDING BLOCK 8-5

Consider again your patient with MS and how her cognitive impairments may affect her rehabilitation. What strategies would you use to increase the likelihood of compliance with a home exercise program and a successful treatment outcome?

Intervention Strategies for Specific Systems—Examples

The following sections contain specific examples of interventions categorized under some of the primary subsystems supporting postural control. However, the same type of complexity represented in the model of normal balance function presented earlier also characterizes most, if not all, exercises prescribed as part of a balance rehabilitation program. Though a specific exercise (e.g., slow weight shifts on a non-compliant surface) may be prescribed for a primary purpose (e.g., retraining the ankle strategy), performance of this exercise requires the individual to draw on many other balance-related resources. Therefore, it is important to bear in mind the various biomechanical, sensory, neuromuscular, cognitive, and affective requirements for each exercise prescribed. This type of task analysis allows the clinician to use exercises for more than one purpose or to make relatively simple modifications to alter the intent or difficulty of a given exercise.

Developing Orientation in Space

Because stability generally precedes mobility, some patients need to begin by working on maintenance of static postural alignment. Use a stable surface such as a hard floor or rigid chair for initiating sitting, kneeling, standing, and single-leg standing. These body postures can be used to facilitate postural orientation and stabilization. Kinesiologic factors, such as achieving and maintaining proper COM alignment and control, as well as learning factors, such as internalization of balance strategies, provide the structural framework for the treatment postures chosen.

Utilize force platforms, scales, mirrors, or tape markings placed vertically on clothing while standing in front of a mirror to train the patient to distribute weight equally on each lower extremity and/or align his/her body posture correctly. However, it is worth noting that patients with visual-perceptual impairments may find working in front of a mirror confusing. For those needing work on core trunk stability first, training may be initiated in a sitting position, which provides an opportunity to develop a sense of trunk posture and equity of weight bearing while sitting. Train sitting balance, trunk stability, and weight distribution on a chair, table, or therapeutic ball (see **Self-Managements 8-1**, **8-2**, and **8-3** and **Fig. 8-9**). Use a variety of arm positions, such as forward or lateral reaching, to change the postural challenge. Utilization of an unstable surface such as a therapeutic ball further challenges balance. Static postures also may be used in combination with foam surfaces to alter the challenge to the patient. Keep in mind that unstable and foam surfaces will alter the sensory demands of this task.

More challenging static postures, such as standing heel to toe or a SLS, should be included when the patient is ready. These postures minimize ankle strategy use and facilitate a hip synergy. Training

SELF-MANAGEMENT 8-1
Minitrampoline Balance

Purpose: To improve stability in SLS.

Movement Technique: Level I: While standing on the minitramp with a stable object at hand, practice standing on one leg. Make sure that your knee is slightly bent. Use the stable object for balance only if necessary.

Level II: Close your eyes.

Level III: Perform repeated minisquats.

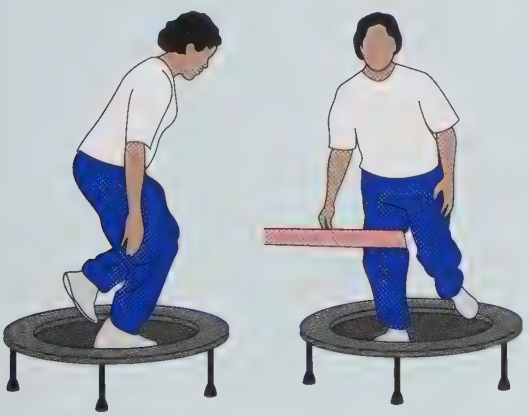
Level IV: Add resistance to the knee.

Level V: Add movement to the arms.

Dosage:

Repetitions: ______________________

Frequency: ______________________



SELF-MANAGEMENT 8-2
Sitting Balance on a Stable Surface

Purpose: To increase awareness of and expand stability limits.

Movement Technique: While sitting on a stable surface such as a chair, practice reaching forward, overhead, and to the side. You may you look in the direction you are reaching or in a different direction, as recommended by your therapist.

Dosage:

Repetitions: ______________________

Frequency: ______________________

SELF-MANAGEMENT 8-3
Sitting Balance on an Unstable Surface

Purpose: To increase postural stability and trunk balance.

Movement Technique: While sitting on the therapeutic ball, practice reaching forward, overhead, and to the side. You may look in the direction you are reaching or in a different direction, as recommended by your therapist.

Dosage:

Repetitions: ______________________

Frequency: ______________________

A B C

FIGURE 8-9 A variety of balance activities can be performed on a therapeutic ball: **(A)** single-arm lateral reach, **(B)** bilateral reaching, **(C)** assistance for balance while lifting one leg.

balance in altered stance positions is functionally relevant to tasks such as lower-body dressing. For the athlete, postures encountered in sport should be duplicated and systematically challenged in the clinic. Lunge positions, SLS with a variety of trunk postures, and squat positions are commonly encountered in sport.

After stability and optimal posture are achieved in static positions, dynamic movement should be superimposed on the activity (see **Selected Intervention 8-1**). Adding dynamic movement increases use of automatic postural adjustments during the preparation for movement and reactive strategies to counteract perturbations of the COM (see **Building Block 8-6**).

BUILDING BLOCK 8-6

How might you conduct retraining of orientation to vertical posture in standing for an outpatient who has moderate left-sided hemiparesis status-post right middle cerebral artery stroke and is not able to stand unsupported?

Retraining Movement Strategies

A variety of movement patterns superimposed on stable postures can increase the balance challenge and encourage development of both reactive and proactive balance strategies. Adding anteroposterior and lateral sway assists the patient in determining and increasing his/her stability limits. A variety of modes (e.g., supportive chair, therapeutic ball, firm floor, foam roll, foam pad, balance board, pool) and postures (e.g., sitting, half kneeling, tall kneeling, standing, SLS) using varying arm postures and/or movements may be used. Customize the intervention by selecting the mode and posture that provides the most appropriate combination of safety, functional relevance, and postural challenge for each patient. Trunk rotations with the arms in a variety of positions (e.g., abducted, forward flexed, arms across chest) with changes in head position (e.g., rotated, laterally flexed) to alter vestibular input can be combined in a multitude of ways. Proprioceptive neuromuscular facilitation (PNF) techniques in trunk rotation, called chops and lifts, are excellent dynamic movement patterns. These patterns include arm, trunk, and head rotation, flexion, and extension (see Chapter 15) (**Fig. 8-10**).

SELECTED INTERVENTION 8-1

Single-Leg Balance on a Foam Roller

ACTIVITY: Single-leg balance on foam roller with added dynamic activity

PURPOSE: To increase stability limits and dynamic balance

PRECAUTIONS: Patient safety: ensure readiness for activity and safeguards in case of balance loss; adequate trunk control

POSTURE: Standing on a foam roller with dynamic control of head, spine, and lower-extremity posture

MOVEMENT: Maintain balance while moving a ball into a variety of positions or while playing catch with ball

PROCEDURE: Isometric, concentric, and eccentric muscle contractions of the spine extensors, flexors, and abdominal oblique muscles. The closed-chain nature of the activity will produce cocontraction of lower-extremity musculature including, but not limited to the gastroc-soleus, quadriceps, hamstrings, and gluteal muscles.

DOSAGE: Three to six sets of 30-second intervals

FUNCTIONAL MOVEMENT PATTERN TO REINFORCE GOAL OF EXERCISE: A variety of single-leg instability situations are encountered in sports. The individual learns to control posture through core muscle contraction while performing a dynamic activity on an unstable surface.

For patients who need to train an ankle synergy, begin with weight shifts on a firm surface, with gradually increasing sway. Training of the ankle strategy is facilitated when the individual is asked to maintain balance on any surface that is wide, non-compliant, or stable; when slow balance reactions are required; or when the COM is far from the LOS. Using rehabilitation balls, foam rollers, and foam surfaces provides uneven or unstable surfaces and encourages a shift toward use of proximal muscles for balance control (**Figs. 8-11** and **8-12**). More challenging

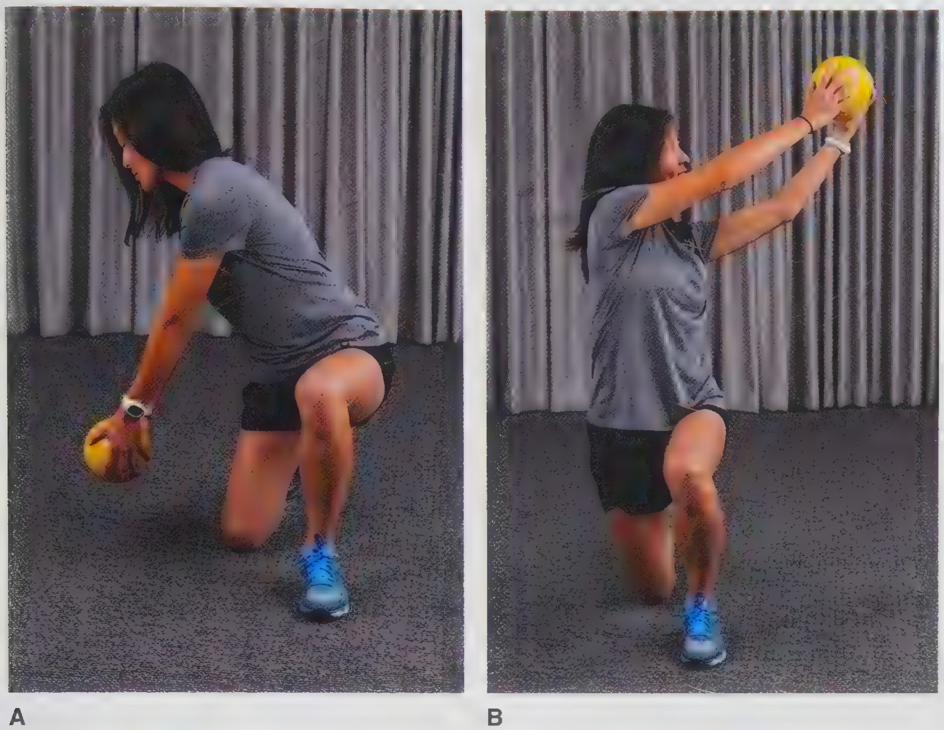


FIGURE 8-10 PNFs of chop and lift in half-kneeling position: **(A)** starting position and **(B)** ending position.

FIGURE 8-11 Foam rollers are used in bilateral stance when the person practices weight shifting while catching a ball.

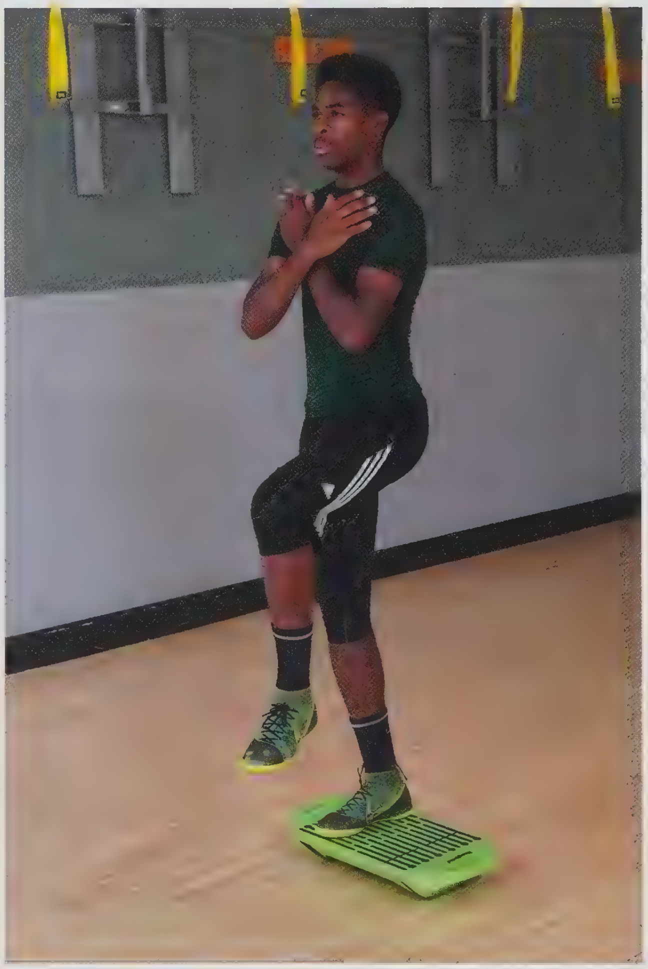


FIGURE 8-12 T'ai Chi exercise to improve single leg balance

FIGURE 8-13 **(A)** Single leg balance on an unstable surface. **(B)** Adding a soccer ball to drill activities increases the challenge.

surfaces such as a minitrampoline can also provide a variety of balance experiences that emphasize use of proximal musculature (see Self-Management 8-1). Modifying this simple task in these ways also alters the environmental demands and sensory feedback available for controlling balance and prepares the individual to face real-world challenges.

Balance beams, lines drawn on the floor, and balance boards are often used for balance training (**Fig. 8-13**). These intervention strategies are particularly useful for patients needing to train a hip synergy, as they prevent the use of an ankle synergy as a substitute. Training of the hip strategy is encouraged when the individual is asked to maintain balance on any surface that is narrow, compliant, or unstable; when rapid balance reactions are required; or when the COM is near the LOS.

Maki[31] suggests that training includes mimicking the varied and unpredictable events that precipitate falls in the elderly and that activities include not only COM displacements but also BOS compensatory movements. Thus, activities that require a change in BOS using stepping and reaching strategies should also be considered. Stepping exercises such as lunges provide an opportunity to control balance as the client first moves outside the stability limit and then restabilizes when his/her foot hits the ground. Starting with small steps and progressing to full lunges (**Fig. 8-14**) increasingly

FIGURE 8-14 **(A)** Minilunges are progressed to **(B)** full lunges.

FIGURE 8-15 Catching a ball in a variety of situations increases task complexity: **(A)** on an unstable foam, **(B)** combined with lateral lunges, and **(C)** moving to a specified spot on the floor in response to a verbal command.

challenges the patient. Adding a concurrent arm activity can further challenge balance. For example, reciprocally swinging the arms during stepping can make the task easier, but performing a PNF chop or catching a ball can make it more difficult (**Fig. 8-15**). Completely eliminating the arms for balance by holding them across the chest or overhead can make the exercise extremely difficult for a person with poor trunk and hip stability.

More advanced balance exercises include hopping, skipping, carioka, slide board, and rope jumping (see **Self-Management 8-4**). Perform these exercises in a variety of patterns, with exaggerated step length or knee lift. Many can be performed backward, with a variety of step techniques incorporated. The "hop and stop" can be performed on a firm surface or a soft surface such as foam or minitramp (**Fig. 8-16**). The patient is asked to hop single or double footed and to "stick" the landing without losing balance. Exercise equipment such as a stepper can also challenge balance if performed without hand support, backward, or with the eyes closed. Closing the eyes assists in emphasizing the use of somatosensory and vestibular feedback control of balance. For athletes, reproducing movement patterns found in their sports can prepare them for the return to activity. Many traditional sports drills can be modified for use in a clinical setting. Changing the speed of the stepping exercise to approximate functional speeds is essential to the movement strategy. These challenging tasks have elements of proactive and reactive dynamic balance. Consider which aspects to emphasize for each individual.

As mentioned previously, the pool provides an interesting and dynamic environment. The viscosity and movement of the water constantly challenge posture and balance. Any arm or leg movement can potentially disrupt the patient's balance. For example, performing bilateral shoulder horizontal adduction and abduction results in posterior and anterior displacement of the body, respectively. Perform this exercise with the feet in stride, in normal stance, in a narrowed stance, or in SLS for progressively increasing difficulty (see **Self-Management 8-5**). The increased unpredictability experienced in the water may help prepare the individual for changing environmental conditions in the real world (see **Building Block 8-7**).

SELF-MANAGEMENT 8-4
Slide Board

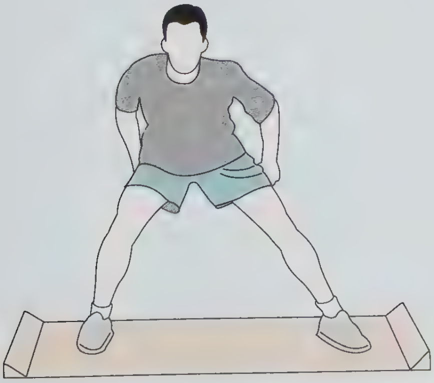
Purpose: To increase balance and coordination during a functional activity.

Movement Technique:
Level I: Laterally glide on a slide board.
Level II: Continuously catch and toss a ball.
Level III: Increase speed.
Level IV: Increase the number of balls tossed.

Dosage:

Repetitions: ____________

Frequency: ____________



A B

FIGURE 8-16 Hop and stop for dynamic balance. **(A)** The patient starts from a small stool, hops down, and **(B)** "sticks" the landing.

SELF-MANAGEMENT 8-5
Shoulder Level Claps in the Pool

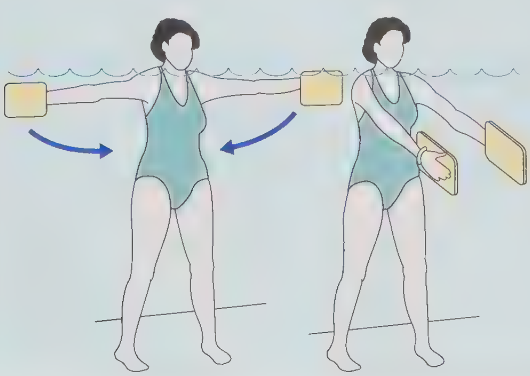
Purpose: To increase upper back and chest strength and to challenge balance.

Movement Technique: Level I: While standing in good postural alignment with your arms to the side at shoulder level, bring them forward and back to the starting position.
Level II: Bring your feet closer together.
Level III: Stand on a single leg.
Level IV: Close your eyes.
Level V: Add resistance to the hands.

Dosage:

Repetitions: ______________________

Frequency: ______________________



BUILDING BLOCK 8-7

List several ADL that require use of an ankle strategy that could be used as functional task practice in rehabilitation for a 52-year-old man who is in the chronic phase of recovery following an acute ankle sprain sustained while playing in a weekend basketball league. The patient is ferry boat operator and must stand for long periods of time. Choose the ideal mode of exercise and several exercises for retraining the hip strategy for a 60-year-old, morbidly obese woman, status post right total hip replacement. Explain your rationale. She is 2 months post-op and has minimal discomfort in the right hip. Her gait is antalgic, and she continues to use cane, and rates her osteoarthritic pain in the left hip and knee at 8/10 while walking.

Facilitating Sensory Strategies

Awareness of posture and the position of the body in space are fundamental to balance training. Jeka[117] demonstrated that the use of light touch through a cane or balance aid enhances the use of somatosensory and can reduce postural sway. Compensatory strategies such as this can be used to increase spatial awareness, as well as facilitate performance and minimize the fear and anxiety sometimes associated with balance retraining.

There are many ways to facilitate relearning sensory strategies. As noted above, the environmental characteristics, such as the support surface, can be altered to change the mode of balance exercise. Understanding how to manipulate the surface or other environmental cues is critical to providing the appropriate sensory context in which patients practice. To that end, patients should be trained in situations that enhance the nervous system's ability to attend to specific types of feedback.

Patients who need to develop effective use of somatosensory feedback for balance control begin activities with the eyes closed on a stable surface. Attention to surface cues can be enhanced by having the individual perform exercises with her shoes off, while standing on a textured surface, or by using knobby insoles in the shoes. If the ability to use existing visual cues effectively for maintaining stability is compromised, training the patient on a compliant or unstable surface with the eyes open and fixed on or attending to visual references in the environment is appropriate. Attention to visual cues can be enhanced by asking the individual to fixate gaze on a stationary target less than 5 feet away or by performing the task near a doorway or other distinct cues of vertical alignment. Alternatively, patients with difficulty using vestibular feedback about head position and acceleration should be trained on compliant or unstable surfaces with their eyes closed in order to force the nervous system to attend to vestibular inputs. The challenge to use vestibular cues for balance is increased by adding varied static head positions, active rotations, or tilts. Use caution with these activities for persons with vestibular disorders as these activities may cause dizziness. Real-world environments often present patients with confusing and conflicting sensory information. Thus, patients also need training in how to resolve conflicting inputs. For example, patients may need to learn how to balance when standing still in an environment with overwhelming motion of the crowd, lighting, or displays. Partially distorting or obscuring vision may also help encourage patients to resolve sensory conflicts. Whether or not these specific sensory manipulations are included in the plan of care depends in large part on the underlying impairments and the patient's prognosis for functional recovery. Thus, understanding the expectations for recovery of function as they relate to the patient's health condition and their response to its influence on their life is critical to effective treatment planning (see **Building Block 8-8**).

BUILDING BLOCK 8-8

What parameters or variables would likely manipulate when re-training sensory strategies for a 57-year-old woman with diabetes mellitus and associated peripheral neuropathy (diminished vibratory sensation below the ankles bilaterally) and retinopathy (legally blind in both eyes)?

Sequencing Considerations

Progression of exercise from simple to complex involves creating increasingly more challenging tasks for the individual to practice in meaningful environmental contexts. Variables related to the individual body systems contributing to balance control, characteristics of the environment, and task setup can be sequentially and systematically manipulated to develop and progress a customized intervention program. Remember, there are complex relationships between each of these domains. Thus, manipulation of one variable in any given domain has broad implications.

Task Variables

Appropriate sequencing related to postural demands involves progression from stable postures (e.g., sitting) to more unstable postures (e.g., SLS). Spatial characteristics such as the distance traveled with each step while side stepping or the amplitude of arm movements produced while performing single-limb stance should be considered. Generally, patients are progressed by increasing step length or the amount of reach. Temporal factors such as the velocity of movement and the time allowed to complete a series of movements can be used to influence performance. Patients may progress from slow movement to attempting to control ballistic movements while maintaining a particular posture. Encouraging increased speed is easily accomplished by decreasing the time allowed to complete a block of practice. Whether or not the patient is asked to manage a physical load or simultaneously manipulate an object in the hand while maintaining stability is another consideration. The patient may begin by practicing walking on a level surface and eventually progress to walking while carrying a full glass of water or a large bag of groceries. Other task-related variables include the frequency, intensity, and schedule for practice. Patients progress from less to more frequent practice, fewer to greater repetitions, and blocked to random practice in order to address variables such as managing fatigue, encouraging motor learning, and developing greater motor control.

Individual Variables

The individual body systems that contribute to balance control can also be manipulated to create appropriate challenges and facilitate progress. As stated, base element problems related to the biomechanical system should be addressed early. Cognitive factors should be considered in all cases regardless of age or condition because many real-world activities are frequently performed under dual-task conditions. Training should begin with intense concentration and minimal cognitive distractions. Progression related to cognitive demands may involve having the individual perform a simultaneous cognitive task that requires listening, comprehension, mathematics, problem solving, etc. The patient's emotional engagement in training in terms of self-efficacy and their level of anxiety are additional considerations. Some individuals may need to practice deep breathing or other relaxation strategies in conjunction with task practice. As an indicator of self-efficacy, the patient should be encouraged to perform exercises that he/she is at least 70% to 80% confident in his/her ability to safely exercise at home.

Facilitation of movement strategies as described earlier is often a critical component. The training plan should emphasize mastery of the appropriate use of in-place, automatic postural reactions for control of quiet stance before activities that involve executing change in BOS strategies, such as stepping correction responses. In terms of in-place responses, because the ankle strategy dominates stance control, this strategy should be addressed before impairments in the use of the hip strategy. To accomplish this, start in standing with simple sway activities that elicit an ankle strategy. Reinforce this strategy by verbal or tactile cuing and ensuring proper posture and firing patterns to prepare the patient for larger perturbations. Encourage the patient to gradually increase the stability limits by reaching or swaying farther. Progress the exercise by applying greater disruptions of the COM in order to elicit a hip strategy or a stepping strategy. After these responses are established, progress to more dynamic activities, unstable surfaces, and complex movement patterns. Additional critical variables involve the timing and scaling of these responses. Surface characteristics play major roles in movement strategy retraining as well. Progression is accomplished by increasing movement velocity and/or altering the surface.

Finally, sequencing training for appropriate use of sensory feedback for balance control described earlier should be considered. Generally, patients should be encouraged to perform exercises with all three major forms of sensory feedback available before progressing to practice in environments with complex sensory conflicts. The use of somatosensory feedback should be encouraged by simply having the patient close his/her eyes while practicing on a stable surface. Retraining the use of vision can be facilitated by having the patient practice on an unstable surface with his/her eyes open while fixating his/her gaze on a stable target nearby. Practice emphasizing the use of vestibular feedback by balancing with the eyes closed on an unstable or compliant surface. The dual sensory conflict created by practicing on an unstable surface while being exposed to visual feedback that is out of sync with his/her postural sway is the most challenging practice condition. For example, retraining the ability to maintain dynamic stability while skating forward on one foot, while simultaneously trying to control a moving hockey puck, as teammates and defenders streak passed one's peripheral vision is a daunting task for an athlete. Similarly, attempting to walk through a crowded outdoor marketplace, over uneven sidewalk tiles, while carrying a purse and bag full of purchases may be equally daunting for an elderly person.

Environmental Variables

The terrain is one of the most commonly manipulated environmental variables. Not only can changing the terrain increase the level of difficulty, but, as we have seen, changing the surface can also be used to facilitate the use of specific sensory systems or postural reactions. Progression is best carried out from stable surfaces to unstable surfaces, non-compliant to compliant surfaces, flat surfaces to inclines, and stationary surfaces to surfaces that move. For example, performing postural sway in all directions with the arms folded across the chest while sitting on a firm chair is a good precursor to adding arm movements or for performing the same exercise on an unstable therapeutic ball.

Ambient conditions play a major role, and manipulating vision can serve to increase the challenge or determine whether the visual or vestibular system dominates balance control. Typically, patients should exercise under good lighting conditions before progressing to practice in a dim room or in the dark.

Patients should demonstrate mastery in predictable environments before practicing under unpredictable conditions in order to minimize the effects of contextual variability. Vary displacements from those generated by the patient to an external force, and from an anticipated displacement to an unanticipated one to simulate balance control in crowds. Patients should be taught to handle motion in the world around them (optokinetics) by first practicing in environments with no or very little environmental motion, such as a plain exam room, and then progressing to more visually busy environments, such as a crowded grocery store. Increasing the movement in peripheral vision during exercises will also challenge the balance system more.

Beginning with simple tasks on a stable surface and moving to progressively more unstable surfaces and complex tasks is the sequence plan, regardless of the age or condition of the patient. For the athlete, progression to a balance board, minit-ramp, slide board, or computerized balance training system may occur rapidly. Although training the individual in postures or activities encountered in his/her sport can prepare him/her for those situations, many unpredictable situations occur, and unpredictable perturbations should be included in the training program to teach the nervous system to respond to novel situations (see **Building Block 8-9**).

BUILDING BLOCK 8-9

Describe an appropriate sequence for developing SLS for an otherwise healthy 22-year-old classical dancer recovering from left knee arthroscopy with resection of a medial meniscus tear.

Feedback

Learning factors are essential in planning the activity mode for treating balance impairment. Early in the treatment program, simple balance challenges with external feedback are necessary. This allows the patient to develop gross strategies to manage the perturbation. As the patient learns and develops these gross strategies, increasing the balance challenge while decreasing the external feedback allows internal strategies to develop. Initially, ask the patient to describe what obstacles are in his/her path and what his/her strategies will be to negotiate through the room (enhanced use of cognition). Try to add distractors later in the rehabilitation process and look for more automatic postural presets. In the case of balance training, learning is the ultimate goal.

Mirrors and force platforms can provide visual postural biofeedback, regardless of the position of exercise. This allows visual feedback (i.e., external feedback about position), which must be removed at some point to allow internalization of the balance strategies. Computerized force platforms allow for multiple variations of task practice with highly motivating performance feedback and the ability to readily track progress.

EXPANDED ECOLOGICAL MODEL OF BALANCE REHABILITATION

As stated previously, the ecological model describes the interactions among the individual, the environment, and the functional task.[5,16] The relationships between these domains are complex, dynamic, and lead to a highly individual experience of impaired balance and mobility. **Figure 8-17** presents the variables available for manipulation by the clinician when developing interventions within the ecological framework discussed in this chapter. Systematic and skillful manipulation of specific variables related to the individual, environment, and the task provides the clinician with endless opportunities to customize a rehabilitation program for each person.

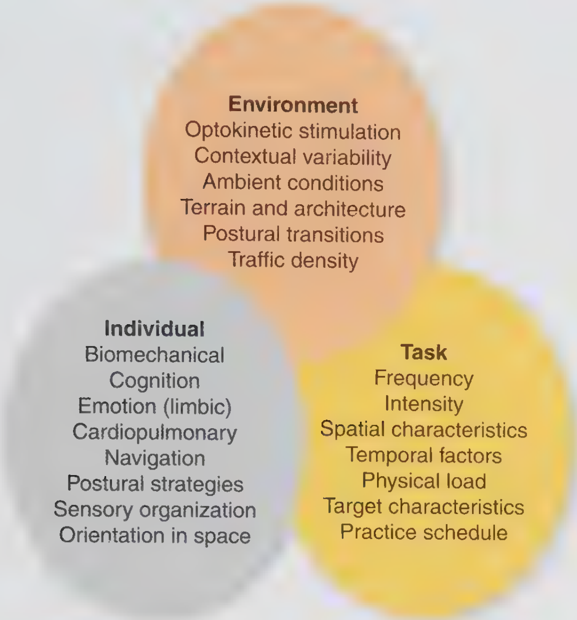


FIGURE 8-17 Expanded ecological model of balance rehabilitation.

PRECAUTIONS AND CONTRAINDICATIONS

The most important precaution in balance training is the individual's safety. Because the potential for falls is high, choose activities that are appropriate for the patient's skill level. A well-performed evaluation and initiation of activities at a lower level than determined by the examination can ensure appropriate exercise choice. It is safer to start the patient with tasks that are simpler and safer and progress to more complex exercises than to misjudge and place the patient in an unsafe situation. Again, measuring the patient's self-efficacy regarding his/her ability to safely perform the prescribed exercise regime at home can also assist in selecting the appropriate level of challenge. Simply have the patient rate his/her level of confidence on a scale of 0% to 100% regarding his/her ability to perform each exercise. Select exercises which the patient has a high level of confidence performing.

The surrounding environment should have maximum safety as the principal design factor. Eliminate obstacles or unsafe objects from the exercise area and provide additional stabilization for the patient. A gait belt, hand contacts from the clinician, parallel bars, or other stable external objects for the patient to hold should be immediately available. However, keep in mind that relying on such support alters balance responses. Balance training is contraindicated for persons who are inherently unsafe in balance-challenged positions. For example, those with cognitive impairments may be unable to understand the purpose and mechanics of the activity.

PATIENT EDUCATION

Patient education is an ongoing process for the patient with balance impairment. Safety is the most important area of education. Counsel the individual with significant balance impairments regarding use of assistive devices to maintain stability. A walker, one or two crutches, a cane, or hiking stick can widen the BOS, thereby increasing the stability limits. Evaluate the home for potential balance hazards. Loose rugs, slippery floors or bathtubs, uneven doorway thresholds, and stairs without railings may be hazards. A systematic review by Lyons and colleagues[118] concluded that there is insufficient evidence to determine the overall effectiveness of these strategies in terms of risk reduction when used alone. However, these authors encourage the commonsense use of home safety strategies given that there is no evidence that these strategies do not work. Footwear may also affect balance; thus, education regarding appropriate footwear is often essential. Shoes that slip on the foot or on the floor or shoes with rubber bottoms that stick on the floor may cause a fall. Additionally, consider the impact of eye conditions and surgical and optical vision correction strategies (glasses, mono-vision contact lenses, Lasik).

Educate the patient regarding the limits of his/her balance. Factors include time (e.g., walking more than 20 minutes), distance (e.g., after walking more than four blocks), time of day (e.g., better in the morning than in the evening), and environment (e.g., crowds, noise, lights). Coaching patients to anticipate and recognize situations that place them at risk can help them make appropriate, safe choices while still participating in desired activities.

The patient should be taught strategies to maximize balance in compromised situations. For reasons beyond their control, patients may find themselves in situations where their balance is at risk. For example, when coming out of a movie, a person may have difficulty adjusting to the light, noise, and crowds in the lobby. Patients should be counseled in strategies to optimize balance, which may include using an assistive device (when the patient normally does not use one), using a friend's arm for balance and escort through the lobby, sitting and planning a path where stable objects may provide some external assistance, or asking someone for assistance.

Falls—A Significant Problem

Falls by the elderly are of great concern, because the resultant injury and disability are significant. Each year, approximately 30% of persons older than 65 years of age fall, and one half of them fall multiple times.[119] Falls are a leading cause of death of persons older than 75 years of age.[120] Hip fracture–associated mortality is greater for women and has been reported as high as 8% to 18% within the first 2 years after fracture.[120] As many as 53% of patients fall within the first 6 months after hospitalization for a previous fall.[121] Previous falls and use of an assistive device before the fall resulting in hospitalization predict falls post-discharge.[121] Falls following hospitalization have been associated with significant balance impairments and mobility limitations as measured by lower BBS Scores and slower gait speed on average.[121]

Falls by the elderly have been attributed to increased postural sway and imbalance and to a decreased ability to balance on a single leg.[8,59,120,122] An individual's perceived stability limits may differ from their actual stability limits, making them susceptible to falls.[5] Most falls occur during walking, turning, or on stairs.[89,123] Lower maximum walking speed and diminished self-perception of balance have been found in patients with hip fractures.[59] Older individuals have demonstrated larger sway areas than young adults in upright stance and forward lean stance.[124] The elderly are rarely able to complete a test of SLS while blindfolded.[125,126]

A study of multiple factors predictive of future falling found control of lateral stability to be a significant predictor of future falling risk.[127] Thus, examination and intervention for lateral stability are important fall prevention measures. However, the single best predictor of future falls appears to be a history of previous falls.[65] Thus, clinicians should ask about prior falls. Many patients may have difficulty remembering if they have fallen more than 2 months prior. Thus, the clinician should ask the patient, "When was the last time you fell?"

Fear of falling is a separate factor to be considered.[89] An approximate 30% prevalence of fear of falling exists in non-fallers, and 60% or more in those who have fallen.[128] Fear of falling is associated with poorer health status, functional decline, activity restriction, depression and anxiety, and decreased quality of life. Maki[129] found reduced stride length, reduced speed, increased double-support time, and poorer clinical gait scores to be associated with fear of falling, but these factors did not have an independent association with actual falling. Increased stride variability (length, speed, and double support) was associated with falling but was not related to fear of falling. Clinically, balance-related confidence, as measured by the ABC Scale, and self-perceived need for personal assistance with outdoor ambulation have been associated with balance performance measures.[130] The subjects' perceived balance capability was correlated with current behavior, but not their history of falls.

Further, consider the potential impact of other factors such as medication use, footwear, and vision correction when assessing balance. Antidepressants and psychotropic drugs have been associated with an increased risk of falling, whereas diuretic use has not.[89,131] Falling indoors has been more frequently associated with walking barefoot or in stockings in an elderly population; thus, these patients should be encouraged to wear shoes indoors.[132] Individuals who wear bifocal and trifocal lenses are at significantly greater risk for falling.[133] Cataracts significantly influence balance, and cataract surgery has been associated with significant reductions in risk for falls and fall-related injuries.[134]

Finally, it is important to remember that falling is not just a problem of the elderly. Children and athletes fall frequently. Falling is also a very common problem for persons with a variety of health conditions, including MS[135] and Parkinson's disease,[136,137] and persons with vestibular disorders.[138,139] The consequences of falls are often greater in these groups and the elderly because of the fact that these populations are more susceptible to serious injury.

EFFECTS OF TRAINING ON BALANCE

A variety of effects have been noted with training. Some training programs emphasize base elements such as strength, mobility, and cardiorespiratory exercise, whereas other programs use specific postural and balance training, or some combination of activities. Population-level fall risk reduction programs have been implemented in countries around the globe in an attempt to proactively address risk factors on a community level as well.[140,141] In a systematic review by the Cochrane Collaboration, McClure et al.[142] suggested that effective community-based intervention programs could be instrumental in driving public health policy as a result of their impact in term of reducing falls and fall-related injuries.

Several community-level interventions have been developed and examined. T'ai Chi Chuan has been studied extensively for its effects on impairments in the elderly. Lan et al.[143] found increases in knee concentric and eccentric peak torque and the knee extensor endurance ratio in both men and women who performed T'ai Chi. Additionally, improvements in resting heart rate, 3-minute step test heart rate, modified sit and reach, total body rotation testing and SLS with eyes closed were found in a T'ai Chi group compared with a control group.[144] The effects of T'ai Chi directly on balance have been analyzed. Participating in T'ai Chi was found to reduce the risk of multiple falls by 47.5%.[145] Significant improvements have been found in self-reported physical functioning, general health status, arthritis symptoms, Sensory Organization Testing, and the DHI following T'ai Chi training.[146–149] However, others have found computerized balance training to produce greater improvements in balance measures than T'ai Chi, suggesting that T'ai Chi may delay the onset to first or multiple falls by improving confidence without actually changing sway measures.[145] This is consistent with others who found significant self-reported benefits of T'ai Chi training (improvements in daily activities) compared with individualized balance training.[150]

The Cochrane Collaboration found the following interventions to be effective in minimizing the effect of or exposure to risk factors for falling in the elderly on an individual level[151]:

- Multidisciplinary, multifactorial, health/environmental risk factor screening
- Individualized muscle strengthening and balance retraining, prescribed at home by a trained health professional
- Home hazard assessment and modification, professionally prescribed
- Withdrawal of psychotropic medication
- Cardiac pacing for appropriate patients
- T'ai Chi group exercise intervention (see **Evidence and Research 8-4**).

EVIDENCE and RESEARCH 8-4

Community-based programs effective in reducing fall risk in the older adult[137,142]:

- Participating in T'ai Chi was found to reduce the risk of multiple falls by 47.5%.[146–149,152]
- T'ai Chi may delay the onset to first or multiple falls by improving confidence without actually changing sway measures.[145]
- Stepping on program focuses on progressive balance and strength exercises, home safety, vision, and medication review and showed a 31% reduction in falls.
- Sherrington[153] found the critical components of effective exercise program included:
    - Minimum effective dose of two times per week for 25 weeks (>50 hours)
    - Challenging balance exercises in standing (feet close or one foot, minimal use of hands, and practiced controlled movements of their COM)
    - Did NOT include a walking program

The majority of patients with balance impairments will require skilled, individualized interventions that target the specific underlying impairments contributing to instability. The literature suggests that rehabilitation after lower-extremity injuries that includes balance training results in improved static and dynamic balance[110] and contributes to greater success in return to play in athletes.[111] A three times per week program of balance and lower-extremity strength training leads to improvements in balance measures equivalent to an individual 3 to 10 years younger, as well as increases in lower-extremity strength.[154] According to Gardner et al.,[155] successful falls prevention programs include activities for strength, endurance, and balance training. Specifically, these authors recommend individually tailored exercises, criterion-based progression for strength and balance training conducted three times a week, use of a walking program to increase aerobic capacity, and follow up with the exercise instructor over several months to 1 year. Adherence to a program guided by these principles has resulted in reduced risk for falling for up to 2 years.[156]

KEY POINTS

- Balance and coordination are separate concepts that are integral to each other and, together, support all skilled movement.
- Balance is a function of the interaction of multiple body systems including biomechanical, neuromuscular, sensory, perceptual, cognitive, emotional, and cardiopulmonary functions.
- Some musculoskeletal disorders or injuries are associated with balance impairment. Balance training should be incorporated into the treatment program.
- Aging is associated with balance impairment and places the elderly at risk for falls.
- Ankle strategies are used in response to small perturbations, and hip or stepping strategies are used to counter larger perturbations.
- Measurement of balance impairment should involve each of the assessment of each of the body systems contributing to postural control.
- Treatment should be aimed at the cause of the problem, whether biomechanical, sensory, motor, cognitive, affective, or a combination of impairments.

CRITICAL THINKING QUESTIONS

1. Consider Case Study No. 1 in Unit 7. Design a progressive balance program for this basketball player. How would your treatment program differ if she were a
   a. Gymnast
   b. Figure skater
   c. Wrestler
   d. Cross-country runner
2. Consider Case Study No. 5 in Unit 7. Design a progressive balance program for this woman. Include sitting, standing, and transitional postures and movements. What other interventions probably are necessary to improve her balance?
3. What aspects of home design can maximize an individual's independence if balance is impaired?

LAB ACTIVITIES

1. With a partner, perform the following activities. Which balance strategy is elicited and why?
   a. With the patient's feet shoulder width apart, attempt to gently disrupt the patient's balance.
   b. With the patient's feet shoulder width apart, attempt a larger disruption of the patient's balance.
   c. With the patient standing heel to toe, attempt to gently disrupt the patient's balance.
   d. With the patient standing on a balance beam, attempt to gently disrupt the patient's balance.
   e. Restrict the patient's ankle mobility with a brace or tape. Attempt to gently disrupt the patient's balance.
   f. Repeat a to c on a soft foam surface.
2. Compare the amount of postural sway observed when standing with the feet together in the following conditions. Which activities are the most challenging and why?
   a. Eyes open on a stable surface.
   b. Eyes closed on a stable surface.
   c. Eyes open on a thick foam surface.
   d. Eyes closed on a thick foam surface.
   e. Eyes open on a rocker board.
   f. Eyes closed on a rocker board.
   g. Repeat tasks a to f while simultaneously rotating or tilting the head.
3. Compare the length of time balance can be maintained in the following situations. Which muscles are working, and how are changes in COG compensated by postural changes? What do the arms attempt to do?
   a. SLS with eyes open (left and right)
   b. SLS with eyes closed (left and right)
   c. SLS, performing tubing-resisted shoulder horizontal abduction, unilateral and bilateral
   d. SLS, performing tubing-resisted shoulder flexion from 120 to 180 degrees of overhead flexion, unilateral and bilateral
   e. SLS, performing tubing-resisted hip extension
   f. Single-leg minisquats with the contralateral knee flexed
   g. Single-leg minisquats with the contralateral knee extended and hip flexed
   h. Single-leg minisquats on a minitramp
   i. Single-leg toe raises from a level surface
   j. Single-leg toe raises from the edge of a step
4. Compare muscle activity in the following situations:
   a. Single-leg minisquats on a minitramp, with tubing around the posterior knee pulling the knee into flexion
   b. Single-leg minisquats on a minitramp, with tubing around the medial knee pulling the hip into abduction
   c. Single-leg minisquats on a minitramp, with tubing around the anterior knee pulling the knee into extension
   d. Single-leg minisquats on a minitramp, with tubing around the lateral knee pulling the hip into adduction
5. Perform the following activities. Which activity is the most challenging to your balance?
   a. Repetitive single-leg hopping with arms free
   b. Repetitive single-leg hopping with arms across the chest
   c. Repetitive single-leg hopping with arms overhead
   d. Rope jumping on alternate feet
   e. Rope jumping on a single foot
   f. Single repetition of a single-leg hop, controlling and stopping the landing as quickly as possible (i.e., hop and stop)
   g. Hop and stop on a minitramp

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CHAPTER

9

Impaired Posture and Movement

CARRIE M. HALL

It is intuitive for physical therapists to consider posture and movement as an underlying cause of, or contributor to, musculoskeletal pain syndromes (MPS)[1] (**Display 9-1**). However, much to our dismay, the literature generally does not support strong correlations between posture, movement, and pain.[5–10] Even in the presence of correlational evidence, it is difficult to suggest causation. Just because two factors are correlated does not necessarily mean that one causes the other (*correlation does not imply causation*).[11] (**Evidence and Research 9-1**) Causation is rarely as simple as we tend to assume and, perhaps for this reason, its complexities are often glossed over or even ignored. Misunderstanding causal links can result in ineffective actions being chosen, harmful practices perpetuated, and beneficial alternatives overlooked (**Evidence and Research 9-2**).

EVIDENCE and RESEARCH 9-1

Correlation does not prove causation. For example, in a widely studied case, numerous epidemiological studies showed that women who were taking combined hormone replacement therapy (HRT) also had a lower-than-average incidence of coronary heart disease (CHD), leading doctors to propose that HRT was protective against CHD. But randomized controlled trials showed that HRT caused a small but statistically significant increase in risk of CHD. Reanalysis of the data from epidemiological studies showed that women undertaking HRT were more likely to be from higher socioeconomic groups, with better-than-average diet and exercise regimens. The use of HRT and decreased incidence of CHD were coincident effects of a common cause (i.e., the benefits associated with a higher socioeconomic status), rather than cause and effect, as had been supposed.[12]

EVIDENCE and RESEARCH 9-2

Prins et al.[13] performed a systematic review to evaluate the evidence for the contribution of posture and psychosocial factors to the development of upper quadrant musculoskeletal pain in children and adolescents. The initial assumption by most would have been the faulty posture contributed to the pain when in fact, this review concluded that the *duration* of sitting posture and *psychosocial factors* may influence the experience of musculoskeletal pain among children and adolescents to a greater extent than the faulty posture itself.

DISPLAY 9-1

Definition of Musculoskeletal Pain Syndrome

MPS is defined as a localized, painful condition arising from irritation of myofascial, periarticular, or articular tissues.[1] Pain from acute trauma, such as strain, fracture, or dislocation, does not fall into this category. In addition, pain caused by systemic disease such as Parkinson's disease or cancer, inflammatory conditions such as rheumatoid arthritis, or chronic pain with peripheral and/or central sensitization are also excluded from this category.

For the purpose of this discussion, MPS is considered to be the result of cumulative microtrauma imposed on neuromusculoskeletal tissue. Microtrauma can occur from overuse, which is defined as repetitive or prolonged submaximal stress that exceeds the tissue's ability to adapt and repair.[2,3] Overuse can occur during a relatively short period, such as playing the first volleyball game of the season, or over a longer period, such as performing data entry tasks 8 hours a day, 5 days a week, for many years. Microtrauma can also be caused by movements repeated during activities of daily living (ADL) with less than optimal starting alignment or motor control strategies.[4]

When there is indeed a causal relationship between two factors, there is still the question of which is the cause and which is the effect. In other words, what is the direction of causation? By itself, a correlation tells us nothing about this. O'Sullivan[14] discusses the conundrum of whether faulty postures and movements cause pain (adaptive), *or* if pain leads to faulty postures and movements (maladaptive) (**Evidence and Research 9-3**).

Theoretically, it seems reasonable that sustained postures and repeated movements could be a risk factor associated with musculoskeletal symptoms. Most would agree that prolonged physiologic loads could precipitate symptoms through mechanical stress. A number of studies, though weak in design, have documented a link between sustained postures and tissue loading.[15–26] Unfortunately, much of the literature on sustained loading on spinal tissues has either been conducted on individuals without symptoms,[15–26] on cadavers,[27–31] or on animals.[32–34] These studies provide evidence about the possible deleterious effect on tissue from sustained loading, but do not provide evidence about the

EVIDENCE and RESEARCH 9-3

O'Sullivan summarizes in his master class paper:

> Chronic low back pain (CLBP) disorders must be considered within a biopsychosocial framework. The presence and dominance of the potential pathoanatomical, physical, neurophysiological, psychological, and social factors that may impact on these disorders is different for each individual with CLBP. It is critical that classification of CLBP pain disorders be based on underlying mechanism(s). It is proposed that motor control impairments may be adaptive or maladaptive in nature. Treatment of a pain disorder cannot be justified without an understanding of its underlying mechanism as there are subgroups of patients for whom physiotherapy treatment is not indicated. It is proposed that there is a large subgroup of CLBP disorders where maladaptive movements dominate the disorder, which in turn become a mechanism for ongoing pain. Physiotherapy interventions directed to the underlying driving mechanism have the potential to alter these disorders and impact on both the primary physical and secondary cognitive drivers of pain. This approach can be applied to all regions of the musculoskeletal system.[14]

symptom response to sustained loading in humans. In support of symptoms related to tissue loading, McKenzie[35] describes three mechanical syndromes, all of which are based on clinical presentations and the patient's response to repeated movements and sustained postures. One of these is the postural syndrome in which prolonged static loading of normal soft tissues results in discomfort triggered by sustained mechanical stress. The clinical presentation is usually observed in a young person who maintains sustained postures for long periods, most commonly sitting, which provoke transient symptoms that are abolished with the resumption of an upright posture (**Evidence and Research 9-4**).

EVIDENCE and RESEARCH 9-4

In a reliability study of 45 patients with low back pain, only one patient (2.2%) was thought to be classified with postural syndrome.[36] In two surveys with a combined total of 947 patients with spine pain, only 1% were classified with postural syndrome.[37,38] However, among a student population, 50% reported previous transient and mild postural-related backache.[26] None had sought treatment, but over a 3-day period, they reported 46 backache episodes, all triggered by sitting activities, most commonly when studying. Compared with a no backache control group, there were significant differences in the amount of time of uninterrupted sitting and the amount of lumbar flexion when sitting relaxed.

Correlating pain with faulty movement can be just as elusive. Research has shown that excessive arthrokinematic and/or osteokinematic movement can lead to pathology,[39] but pathology does not equate to pain.[40] Pain is more complicated than clinicians would like to think. Physical therapists are trained to look for explanations that are pathologically or kinesiologically driven. One of the issues confounding research results is use of the term *pain*. Though we use the term *musculoskeletal pain syndrome*, pain should not be used interchangeably with nociception. Nociception is the afferent activity in the peripheral and central nervous systems produced by stimulation of specialized free nerve endings called nociceptors or "pain receptors" that only respond to tissue damage caused by chemical (e.g., inflammation), mechanical (e.g., pinching, crushing), or thermal (heat and cold) stimulation.[41] Describing the mechanisms that signal pain is not the same as identifying the underlying cause of pain. Evidence demonstrates that nociception is neither sufficient nor necessary to experience pain[42–45] and that pain is a conscious experience that *can be* associated with nociception, but it is *always* modulated by a myriad of neurobiological, environmental, and cognitive factors.[46]

Despite the lack of evidence, the inclusion of postural assessment in the Guide to Physical Therapist Practice[47] and the accreditation standards suggest that the profession considers postural alignment to have a role in patient care. Sahrmann recognizes that despite very little research to support a relationship between musculoskeletal pain and "posture," she cannot imagine treating any patient without assessing posture or, more precisely, alignment.[1] For example, when a patient with low back pain has a flat back, the emphasis of treatment is different than when the patient has an excessive lumbar lordosis. Sahrmann outlines a sound rationale for the discrepancy between the research data and the clinical experience of generations of physical therapists (**Evidence and Research 9-5**).

EVIDENCE and RESEARCH 9-5

In a 2002 commentary, Shirley Sahrmann stated the following regarding the lack of evidence correlating posture and pain:

I believe some of the explanations are (1) a narrow definition of what constitutes posture; (2) attempts to find a linear correlation between pain and spinal curvature without identifying subgroups of extremes of increased or decreased curvature; (3) failure to consider alignment as only one of multiple factors causing pain; (4) attempts to relate postural faults and muscle weakness; and (5) limited research examining the relationship between alignment impairments and alterations in movement.[48]

She concluded that examination of alignment impairments has to be an important step in designing an appropriate treatment program for correcting mechanical impairments and that future studies need to better correlate relationships among specific alignment impairments, altered movement patterns, contributing muscle adaptations, patient modifiers, and mechanical pain problems.[48] Understanding these relationships will enhance our therapeutic intervention of these impairments.

Accepting that mechanically stimulated nociception (sustained postures or repeated movements) can be a trigger for pain, a clinician should consider the conditions when a mechanical stimulus in the periphery produces a painful response.[1,49–56] Posture and movement matter when mechanical stress is predictably related to sustained postural habits or repeated movement patterns and/or:

1. Is the underlying cause of nociception and pain (altering the pattern changes the experience of pain)
2. Contributes to the recurrence of a painful condition (altering the pattern reduces the ongoing pain)
3. Is associated with the failure of the condition to fully heal (altering the pattern allows injured tissue to heal in a timely fashion).

DISPLAY 9-2

Factors Influencing Posture and Movement Impairment

- Impairments of body functions
  - Range of motion
  - Muscle length/extensibility
  - Joint integrity and mobility
  - Muscle performance
  - Motor control
  - Balance and coordination
  - Pain
- Impairments of body structures (i.e., structural scoliosis, hip anteversion, and structural limb length discrepancy)
- Anthropometric characteristics
- Psychologic impairments
- Developmental factors (e.g., age)
- Environmental influences
- Disease or pathology

Intervention, under these circumstances, therefore should focus on correcting the factors predisposing or contributing to the sustained postures or repetitive movement. When correction is not possible (e.g., anatomic impairments, pathology, disease), modification of the posture or movement is indicated. **Display 9-2** summarizes the factors influencing impairments of posture and movement.

To prepare the clinician with appropriate interventions under the right circumstances, this chapter defines the terms used in the evaluation and treatment of impairments of posture and movement, discusses factors influencing impairments of posture and movement, and outlines the principles of therapeutic exercise intervention for correction of posture and movement impairments.

DEFINITIONS

Posture

Posture is often considered to be a static function rather than being related to movement. However, posture should be considered not only a static function but also in the context of the position the body assumes in preparation for movement. Traditionally, posture is examined in standing and sitting positions, but posture should be examined in numerous positions, particularly postures in which the patient frequently assumes and positions related to frequently performed movements. For example, standing on one leg is 85% of the gait cycle and therefore should be considered an important posture to be examined.[57]

A useful definition of posture was provided by the Posture Committee of the American Academy of Orthopedic Surgeons[58] (**Display 9-3**). Most physical therapists understand the relationship between posture and the musculoskeletal system, but an important message delivered by this definition is the interaction between posture, musculoskeletal tissues, and organ systems (e.g., lungs, abdominal, and pelvic organs). This definition suggests that, without optimal support, organ systems may not function optimally. For example, respiratory insufficiency can result from kyphosis (increased thoracic flexion) or kyphoscoliosis (kyphosis superimposed on a lateral curve).[59] These postural faults can reduce mobility of the thorax and thereby increase the work of breathing.[60] Chronically altered respiratory mechanics have been cited as a contributing factor to cardiopulmonary pathology (e.g., pulmonary hypertension, heart failure).[61]

DISPLAY 9-3

Definition of Posture

Posture is usually defined as the relative arrangement of the parts of the body. Good posture is the state of muscular and skeletal balance that protects the supporting structures of the body against injury or progressive deformity irrespective of the attitude (e.g., erect, lying, squatting, and stooping) in which these structures are working or resting. Under such conditions, the muscles function most efficiently, and the optimum positions are afforded for the thoracic and abdominal organs. Poor posture is a faulty relationship of the various parts of the body, which produces increased strain on the supporting structures and in which there is less efficient balance of the body over its base of support.

Posture or carriage of the body describes the global relationships of body parts and should be considered differently than the orientation or alignment of one segment in relation to an immediately adjacent segment. For example, spino-pelvic balance in the sagittal plane can be considered as a global postural relationship linking the head to the pelvis. However, the shape and orientation (alignment) of each successive anatomic segment (cervical, thoracic, lumbar spine; pelvis, sacrum, hip joints) are closely related and influence the adjacent segment (**Fig. 9-1**). Evidence in the literature demonstrates a relationship between the alignment of the sacrum, pelvis, femoral heads, and various spine pathologies[62] (**Evidence and Research 9-6**). It is critical that the practitioner examine both posture orientation and segmental alignment to understand the relationship of individual segments to one another and to global posture.

EVIDENCE and RESEARCH 9-6

In areas of the spine in which more flexion is present, the disk pressures are maximum and predispose the region to early disk degeneration with disk herniation. In areas where hyperlordosis is present, there is risk of facet hyperpressure and L5 spondylolysis by "crack nuts" effect. The disks L4–L5 and L5–S1 are generally protected. Those individuals with a large anteroposterior diameter of the pelvis and increased sacral slope are at higher risk of spondylolisthesis through L5 isthmic lysis by a "sliding" mechanism.[62,63]

For the purposes of this chapter, the focus will be on examining and treating posture in the global sense. The reader is referred to regional chapters to understand segmental alignment standards, the relationship of alignment faults to pathological conditions, and the treatment of existing segmental alignment faults.

Standard Posture

Although any posture a patient or client assumes for sustained periods on a daily basis should be evaluated and treated, this

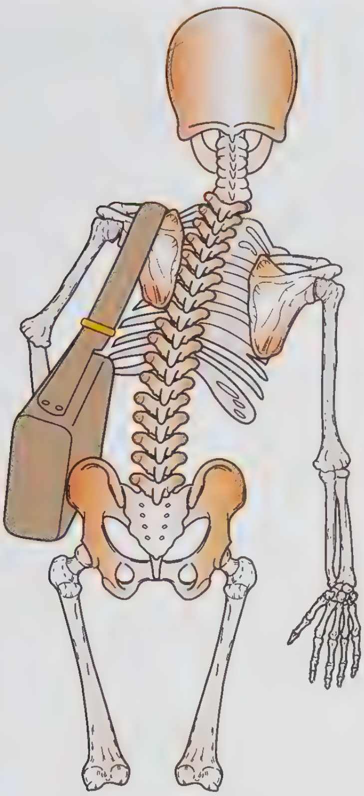


FIGURE 9-1 Spino-pelvic orientation of right thoracolumbar sidebend results in left neck on body sidebend. Specific alignment examples include right scapula depression and left scapula elevation. Later in this chapter, we will discuss the effect of alignment on muscle length and muscle performance. Consider the changes in length of the levator scapula, upper trapezius, and rhomboids in this example.

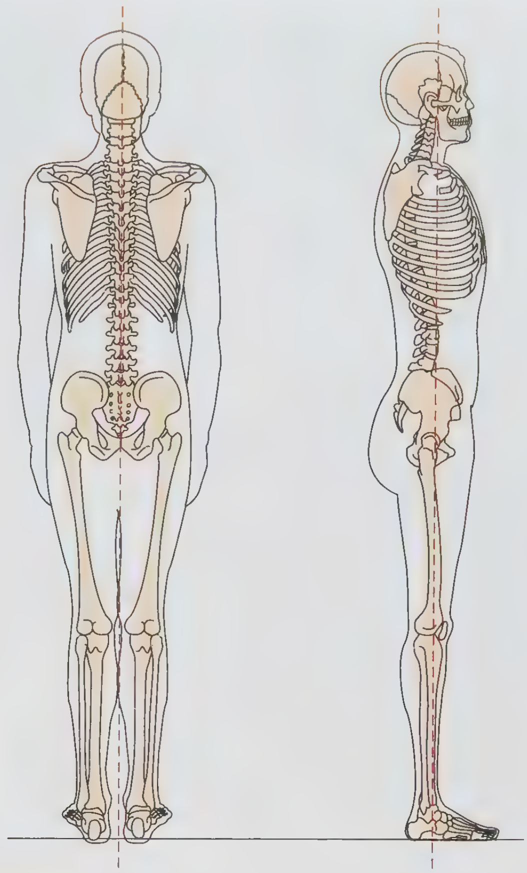


FIGURE 9-2 The back and side views of standard posture. The surface and anatomic landmarks that coincide with the side view are listed in Table 9-1.

chapter considers only the upright standing posture. The **standard posture** refers to an ideal posture rather than an average or normal posture. This standard should be used as a basis for comparison; deviations from the standard are called *impairments of posture*.

An evaluation of postural faults necessitates a standard by which individual postures can be judged. The standing posture is used as the standard in this chapter and is illustrated from the back and side (**Fig. 9-2**). In the back view, a line of reference represents a plane that coincides with the midline of the body. It is illustrated as beginning midway between the heels and extending upward to midway between the lower extremities, through the midline of the pelvis, spine, and skull. The right and left halves of the skeletal structures are essentially symmetric. Hypothetically, the two halves of the body are in equilibrium. The same line of reference can be imagined from a front view of the patient, noting any asymmetries.

In the side view, the vertical line of reference represents a plane that divides the body into front and back sections. Around this line of reference, the body is hypothetically in a position of equilibrium.

From a mechanical standpoint, it may be logical to assume that a line of gravity should pass through the centers of weight-bearing joints of the body. However, the on-center position is not considered stable, because it can be held only momentarily in the presence of normal external stresses.[64,65] For example, when the center of the knee joint coincides with the line of gravity, there are equal tendencies for the joint to flex and to hyperextend. The slightest force exerted in either direction causes it to move off center. If the body must call on muscular effort at all times to resist knee flexion, muscular effort is unnecessarily expended. To offset this necessity, the line of gravity is considered to be slightly anterior to the joint center. Ligamentous structures and ideal muscle length restrain the knee from moving freely posteriorly. At the hip joint, the same principles apply, but the hip is most stable when the line of gravity is slightly posterior to the center of the joint. The strong ligaments of the hip anteriorly prevent additional hip extension (**Table 9-1**).

The pelvis is the link that transmits the weight of the head, arms, and trunk to the lower extremities, and it is considered key to the alignment of the entire lower body. Because of structural variations of the pelvis (i.e., women tend to have a shallow pelvis, with the anterior superior iliac spine [ASIS] inferior to the posterior superior iliac spine), it is not appropriate to use an anterior landmark in relation to a posterior landmark. The pelvis is considered to be in a neutral position when the ASIS and the symphysis pubis are in the same vertical plane (see **Fig. 9-3A**). The anatomic structures and surface landmarks that coincide with the line of reference for the side view are listed in Table 9-1. Specific alignment of the upper extremity is summarized in **Display 9-4**.[1] Specific alignment of the lower extremity is summarized in **Display 9-5**.

TABLE 9-1

Anatomic Structures and Surface Landmarks that Coincide with the Line of Reference for the Side View of Posture

ANATOMIC STRUCTURES	SURFACE LANDMARKS
Through the calcaneocuboid joint	Slightly anterior to the lateral malleolus
Slightly anterior to the center of the knee joint	Slightly anterior to a midline through the knee
Slightly posterior to the center of the hip joint	Through the greater trochanter
Through the sacral promontory	Midway between the back and the abdomen
Through the bodies of the lumbar vertebrae	Midway between the front and back of the chest
Through the dens	Through lobe of the ear
Through the external auditory meatus	
Slightly posterior to the apex of the coronal sutures	

From Kendall HO, Kendall FP, Boynton DA. Posture and Pain. Huntington, NY: Robert E. Krieger Publishing, 1970.

Deviations in Posture

The following terms denote deviations in alignment with reference to the spine.[67]

- *Lordosis* is an increased anterior curve of the spine, usually of the lumbar spine, but it can affect the thoracic or cervical spine. If used without a modifying word, it refers to lumbar lordosis (**Fig. 9-4**).
- *Kyphosis* is an increased posterior curve, usually of the thoracic spine but sometimes of the lumbar spine. If used without a modifying word, the term refers to the thoracic spine (**Fig. 9-5**).

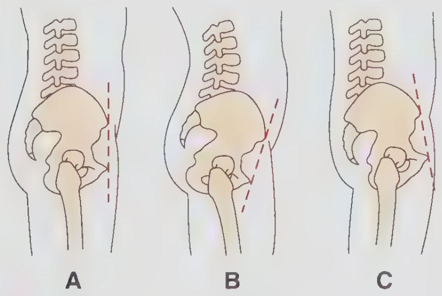


FIGURE 9-3 **(A)** The neutral position of the pelvis is one in which the anterosuperior iliac spines are in the same transverse plane and in which they and the symphysis are in the same vertical plane. **(B)** An anterior pelvic tilt is a position of the pelvis in which the vertical plane through the anterosuperior iliac spines is anterior to a vertical plane through the symphysis pubis. **(C)** A posterior pelvic tilt is a position of the pelvis in which the vertical plane through the anterosuperior iliac spines is posterior to a vertical plane through the symphysis pubis.

DISPLAY 9-4

Alignment of the Upper Extremity

Side View

- Humerus
  No more than one third of the head of the humerus protrudes in front of the acromion.
  Proximal and distal humerus in line vertically
- Scapula
  The inferior pole is held flat against the thorax (if the thorax is in ideal alignment).
  30 degrees anterior to the frontal plane (i.e., scapular plane)

Back and Front View

- Humerus
  Antecubital crease faces anterior; olecranon faces posterior.
- Forearms
  Palms face the body
- Scapula
  The vertebral border of the scapula is parallel to the spine and is positioned approximately 3 inches from the spine.
  The root of the scapula (where the spine of the scapula meets the vertebral border of the scapula) is at the level of T3.
  The vertebral border of the scapula is held against the thorax (if the thorax is in ideal alignment)
- Humerus

**These are general recommendations for alignment based on clinical observation. Precise alignment parameters will be denoted in Unit 6.*

DISPLAY 9-5

Alignment of the Knee

- Side view
  In the sagittal plane, the tibiofemoral angle should be 180 degrees.[66] If the angle exceeds 180 degrees, *genu recurvatum* (i.e., hyperextension) exists (**Fig. 9-6**).[66]
- Back and front view
  The normal angle between the tibia and femur in the frontal plane is about 170 to 175 degrees and is called the **physiologic valgus angle** of the knee.[66] If the valgus angle is <165 degrees, *genu valgum* (i.e., knock knees) exists.[66] Two types of valgus exist: structural and postural as depicted in **Figure 9-7**.[67] Conversely, if the tibiofemoral angle approaches or exceeds 180 degrees, *genu varum* (i.e., bow legs) exists (**Fig. 9-8**).[66]

- *Anterior pelvic tilt* refers to a position in which the vertical plane through the ASIS is anterior to a vertical plane through the symphysis pubis (Fig. 9-3B).
- *Posterior pelvic tilt* refers to a position in which the vertical plane through the ASIS is posterior to a vertical plane through the symphysis pubis (Fig. 9-3C).

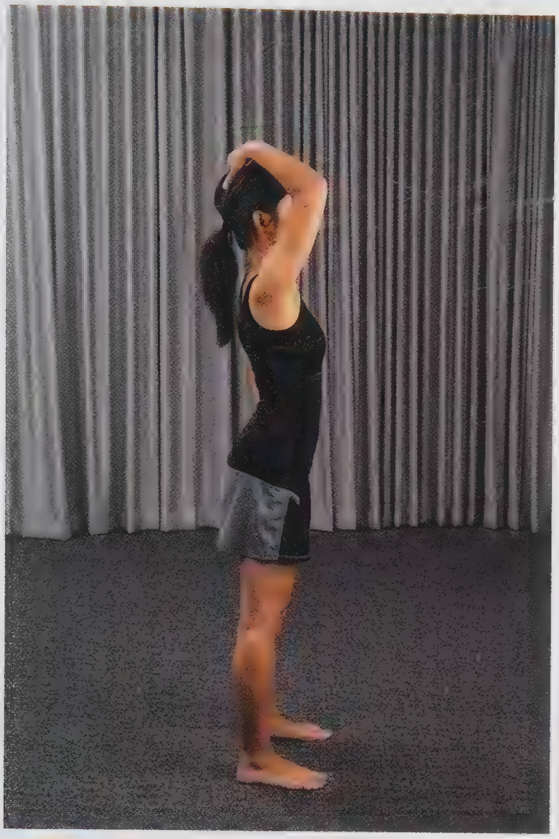


FIGURE 9-4 Marked anterior pelvic tilt and an exaggerated anterior curve of the lumbar spine. This curve is called a lordosis. Note that accompanying the anterior pelvic tilt and lordosis is flexion of the hip joint.

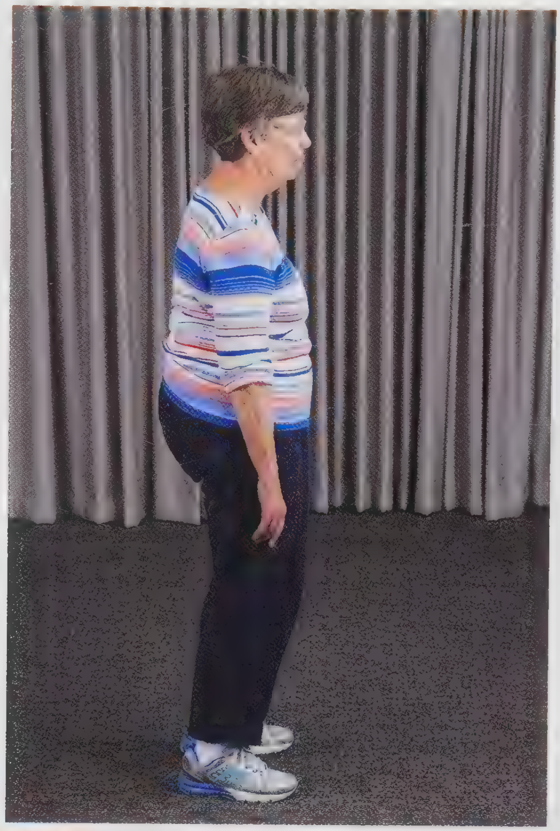


FIGURE 9-5 Person exhibiting an exaggeration of the normal posterior curve of the thoracic spine. This is called a kyphosis.

Display 9-5 denotes alignment terms and definitions related to the knee, while **Display 9-6** denotes alignment terms and definitions related to the shoulder girdle.

MOVEMENT

Movement is the action of a physiologic system that produces motion of the whole body or of its component parts.[71] Evaluating active movement in the clinical setting requires precise observation and palpation skills and extensive knowledge of kinesiologic principles.

A useful criterion for assessing precise or balanced movement is knowledge of the *path of instantaneous center of rotation* (PICR) during active motion.[1,72–74] The instant center of rotation describes the relative uniplanar motion of two adjacent segments of a body and the direction of displacement of the contact points between these segments (**Fig. 9-10**).[72] The instant center of rotation changes over time because of altered joint configurations and external forces. The PICR is a trace of the sequential instant centers of rotation for a joint in different positions throughout the range of motion (ROM) in one plane (**Fig. 9-11**).

It has been proposed that efficiency and longevity of the biomechanical system requires maintenance of precise movement of rotating segments; the PICR must meet a kinesiologic standard.[1] Deviations in the PICR from the ideal for a given joint imply that the arthrokinematic joint motions have become altered, even if the osteokinematic motion remains within the

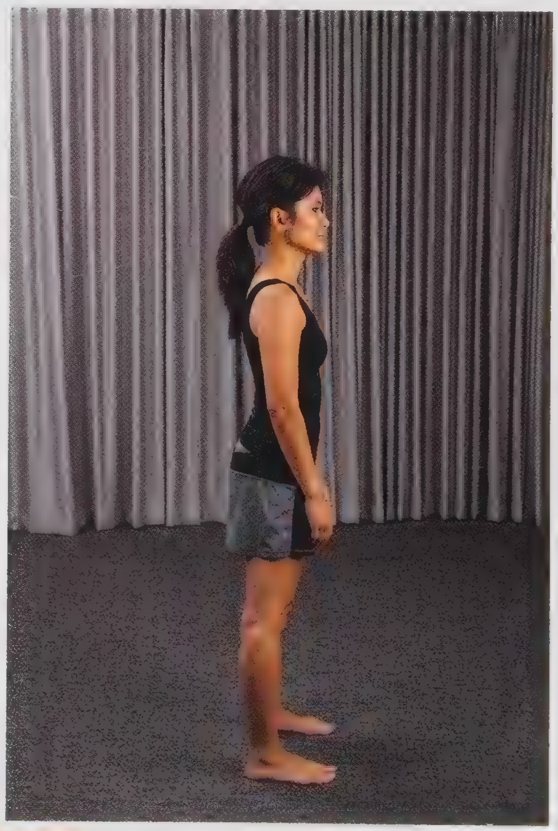
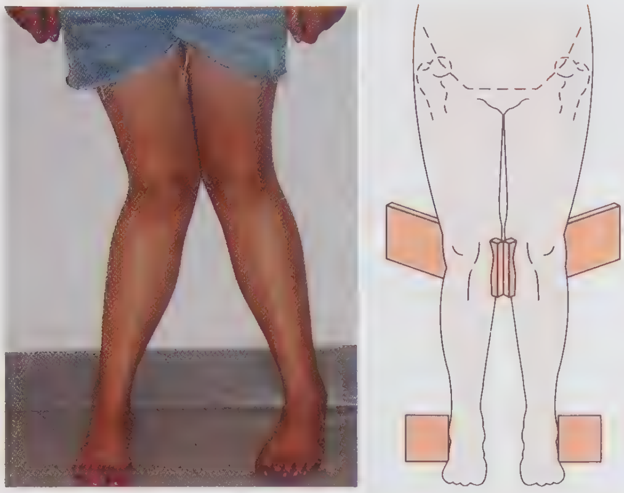
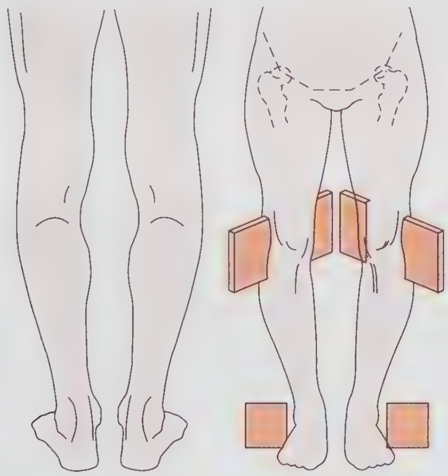


FIGURE 9-6 Moderate genu recurvatum or hyperextension of the knees.



A B

FIGURE 9-7 **(A)** Person with a marked structural genu valgum or knock-knees. **(B)** Postural genu valgum results from a combination of medial rotation of the femurs, pronation of the feet, and hyperextension of the knees. With medial rotation, the axis of the knee joint is oblique to the coronal plane, and hyperextension results in adduction at the knees.



A B

FIGURE 9-8 **(A)** Mild degree of structural genu varum, or bow legs. **(B)** Postural genu varum results from a combination of lateral femoral rotation, supination of the feet, and hyperextension of the knees. When femurs laterally rotate, the axis of motion for flexion and extension is oblique to the coronal axis. From this axis, hyperextension occurs in a posterolateral direction, resulting in separation at the knees and apparent bowing of the legs.

normal range. The quality or precision of the osteokinematic motion is affected. Various investigators have shown that PICR deviations provide a noninvasive means of identifying pathomechanics.[59,61,69] However, because the radiologic[75] or computational modeling methods[76] used to determine the PICR are not available to physical therapists, clinically reliable tools for measuring the PICR need to be established. Techniques used to qualitatively examine uniplanar, multiplanar, and total body movement patterns include precise observation, palpation of joint osteokinematics and arthrokinematics, and palpation

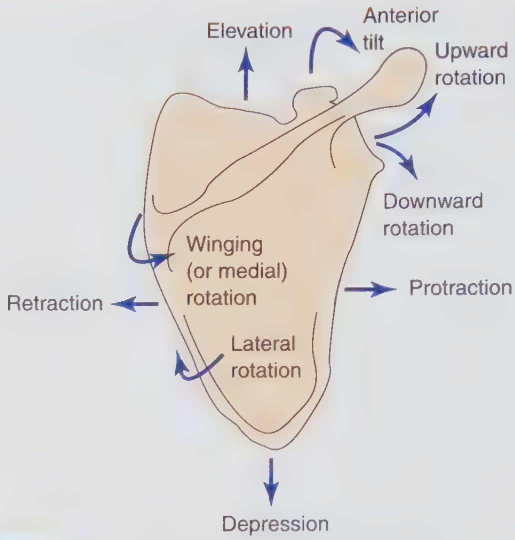


FIGURE 9-9 Positions and movements of the scapula.

DISPLAY 9-6
Alignment of the Shoulder Girdle (See Fig. 9-9)

- *Scapular retraction* is a rest position or movement in which the scapula is positioned or moving toward the vertebral column and occurs primarily at the sternoclavicular (SC) joint.[67,68]
- *Scapular protraction* is a rest position or movement in which the scapula is positioned or moving away from the vertebral column, also occurring at the SC joint.[67,68]
- *Upward rotation of the scapula* is a position or movement about an axis perpendicular to scapular plane[68,69] in which the inferior angle moves laterally and the glenoid fossa moves cranially.[68,69]
- *Downward rotation of the scapula* is a position or movement in which the inferior angle moves medially and the glenoid fossa moves caudally.[68,69]
- *Anterior tilt of the scapula* is a position or movement about a frontal axis parallel to the spine of the scapula[68,69] in which the coracoid process moves in an anterior direction and the inferior angle moves posteriorly and cranially.[67]
- *Posterior tilt of the scapula* is a position or movement in which the coracoid process moves in a posterior and cranial direction, whereas the inferior angle moves in an anterior and caudal direction.[67,68]
- *Elevation of the scapula* is a position or movement about a vertical axis in which the scapula moves cranially, and *depression of the scapula* is a position or movement in which the scapula moves caudally.[67,68]
- *Winging of the scapula or medial rotation* is a position or movement about a vertical axis perpendicular to the spine of the scapula[69,70] in which the vertebral border of the scapula moves posteriorly and laterally away from the rib cage and the glenoid fossa moves in an anterior and medial direction.[70] *Lateral rotation* of the scapula is the converse movement.[70]

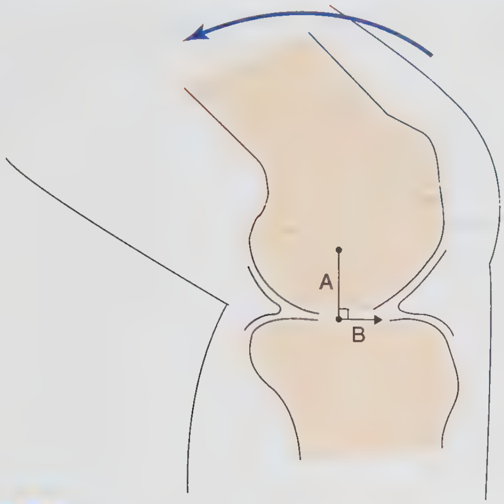


FIGURE 9-10 A normal knee with a line drawn from the instant center of the tibiofemoral joint to the tibiofemoral contact point (*line A*) forms a right angle with a line tangential to the tibial surface (*line B*). The *arrow* indicates the direction of displacement of the contact points. Line B is tangential to the tibial surface, indicating that the femur glides on the tibial condyles during flexion-extension motion.

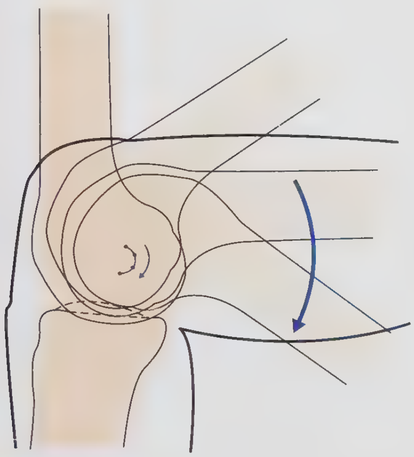


FIGURE 9-11 Semicircular PICR for the tibiofemoral joint in a normal knee.

or the use of surface electromyography to detect muscle activation patterns. The clinician relies on a thorough knowledge of kinesiologic principles to differentiate ideal from impaired movement patterns. A recommended reference to study clinical tools for assessing the PICR can be found in the recommended reading list at the end of this chapter.[1]

A major determinant of the PICR during active motion is the muscular force-couple action on the joint. **Force couple** is defined as two forces of equal magnitude but opposite direction with parallel lines of application.[65] The result of the forces is zero, meaning the body is not displaced (i.e., the body is in translatory equilibrium). The force couple causes the body to rotate around an axis perpendicular to the plane of the forces (**Fig. 9-12**).[65] In biomechanics, the instant center of rotation changes as the joint moves; consequently, the force-couple parameters change as the instant center of rotation changes.

Deviation of the PICR from the kinesiologic standard can be an indication of faulty muscle synergy in the force couple.

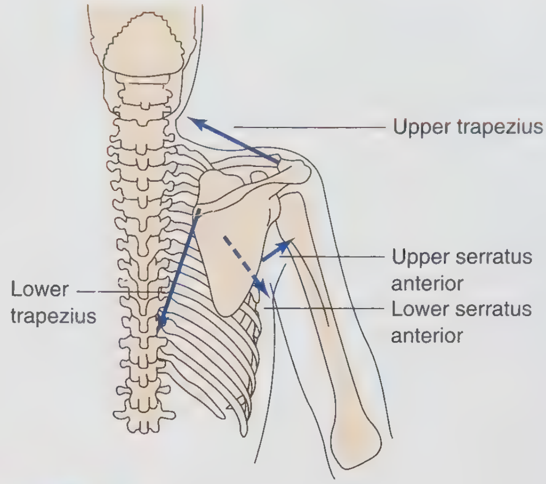


FIGURE 9-12 The action lines of the upper trapezius, lower trapezius, upper serratus anterior, and lower serratus anterior combine in a force-couple action to produce almost pure upward rotation of the scapula.

Muscle dominance is defined as one muscle of a synergistic group of muscles that exceeds the action of its counterparts, causing a deviation of the PICR and potential disuse of the other synergists.[1] The factors that affect force-couple balance are discussed later in this chapter.

CONTRIBUTORS TO IMPAIRED POSTURE AND MOVEMENT

Pathokinesiology is defined as the study of anatomy and physiology as they relate to abnormal movement.[77] Pathokinesiology emphasizes abnormalities of movement as a result of pathologic conditions. For example, in hemiparesis, the abnormal movement is the result of pathology involving the nervous system.[1] However, the reverse can also occur—pathology can result from abnormal movement. This can be defined as **kinesiopathology**.[1] When movement deviates from the kinesiologic standard, the cumulative effect of repetitive movement can be pathology. Therefore, it is reasonable to assume that maintaining precise movement patterns can minimize abnormal mechanical stress. Kinesiopathology can also result from repetitive movements and sustained postures associated with ADL including recreational, fitness, and sports activities. Clinicians use sustained postures and repetitive movements therapeutically to increase ROM and muscle length, improve joint mobility/stability, increase muscle performance, and improve motor control, balance, and coordination. Most often, adaptations such as these are considered advantageous; however, they can also be detrimental and contribute to movement impairments. Everyday activities can change muscle performance, ROM/muscle length, joint mobility/stability, and motor control, which in turn can alter the relative participation of synergists and antagonists and eventually movement patterns.

The following sections describe the relationship between posture and movement and physiologic, anatomic, and psychologic impairments, lifespan considerations, and environmental factors.

Range of Motion

The normal limitation of ROM in certain directions has postural significance in relation to the stability of the body, particularly in standing. ROM is impacted by joint mobility and soft-tissue extensibility. For example, dorsiflexion ROM at the ankle with the knee straight is normally about 10 to 15 degrees. To prevent excessive hyperextension of the knees, when standing barefoot with the feet nearly parallel, the tibia should not sway posteriorly beyond vertical alignment, nor should the hip move beyond its 10 degrees of extension. The combination of posterior sway of the tibia (ankle plantar flexion) with hip extension in standing creates knee joint hyperextension. Excessive segmental joint ROM (i.e., hip hyperextension) can allow proportional postural deviations in the corresponding directions. This is an often an overlooked impairment – excessive ROM or muscle length – but equally important to reduced ROM or muscle length.

With respect to movement, ROM impairment can contribute to movement dysfunction in that normal movement cannot occur at a joint with limited ROM. On the other hand, excessive ROM can allow extremes of movement that are detrimental to the joint, periarticular structures, and associated muscles. Typically, limited ROM at a joint encourages faulty movement at another segment. For example, a common faulty movement pattern seen associated with adhesive capsulitis of the shoulder is excessive scapula elevation.[78] Normal ROM at a joint does not ensure accuracy of the PICR during active movement. Recall that precise active movement is dependent on balanced active force couples acting on the joint.

Muscle Length

Impairment of muscle length can both be the *result of* impaired posture and movement as well as *affect* posture and movement. Prolonged posture alterations can result in muscle length changes. The time a muscle spends in the shortened range and the amount a muscle is contracted in the shortened range determines whether it becomes shortened.[79–81] Conversely, the stimulus for lengthening a muscle is the amount of tension placed on the muscle over a prolonged period.[79–81]

Sustained postures, particularly those postures that are maintained in faulty alignments, can induce changes in the muscles and supporting tissues that can be injurious, especially when the joint is at the end of its range.[82]

A clinical example can provide a better understanding of these concepts. Consider a person with thoracic kyphosis with a scapula positioned in medial rotation (winging), downward rotation, and anterior tilt. The lower trapezius muscle can experience sustained tension, resulting in lengthening, from the three-dimensional alignment faults coupled with gravity and the weight of a limb. In the case of the anterior tilt, the pectoralis minor experiences little to no counterbalancing tension from the lengthened lower trapezius and is assisted by gravity and the weight of the limb to remain in the shortened position. If the pectoralis minor contracts repeatedly in the shortened range (e.g., as an accessory muscle of respiration), it can develop adaptive shortening. Muscles that are sustained in a lengthened or shortened position develop changes in sarcomeres and length–tension relationships. This ultimately affects the force couple action of the muscles, thereby ultimately affecting the PICR during active motion[1] (see **Building Block 9-1**).

BUILDING BLOCK 9-1

With a scapula aligned in downward rotation, anterior tilt, and medial rotation, classify all the axioscapular muscles in this table as to whether they are at risk of a lengthening or shortening adaptive change.

Axioscapular Muscle	Short	Long
Serratus anterior		
Upper trapezius		
Middle trapezius		
Lower trapezius		
Levator scapula		
Rhomboid		
Pectoralis minor		

Joint Mobility

Joint mobility can be reduced *or* excessive. A joint can only move through a precise PICR if the joint has the available passive range in osteokinematic and arthrokinematic motions *and* the appropriate soft-tissue length to guide/restrict excessive motion. However, normal passive joint mobility does not guarantee precise PICR during active motion.

Impairments in joint mobility rarely occur in isolation. Active motion is usually affected by a combination of factors such as muscle length, muscle performance, joint mobility, and motor control. For example, during active shoulder medial rotation in the prone position with the arm abducted to 90 degrees, the shoulder should be able to medially rotate 70 degrees without an associated anterior glide of the head of the humerus or anterior tilt or superior glide of the scapula.[83] The active ROM can be limited by stiff or short lateral rotators, stiff periarticular structures (particularly the posterior capsule), and/or weak or poorly recruited medial rotators.

In some cases, though the ROM may be normal, the *quality* of motion is affected. For example, during medial rotation, one deviation of the PICR that may be observed or palpated is an arthrokinetic motion of the head of the humerus gliding excessively anteriorly. This movement may result from one or a combination of factors, such as those previously mentioned, combined with specific weakness or poor control of the subscapularis; dominance of the pectoralis major, latissimus dorsi, and teres major muscles; and/or excessive extensibility of the anterior capsule. Joint mobility, whether limited or excessive, can affect active motion, particularly when combined with other impairments of body functions (see **Building Block 9-2**).

BUILDING BLOCK 9-2

Explain why subscapularis is an important muscle to promote quality of glenohumeral medial rotation ROM.

Muscle Performance

A long-held belief is that deviations in posture reflect muscle weakness. However, the relationships between postural deviation and muscle strength have been questioned,[84,85] and the literature instead suggests that the relationship between muscle length and strength may contribute to postural deviation.[1]

Stretch weakness is a term used by Florence Kendall to describe the effect on muscles maintained in an elongated condition beyond neutral physiologic rest position.[67] This definition is based on the results of manual muscle strength testing.[67] For example, when the shoulders are maintained in a forward position and the scapulae are positioned in medial rotation (winging), downward rotation, and anterior tilt, the lower and middle trapezius muscles are positioned in an elongated rest position. The manual muscle test, when completed in midrange, as is typically done, would demonstrate weakness (**Fig. 9-13**). However, the apparent weakness of the posturally lengthened muscle may be an indication of altered length–tension properties such that the elongated muscle cannot produce tension in the shortened range (i.e., the manual muscle test position).[79–81] Length–tension properties of muscle are also discussed in Chapter 5.

If the elongated middle and lower trapezius muscles are tested in a relatively lengthened range, the force production capability is greater than in the traditional manual muscle test position. This phenomenon can be called a length-associated change.[82]

FIGURE 9-13 Manual muscle test position for the lower trapezius. Note that the arm is in elevation, positioning the scapula in upward rotation. The test position for the scapula is upward rotation, adduction, and depression. Failure to hold the test position indicates weakness.

For the muscle to become lengthened, it adds sarcomeres in series and, therefore, is capable of producing greater peak force than a normal-length or shortened muscle when tested at its optimal length. However, if the lengthened muscle is placed in a shortened position for manual muscle test, the filaments would overlap and be less efficient at producing force than a short or normal-length muscle. When testing muscles in the shortened range, a more appropriate description may be *positional strength*, because it indicates only the torque the muscle can create in the short range.[1] One form of stretch weakness may be positional weakness. Testing the muscle at multiple points in the range and comparing findings with those for the opposite extremity (or half of the body when examining axial muscles) can help to differentiate positional weakness from weakness resulting from strain, disuse, or neurologic involvement. The muscle with length-associated changes tests weak in the short range and strong in the lengthened range, whereas the other sources of weakness should test weak throughout the range.

The length–tension properties of the muscle correlate directly with the participation of the muscle in the force couple. The line of pull of its fibers determines the specific function of each muscle. No two muscles in the body have exactly the same line of pull. Whenever muscle weakness exists, the performance of some movement or the stability of some part of the body is affected. A muscle that becomes elongated over time exhibits positional weakness relative to the same point in the range of normal length or shortened synergists. Compared with its normal-length or shortened synergists, its participation in the force couple is lessened until it can achieve its optimal length–tension relationship. The result is a deviation of the PICR, which may contribute to repeated microtrauma and eventually to macrotrauma, pathology, further impairment, and disability.

A clinical example may illustrate the relationship between length–tension properties and movement. In an individual with a functional limb length discrepancy with a high iliac crest on the right, the right hip is in postural adduction, which places the gluteus medius on stretch. During gait, the gluteus medius participates in the hip abduction force couple to decelerate hip adduction from the initial contact to midstance phase (see **Selected Intervention 9-1** and **9-2**). The tensor fascia lata (TFL) does not necessarily encounter the same stretch stimulus as the gluteus medius when the hip is in postural adduction (particularly the anteromedial fibers) and therefore can create better tension for abduction at initial contact when the hip is in more relative adduction. However, because the TFL is also a hip flexor and medial rotator, without strong counterbalance from the gluteus medius (particularly posterior gluteus medius), the PICR of the hip can deviate in the direction of flexion and medial rotation. The overstretched gluteus medius can generate greater counterbalancing tension only after the hip is adducted, flexed, or medially rotated, which places the muscle on stretch. The posturally lengthened muscle affects the force-couple action and ultimately affects active movement patterns (see **Building Block 9-3**).

BUILDING BLOCK 9-3

What kind of injury can the gluteus medius sustain if it is chronically activated in a stretched position? Could this be an explanation of lateral hip pain?

SELECTED INTERVENTION 9-1

Prone Hip Abduction

See Case Study No. 9

Although this patient requires comprehensive intervention, one critical exercise is described:

ACTIVITY: Prone hip abduction through full ROM

PURPOSE: Strengthen 2+/5 gluteus medius through full range (need to increase the muscle's ability to create tension through full range)

RISK FACTORS: No appreciable risk factors

EFFECT OF PREVIOUS INTERVENTIONS: None

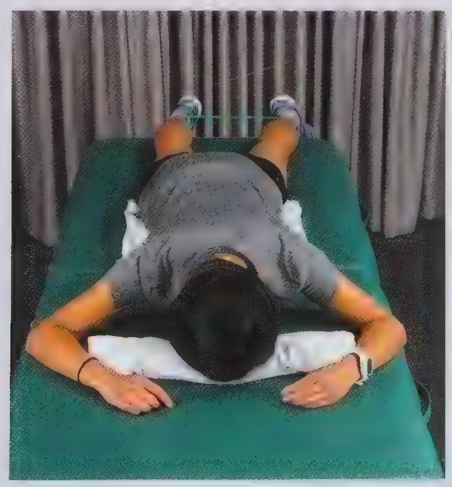
SUBSYSTEM OF THE MOVEMENT SYSTEM: ACTIVE

STAGE OF MOTOR CONTROL: Mobility

MODE: Resisted exercise in a gravity-lessened position

POSTURE: Beginning and ending position—prone, with a pillow under stomach, hip slightly laterally rotated, elastic around the ankle (**Fig. A**).

MOVEMENT: The hip extends just enough to clear from the supporting surface, abducts through the full available range (concentric), rests on the supporting surface, returns to a slightly extended position, and slowly adducts to the starting position (eccentric; **Fig. B**).



SPECIAL CONSIDERATIONS: Ensure that the gluteus medius is contracting throughout the entire activity (concentric and eccentric) and that the TFL is maximally relaxed. Ensure that full *end-range* motion is achieved and that the abdominal muscles are stabilizing the spine against extension and the pelvis against anterior tilt and side-bending forces imposed by motion of the hip. Be sure motion is isolated to the hip and that no motion occurs in the spine or pelvis.

DOSAGE

Special Considerations:

Anatomic: Gluteus medius
Physiologic: No strain, 2+/5 manual muscle test (MMT) grade
Learning Capability: Difficulty isolating gluteus medius over TFL may require tactile facilitation or surface electromyography with biofeedback on gluteus medius for better isolation.
Type of Contraction: Concentric during abduction motion and eccentric during adduction motion
Intensity: Light-resistance elastic tied around the ankle and taut in hip-neutral position
Speed of Activity: Moderate on concentric portions; slow on eccentric portion
Duration: To form fatigue for two sets (maximum of 30 repetitions)
Frequency: Daily
Environment: Home
Feedback: Initially tactile facilitation or surface electromyography with biofeedback, tapered after isolated contraction is achieved.

RATIONALE FOR EXERCISE CHOICE: This exercise was chosen to increase the strength of the gluteus medius in isolation from the TFL. Because the MMT grade is 2+/5, a gravity-lessened position was chosen to allow full ROM. Light elastic was used to ensure concentric contraction of the gluteus medius during the abduction motion and eccentric contraction on the return from abduction in a gravity-lessened position. Full ROM is expected to work on length–tension properties of the gluteus medius (i.e., ability to create force throughout the range, including the shortened range).

EXERCISE MODIFICATION/GRADATION: As strength through a full range is developed, the exercise should be progressed to an against-gravity position (i.e., sidelying). After a 3+/5 MMT grade is achieved, standing functional activities should be introduced (i.e., stability and controlled mobility). After proximal stability and controlled mobility are achieved, the exercise can be progressed to functional gait activities (i.e., skill).

Within each activity level, specific dosage parameters can be manipulated to progress the exercise and prepare for gradation to the next level. At each level, care must be taken to ensure synergy between the gluteus medius and TFL in stabilizing the hip in the frontal plane by observing the pelvic and femur positions and preventing anterior pelvic tilt, Trendelenburg gait, or femoral medial rotation. In closed chain positions, neutral pelvic, tibial, and foot alignment about all three axes complement the hip position.

FUNCTIONAL MOVEMENT PATTERN TO REINFORCE GOAL OF SPECIFIC EXERCISE:

Posture: Educate the patient about asymmetric postures that reinforce a weak, lengthened gluteus medius (i.e., standing with weight shifted to the involved side, resulting in a high iliac crest).
Movement: During gait, think of contracting gluteal musculature at heel strike to prevent a Trendelenburg gait.

SELECTED INTERVENTION 9-2

See Case Study No. 9

PROBLEM: Right hip pain with prolonged weight bearing

SHORT-TERM GOAL (4 TO 6 WEEKS):

- Patient has 3+/5 muscle grade in gluteus medius
- Patient is able to walk 10 minutes with 2/10 pain and reduced Trendelenburg gait

LONG-TERM GOAL (12 TO 16 WEEKS)

- Patient has 4+/5 muscle grade in gluteus medius
- Patient is able to walk miles with 1/10 pain

Exercise	Early Phase	Late Phase
Hip abduction	Prone hip abduction (see Selected Intervention 9-1)	Sidelying hip abduction (Self-Management 19-4—Levels III-IV)
Active stretch Band (ITB)	Teach foam roll to self-mobilize ITB (Fig.7-49)	Active stretch at the end of Level V—Self-Management 19-4.
Functional training	Squat (Self-Management 19-8)	Split squat (Self-Management 19—Level III)

The theory of "core strength" in the lumbopelvic and cervical regions is another key concept that certainly pertains to optimal posture and movement.[86–89] Chapter 17 discusses the theory of core strength in detail along with therapeutic exercise descriptions to develop core strength. The reader is referred to the section "Muscle Performance" in Chapter 17, The Lumbopelvic Region for the literature review, and detailed discussion of this topic.

With respect to the endurance component of muscle performance, the fatigability of a muscle affects its participation in a force couple, particularly in repeated movements. Muscle fatigue affects movement, but muscle endurance often is not a factor in perpetuating optimal resting alignment; the length of the muscles and periarticular structures support optimal alignment. Little muscle activity is required to maintain a relaxed standing position.[90] However, in the presence of injury, even small demand on the musculature can be problematic.

Control of posture is a highly complex task in the human motor system. There is evidence that the postural control for stability and orientation requires proprioceptive input from numerous muscles in order to generate the appropriate torque in maintaining the body position.[91,92] The sensory organs involved in maintaining balance control and body orientation incorporates somatoafferent, vestibular, and visual input in order to assess the current body position. Consequently, the motor process coordinates postural strategies to decrease body sway and maintain it within the base of support. It has been suggested that the injury to the neck and/or the otolith structures that influence afferent feedback might contribute to loss of awareness and control of posture.[93] Therefore, the practitioner needs to look at global strategies as well as local, segmental strategies, when it comes to examining and treating posture impairment (see **Building Block 9-4**).

BUILDING BLOCK 9-4

Consider a 23-year old that sustained a second-degree ankle sprain. Provide an explanation as to why the physical therapist should consider closed chain balance drills in the plan of care.

Pain

The introduction to this chapter discussed the cautious approach to assigning correlation and/or causation of pain with posture and movement. Sometimes, under certain circumstances, posture and movement patterns matter, while other times, it is not so clearly associated.[13] One concept worth discussing is the notion that too much attention to posture and movement can in and of itself create an inadvertent "nocebo" effect. The nocebo effect is a detrimental effect on health produced by psychological or psychosomatic factors such as negative expectations of treatment or prognosis.[94] *What* we say to patients matters. If we place too much emphasis on posture and movement, the patient might feel they can never achieve a high level of adherence and performance and therefore not be effective at reducing pain levels. In addition, therapists can inadvertently contribute to maladaptive patterns with fear avoidance of postures and movements that the patient is told *cause* pain. We can use language such as "optimizing posture and movement patterns can help calm down the trigger from pain sensitive tissues," as opposed to giving them the message that they have pain because of posture and movement faults. Ultimately, we want to restore homeostasis to the system and "comprehensive capacity,"[95] a term used to refer to variability of the movement system, not just ideal posture or form, but the ability to position or move in a variety of patterns without provoking symptoms.

We have all had a painful limb and find ourselves moving differently because of the pain. Pain can induce abnormal movement (maladaptive), abnormal movement can induce pain (adaptive), and it can be difficult to differentiate cause from effect. When a mechanical stress perpetuates the symptom or prevents resolution of the painful condition, the mechanical cause must be diagnosed and treated. Ultimately, the posture habits and movement patterns contributing to the mechanical cause of pain must be modified to allow the nervous system to calm down and create a healing environment with the optimal stress for tissues to heal.[96]

Pain may or may not alter a given posture or movement, depending on the severity of the symptom and the magnitude or intensity of stress imposed by the posture or movement. However, pain that is predictably associated with posture and movement can lead the clinician to an understanding of the kinesiopathologic factors contributing to the pain. For example, a patient has shoulder pain during swimming; the movement impairments associated with the pain experienced during the swim stroke (nociceptive trigger) and secondarily the alterations to the movement pattern that reduce or eliminate the pain (calm down the nervous system) can drive the intervention.

A clinical test that can be administered is a prone 90/90 glenohumeral rotation test. The patient is positioned prone with the arm abducted 90 degrees with the elbow flexed 90 degrees and the forearm hanging vertically off the side of the table (see **Fig. 9-14**). The patient is asked to actively medially rotate his

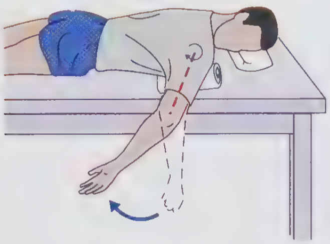


FIGURE 9-14 Illustration of movement test position for glenohumeral medial rotation.

shoulder. The examiner palpates and observes the PICR of the humeral head. If excessive anterior translation of the humeral head is observed and the movement is painful, the follow-up test is to teach the patient to control anterior translation and note the effect on pain. If the pain is reduced or eliminated with control over the anterior translation, this change will drive the intervention. The clinician must perform additional tests to determine the specific impairments that contribute to the anterior displacement of the head of the humerus such as a weak or overstretched subscapularis, stiff posterior capsule, and/or dominant and short teres major or anterior deltoid.

Treatment is based on resolving the impairments associated with the kinesiopathologic pattern during specific exercises and eventually during functional movement patterns. By treating the movement impairment, the pain often resolves without necessarily requiring direct treatment of the tissue that is the source of pain (see **Building Block 9-5**).

BUILDING BLOCK 9-5

Consider a 54-year-old female master swimmer with anterior shoulder pain after 15 minutes of freestyle swimming. She has had a full evaluation by her orthopedist including an MRI to R/O rotator cuff tear. Your physical therapy examination reveals the following primary impairments of body functions:

1. Painful weakness to glenohumeral medial rotation and adduction
2. 3+/5 lower and middle trapezius and serratus anterior

How could weakness of the glenohumeral medial rotators and scapular upward rotators contribute to pain in the anterior shoulder during swimming freestyle?

Anatomic Impairments and Anthropometric Characteristics

Anatomic impairments can predispose persons to impairments of posture and movement that can result in MPS. Individuals with anatomic impairments (e.g., scoliosis, kyphosis from Scheuermann disease, hip anteversion) can be at higher risk to develop MPS because of altered posture habits and movement patterns. For example, an individual with Scheuermann disease typically has moderate to marked kyphosis. This patient is prone to even more exaggerated kyphosis beyond the anatomic impairment because of the effect of gravity and the weight of the upper extremities on the kyphotic posture. Increased thoracic kyphosis can give rise to thoracic, neck, shoulder, low back, or lower quadrant pain because of compensatory spinal, shoulder girdle, pelvic girdle, and lower extremity alignments.

The patient may adopt movement patterns that perpetuate the kyphotic posture. For example, during forward bending, instead of initiating the movement with concentric phasic activity from the rectus abdominis and controlling the lowering with eccentric spinal and hip extensors, the bending movement may be produced by tonic concentric rectus abdominis activity and phasic eccentric deceleration from the spinal and hip extensors. The latter movement pattern would contribute to greater kyphotic forces on the thoracic spine than the former pattern.

Anthropometric characteristics can also contribute to impairments of posture and movement.[97,98] Consider a tall man with broad shoulders and a tall, narrow pelvis. Ideal lumbopelvic rhythm is such that motion at the lumbar spine should be accompanied by motion of the pelvis rotating over the hips.[99] The tall man with broad shoulders and a tall, narrow pelvis has a higher center of mass than an average-height woman with a relatively broader pelvis. When the man bends forward, the fulcrum point is more likely to be in the lumbar spine than at the hips because of the high center of mass. The man therefore has a greater tendency to bend with excessive lumbar flexion and limited pelvic rotation (**Fig. 9-15**). With this forward bending strategy used over a lifetime, the hip joint is at risk for developing hypomobility in the direction of flexion, and the lumbar segments are at risk of becoming hypermobile in the direction of flexion. The hypermobility of the lumbar spine into flexion may be carried over to other postures and movement patterns such as sitting, reaching, and sports activities such as the follow-through phase in serving the ball in tennis. Related impairments of muscle length and performance can result from impairments of movement and contribute to perpetuating and further exaggerating faulty movement (see **Building Block 9-6**).

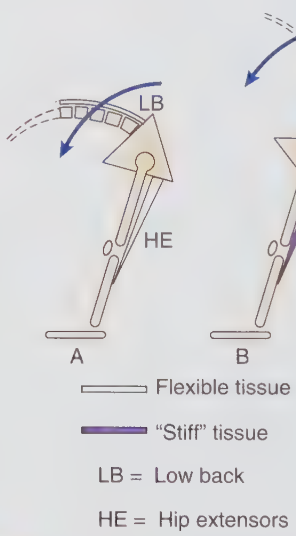


FIGURE 9-15 **(A)** Normal lumbopelvic rhythm. **(B)** Faulty lumbopelvic rhythm with less movement of the pelvis relative to the hips. In men, this could result from the anthropometric characteristics of a heavy upper body relative to the lower body.

BUILDING BLOCK 9-6

The valgus angle of the male is different from that of the female with females tending toward higher valgus angles. How could the valgus angle in the female athlete predispose her to noncontact anterior cruciate ligament injury? What preventive exercises would you want to include in the training regimen of the female athlete?

Psychologic Impairments

The link between posture and movement and the experience of pain has been discussed in some detail already in this chapter, but it is worthy of further exploration from a psychologic point of view. Research points to a complex and dynamic interaction of biologic, psychologic, and social variables influencing movement and its relationship to pain and pain-related disability.[100] There is growing evidence that pain-related fear may be a particularly important mechanism in the onset and maintenance of pain-related disability.[101–106] Pain-related fear refers to the extent that an individual believes that certain movements or actions will result in either increases in pain levels or exacerbation of an injury that is associated with pain[106] and it is usually associated with avoidance of those movements or activities.[106–109] A reduction in activities on an ongoing basis can lead to the establishment of a negative cycle characterized by altered movement patterns, physical deconditioning, decreased self-efficacy, and negative affect.[110] This can result in a detrimental impact upon the musculoskeletal and cardiovascular systems,[111] further worsening the pain problem and leading to still greater avoidance of activities. Such a cycle, termed "fear-avoidance,"[111] is thought to be maintained by both the reduction in anxiety that comes from the successful avoidance of feared activities[112] and the further entrenchment of pain-related fears as the individual allows themselves few opportunities to "challenge" their beliefs about the consequences of certain movements.

There is considerable empirical support for the notion that pain-related fear is related to disability in patients with chronic pain.[104,113] Studies have shown that patients with high pain-related fear tend to overestimate their expected levels of pain in certain situations and to terminate activities earlier than those who predict less pain.[114] There are also indications that pain-related fear may be more strongly associated with disability than either pain severity or other biomedical characteristics of the patient's condition.[101,103,109,111,115] For example, Waddell et al.[116] found that fear-avoidance beliefs about pain were better predictors of self-reported disability in ADL than were the anatomic pattern of pain, the time pattern of pain, or pain severity. And although this research is compelling, and we cannot underestimate the fear-avoidance component of movement impairment, we must also pay close attention to the quality of movement. We must teach the patient to move efficiently, safely, and with the least biomechanical stress to the affected tissues to address the impairments of body functions contributing to the pain.

It is beyond the scope of physical therapy practice to deal with the complexity of the biopsychosocial framework contributing to pain and movement impairment. A multidisciplinary approach toward complex chronic pain is warranted. If the physical therapist determines that the psychological state of the patient is inhibiting recovery, referral to an appropriate mental health practitioner is indicated. Physical therapy intervention may need to pause until the psychological condition improves, or it can proceed if it is determined that continued intervention is beneficial to psychologic recovery. As the psychological status improves, the PT's role is to reintroduce movements that have been avoided. As movement is restored, confidence improves, and fear avoidance reduces—thus breaking the cycle of pain and fear avoidance of movement (see **Building Block 9-7**).

BUILDING BLOCK 9-7

Consider a 45-year-old female with a chronic history of hip and low back pain. She is able to perform a comprehensive self-management program safely and has been able to control her pain 80% of the time. However, she is fearful to return to her health club which you feel is necessary for her to improve her global physical condition. How would you assist her in returning to her gym setting with a comprehensive gym-based program?

Lifespan Considerations

We all have observed the effect of age on posture and movement. Children are not expected to conform to an adult standard of posture and movement, primarily because the developing individual exhibits much greater mobility and flexibility than the adult.[117] Developmental deviations appear in many children at about the same age and improve or disappear without any corrective treatment, despite unfavorable environmental influences.[117] However, developmental deviations are perpetuated by habit in some children. Repeated observation (not a single examination) can determine whether a developmental deviation is being perpetuated by habit. If the condition remains static or if the deviation increases, corrective measures are indicated. A young child (younger than 5 years) is not likely to have habitual faults and can be harmed by corrective measures that are not needed. When screening a developing child, check ROM of the hips and spine to see if the postural impairment is flexible. If not, radiographs may be necessary and immediate attention may be required (**Fig. 9-16**). Developmental changes occur in the feet, knees, hips, pelvis, trunk, and shoulder girdle. **Display 9-7** lists the common developmental deviations in children that should gradually diminish as the child reaches adolescence and adulthood.

One particular anatomic impairment that is not considered a normal developmental posture occurs during adolescence. Physical therapists working with preadolescent and adolescent populations should be routinely screening for the onset of scoliosis. After scoliosis is diagnosed, the adolescent can be referred to a physician specializing in the treatment of scoliosis and a comprehensive management plan can be developed.

FIGURE 9-16 Physiologic lordosis of puberty. This form of lordosis (*red arrow*) is seen during late childhood just prior to puberty. The spine is flexible and the lordosis disappears on forward bending (*white arrow*).

DISPLAY 9-7

Developmental Deviations in Posture

Feet

- Flat arches are normal in the small child.
- By age 6 or 7, expect good arch formation.

Knees

- Genu valgum is normal in a child age 5 or younger (about 2 inches in between ankles is normal for an average-height child).
- By age 6 or 7, genu valgum should be diminished or gone.
- Postural genu varum in the school-age child is not acceptable, and corrective measures should be taken, because it is difficult to change in the young adult.
- Genu varum may be compensatory for genu valgum by hyperextension of the knees.

Hips

- Femur medial rotation is the most common and often results from hip anteversion, foot pronation, knee hyperextension, postural genu varum, and less often, genu valgum. Check for structural sources and treat with the appropriate corrective measures.
- By adolescence, the femur should be in near-neutral alignment.
- Femur lateral rotation is more common in young boys.
- Persistent lateral rotation should be treated, because it can be detrimental in adulthood.

Lumbopelvic Region

- A protruding abdomen is normal for a child.
- By the age of 10 to 12, the abdomen should no longer be protruding.
- Lordosis peaks at age 9 to 10 and should gradually diminish thereafter.
- Handedness patterns emerge in school-age children, most commonly with the hip high and shoulder low on the dominant side. This should be monitored if it is borderline or excessive.

Shoulder Girdle

- Scapular tilting is normal in school-age children.
- The prominence should diminish as the child approaches adolescence.

From Kendall HO, Kendall FP, Boynton DA. Posture and Pain. Huntington, NY: Robert E. Krieger Publishing, 1970.

There is evidence that alterations in movement begin to occur in late middle age, probably because the functional abilities gradually decline.[118] In the broad sense, the execution of voluntary movements requires two goals to be achieved simultaneously: accurate performance of a goal-directed movement on the one hand, and maintenance of equilibrium and appropriate posture, or set of postures, on the other (for a review, see Horak and Macpherson[119] and Massion et al.[120]). Aging adds an additional challenge with coordination between equilibrium and movement, causing progressive impairments at the level of the central nervous system as well as in the sensory motor system. According to Millanvoye,[121] decrements in performance are initially imperceptible, become detectable around the age of 40 to 45 and only become noticeable to the point that they cannot be ignored after the age of 60. Thus, the possibility of early detection of minor changes between young and aging adults in the coordination between equilibrium and movement may provide a window into the evolution of fall risk as individuals age. Identification of these changes and their time course could provide the basis for preventive rehabilitation programs to diminish the risk of traumatic falls and to enhance maximum autonomy.[122] Exciting research is on the horizon in this area, with a greater emphasis on prevention as we understand the effect of aging on equilibrium and movement.

Environmental Influences

The activities in which an individual participates and the surrounding environment may have favorable or adverse effects on posture and movement. The nature of the activities and the time spent doing them and whether the effect of *habitual* postures and *repeated* movements during one activity are reinforced or counteracted by *habitual* postures or *repeated* movements in other activities determine the overall, cumulative posture and movement effect. Stresses are put on the basic structures of the human body by increasingly specialized and limited or repetitive activity (e.g., working endless hours at a computer display terminal, going home exhausted, sitting most evenings in a recliner chair in front of a television).

The activities of an individual must be considered as a whole in gauging their postural or movement effects. Concentration on one type of activity can ensure muscle imbalance, but a combination of activities may be almost as unfavorable if each involves the same kind of movement or position. For example, a person working at a video display terminal who engages in piano playing in her leisure time has no real change in the type of activity.

Several environmental factors, such as workstations, beds, pillows, car seats, school chairs and desks, and footwear, influence posture and movement. These environmental influences should be made as favorable as possible. **Patient-Related Instruction 9-1** outlines important tips for proper workstation ergonomics. This would be a useful handout to provide all your patients that spend time at a computer workstation. When major adjustments cannot be made, small adjustments often help considerably. A discussion of environmental influences is not complete without reference to body mechanics related to lifting and carrying. These strategies should be examined and favorably modified as much as possible for the individual's circumstances.

EXAMINATION AND EVALUATION

Posture

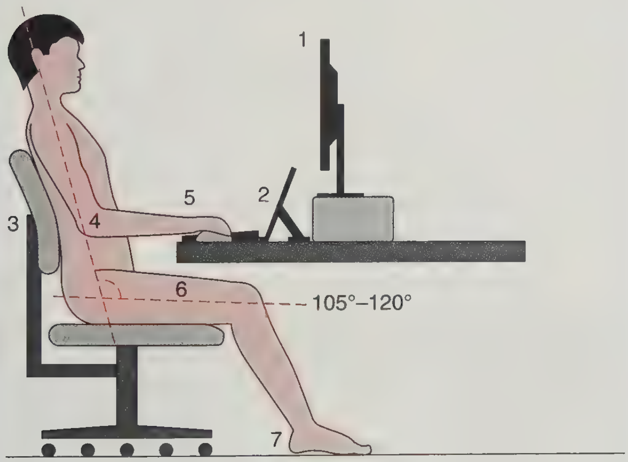
The bony landmarks and postural reference points that were discussed earlier in the chapter are put to practical use in plumb line tests for postural alignment (**Fig. 9-17**). In standing, the patient's posture should be examined twice: once in their "typical" posture and once in a "standardized" posture. To observe the patient's "typical" posture, have the patient march in place 10 times, take a deep breath and exhale. This encourages the patient to stand in their natural, weight-bearing posture. The plumb line should bisect the patient's pubic tubercle, as the feet are allowed to be in an asymmetrical distance from the midline. The therapist should then observe the patient from the front, both sides and the back, noting any asymmetries. For example, a person who stands with the majority of their weight

Patient-Related Instruction 9-1

Checklist for a User-Friendly Workstation

Sitting position is an important factor in keeping your body aligned properly to minimize stress on your back and muscles. Leaning back slightly into your chair's back rest relaxes your back muscles and promotes blood circulation. Leaning back too far however can result in an awkward neck posture.

1. Eye level: The top of the screen should be at eye level; lower for bifocal wearers. Screen distance at arm's length (18 to 36 inches).
2. Document holder: Centered between monitor and keyboard or next to the screen.
3. Chair backrest: Provides firm lower back support. The chair backrest and seat should be easily adjustable for height and tilt by the user.
4. Keyboard and mouse: Keyboard height promotes relaxed arms with forearms parallel to the floor. If you use a mouse or other pointing device, it should be placed next to the keyboard.
5. Wrist position: Straight (neutral). Wrist rest—padded, moveable wrist rest, same height as the front of the keyboard. (Do not use a wrist rest while keying.)
6. Knee position: Knees should be at or below hip level. Provide ample legroom under your work surface.
7. Feet position: Feet should rest firmly on the floor or footrest.



Reclined sitting
Leaning back slighlty into your chair's back rests relaxes your back muscles and promotes blood circulation. Leaning back to far can result in awkward neck postures.

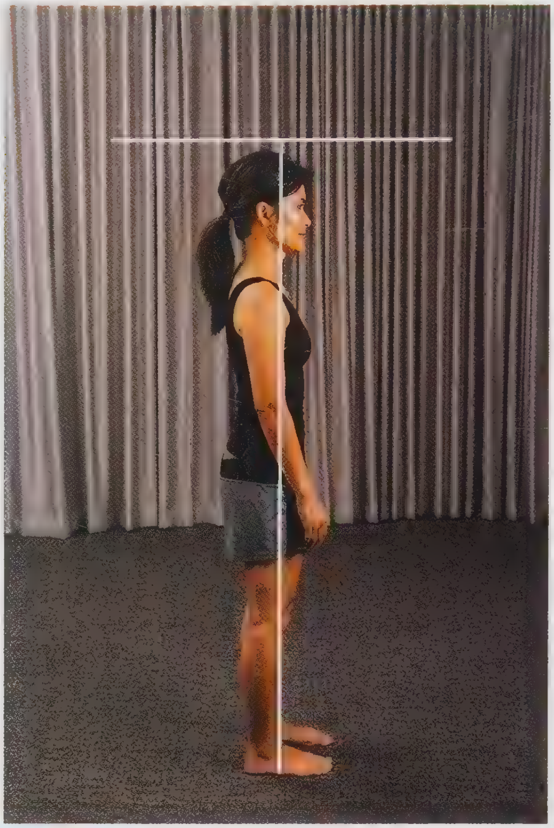


FIGURE 9-17 For the purpose of testing, the client steps up to a suspended plumb line. For the back or front view, the subject stands with feet equidistant from the line; for the side view, the point on the plumb line is just anterior to the lateral malleolus. The base point should be the fixed reference point, because the base is the only stationary or fixed part of the standing posture.

on their right lower extremity with their left lower extremity in hip abduction may experience stretch weakness of the right hip abductors and shortness of the right hip adductors. In addition, this posture creates right lumbar sidebending with shortening of the right quadratus lumborum and lengthening of the left quadratus lumborum. Once the patient's natural posture has been observed and asymmetries noted, the therapist should then observe posture from a "standardized" position. To standardize the position, have the patient place one foot on either side of the therapist's foot. The therapist then removes their foot from between the patient's feet. The plumb line should bisect this space. The advantage of using the therapist's foot as a reference is that the position is repeatable at every patient visit, regardless of plumb line availability. The patient should again be observed from the front, both sides and back, noting any asymmetries in this position. The amount of deviation of the various points of reference from the plumb line reveals the extent to which the subject's alignment is faulty. When deviations from plumb alignment are evaluated, they are described as slight, moderate, or severe.[67] Additional alignment tests can be performed in several positions, such as sitting, recumbency, and single-limb stance. Side to side differences as well as deviations from acceptable standards can be noted.

In addition to standard posture assessment, the physical therapist must also examine specific segmental alignment of adjacent segments in a region. For example, the position of L5 relative to S1 may be relevant in a lumbar condition. If L5 is in a slight rotation, this may be a source of nociception due to the biomechanical stress on the tissues of the motion segment. Treatment of this specific segmental alignment fault may be vital to the reduction of symptoms and the overall recovery of the patient.

Posture can assist the clinician in generating hypotheses regarding muscle length. For example, anterior pelvic tilt can suggest short hip flexors and elongated abdominal muscles. Specific muscle length tests are necessary to validate the hypotheses, and determine actual muscle length. Definitions of terms regarding muscle length are outlined in **Display 9-8**.

DISPLAY 9-8

Definitions of Terms Regarding Muscle Length

- Tautness is defined as muscles or ligaments put on tension. It implies a state in which slack is taken up in the muscles or ligaments.
- A short muscle limits the ROM as it relates to the kinesiologic standard.
- An elongated muscle is longer than the kinesiologic standard; tautness appears after the motion has exceeded the normal joint range.
- The term tight is often used interchangeably with short or taut, but these terms do not have equivalent meanings. On palpation, a muscle that is short and drawn taut feels tight. A muscle that is elongated and drawn taut also feels tight on palpation. Because the word tight implies that a muscle should be stretched, the terms short and elongated are preferred to describe muscle length to ensure that stretching is applied only to short muscles.
- Stiffness is defined as the change in tension per unit change in length.[123] When passive motion of a joint is assessed, all the tissues crossing the joint contribute to the resistance, which can be referred to as joint stiffness.[1] For the purposes of this text, stiffness refers to the resistance present during the *passive* elongation of muscle and connective tissue, not during *active* muscle contraction.

Movement

Examination of movement in the clinical setting can be challenging. Computerized movement analysis equipment is costly and is not user-friendly in the typical physical therapy setting. Video applications are readily available to the consumer and can provide acceptable analysis and feedback. In addition, the clinician can rely on the following test procedures for single-joint movement analysis:

- Palpation skills and precise observation of basic movement patterns at a single joint can be used to determine how closely the movement pattern replicates the kinesiologic standard PICR for a given limb for that movement (e.g., observing or palpating the glenohumeral or scapulothoracic joints while raising the arm in flexion; or the spine, pelvis, knee, ankle, or foot during standing hip and knee flexion).
- Palpation or surface electromyography can be used to determine the pattern and synchronization of muscle activity for a given movement, which is compared with known kinesiologic standards

The clinician can rely on the following test procedures for analysis of multiple-segment movement:

- When performing a gait analysis, break the movement into phases, and look at each segment or component (i.e., group of segments) during each phase and relate the segmental movements to the process of movement. For example, the step-up can be broken into a swing and stance phase (**Fig. 9-18**). Each segment can be analyzed and relationships can be determined. For instance, a hip-hike strategy in the lumbopelvic region is related to insufficient hip and knee flexion and ankle dorsiflexion in the swing phase, and a Trendelenburg position (pelvis is dropped on the side opposite to the weak hip abductors) in the stance phase is related to similar abnormal movement patterns (i.e., hip adduction occurs in a hip-hike and Trendelenburg position).
- Similar movement pattern descriptions can be developed for each basic movement required for ADL (e.g., rising from sit to stand, step-down, bed mobility, reaching). By describing movement pattern strategies, the variations in movement patterns and deviations from efficient and healthy patterns can be determined. The reader is referred to a more complete reference on this topic for specific regional movement impairment syndromes.[1]

A B

FIGURE 9-18 Step-up consisting of **(A)** the swing phase in which the hip and knee are flexing to bring the foot to the surface of the step and **(B)** the stance phase in which the body is being raised onto the step.

Additional examination techniques can offer clues to expected outcomes. By compiling results of ROM, muscle length, joint mobility, and muscle performance tests, the clinician can hypothesize about the quality of the PICR and the muscle recruitment patterns during active movement. The minimal essential tests of muscle length that should be included in any posture or movement examination of the lower and upper quadrant are listed in **Display 9-9**. The minimal essential tests of positional strength that should be included in any posture or movement examination for the trunk, upper quadrant, or lower quadrant are listed in **Display 9-10**. Reexamination of the movement after additional tests have been performed can enable the clinician to better understand the complexity of movement.

DISPLAY 9-9

Essential Muscle Length Tests

Lower Quadrant

- Hamstring: This test should distinguish between the medial and lateral hamstrings.
- Gastroc-soleus: This test should distinguish between the gastrocnemius and soleus.
- TFL and iliotibial band
- Hip flexors: This test should discriminate among the TFL, rectus femoris, and iliopsoas.[1]
- Hip rotators: This test should distinguish between the medial and lateral rotators.

Upper Quadrant

- Teres major and latissimus dorsi
- Rhomboid major and minor and levator scapula
- Pectoralis major
- Pectoralis minor
- Shoulder rotators: This test should distinguish between the medial and lateral rotators.

DISPLAY 9-10

Essential Positional Strength Tests

Trunk

- Abdominal muscles: separate tests should be performed for the rectus abdominis and internal oblique, external oblique.[67] In addition, the transversus abdominis should be assessed for its ability to contract.[124]

Lower Quadrant

- Iliopsoas
- Gluteus medius
- Gluteus maximus
- Hamstrings
- Quadriceps
- TFL

Upper Quadrant

- Serratus anterior
- Upper, middle, and lower trapezius
- Infraspinatus and teres minor
- Subscapularis[1]

INTERVENTION

Healthy, effective, and efficient posture, alignment, and movement are considered to be an integral part of general well-being. Although posture and movement alterations can each be considered as one type of impairment, they cannot be considered in the same way as impairment of muscle performance, ROM, muscle length, or joint mobility. Impairment in posture and movement can be the result of many factors, including physiologic, anatomic, psychologic, and environmental factors.

To develop an efficient, effective intervention for the treatment of posture and movement impairment, all impairments, activity limitations, and participation restrictions resulting from and contributing to posture and movement impairment should be understood. The effect of predisposing risk factors, previous interventions, and environmental influences should also be taken into consideration.

This chapter has presented a foundation for developing therapeutic exercise interventions to treat posture and movement impairments. The remainder is devoted to describing therapeutic exercise intervention for posture and movement according to the intervention model described in Chapter 2.

The Movement System

Any or all subsystems of the movement system can be involved directly or indirectly in the development of posture and movement impairment and therefore should be addressed in treatment. Passive and active subsystems usually require direct intervention for the correction of both posture and movement impairments, whereas the neural subsystem is more critical to movement impairments than posture impairments. Impairments of the cognitive/emotional subsystem can limit the progress of an individual with posture or movement impairments. If this is the case, appropriate referral to a mental health practitioner may be required to reach the desired functional outcome. Impairments of the support subsystem can affect posture and movement directly (i.e., faulty breathing patterns or reduced energy for movement) or indirectly through oxygen transport deficits in systemic disease that contributes to further faults in posture and movement.[61] **Display 9-11** provides examples of impairments of the subsystems of the movement system associated with posture and movement.

Other bodily systems may be involved directly or indirectly and should be considered if necessary to improve posture or movement. For example, a patient who presents with posture and movement impairments about the hip may present with comorbidity of urinary incontinence caused by pelvic floor weakness and estrogen depletion.[125] Full correction of posture and movement impairments about the hip may not be achieved without attention to the pelvic floor dysfunction, which is caused by impairments of the movement, urogenital, and endocrine systems. The link between the movement system and urinary incontinence is discussed in Chapter 18. In this case, without considering the associated urogenital problems and hormonal imbalances, the pelvic floor problem may not resolve, preventing optimal function of the pelvic floor muscles. Because two of the pelvic floor muscles are also used for hip function (i.e., obturator internus and piriformis), dysfunction of the pelvic floor may contribute to posture and movement impairment of the hip,

DISPLAY 9-11
Movement System Factors Contributing to Impairment of Posture and Movement

Passive Subsystem

- Impairments of body structures such as scoliosis or hip anteversion
- Impairments of body functions such as postural genu varum, thoracic kyphosis, or hip adduction as a result of chronically standing asymmetrically
- Anthropometric characteristics such as broad pelvis, tall pelvis, long legs, etc.
- Overstretched gluteus medius, contributing to high iliac crest and functional limb length discrepancy

Active Subsystem

- Easily fatigued serratus anterior, contributing to reduced scapular upward rotation with repetitive overhead activities
- Gluteus medius strain, contributing to reduced activity level and altered movement patterns
- Neural Subsystem
- Reduced or loss of innervation of the gluteus maximus associated with standing in hip hyperextension to avoid using the gluteals eccentrically with controlled hip flexion
- TFL dominance during hip flexion, contributing to hip flexion with medial rotation
- Latent timing of the vastus medialis oblique, contributing to patellofemoral movement impairment

Support Subsystem

- Inappropriate breathing patterns associated with abnormal rib cage alignment and with rib and thoracic spine movement patterns

Cognitive/Emotional Subsystem

- Depression associated with slumped posture or shuffling gait
- Fear avoidance of movement
- Increased muscle tension associated with stress

which may contribute to further pelvic floor dysfunction, and so on as the cycle continues. *All* the systems involved must be addressed to resolve the posture and movement impairment at the hip.

Activity and Dosage

Numerous activities or techniques can be chosen to restore healthy and efficient posture and movement:

- **Stretching** short muscles and improving extensibility of stiff myofascial tissues
- Improving **muscle performance** in muscles exhibiting atrophy, weakness, strain, or poor endurance
- **Supporting** and **strengthening** elongated muscles in the shortened range
- Optimizing **body mechanics, ergonomics,** and **posture awareness**
- Normalizing segmental **alignment**
- Awareness training of **preferred postural patterns**
- Optimizing **balance and coordination**
- Teaching proper motor **control** strategies for optimal control over segmental, intersegmental, and total body movement
- Training appropriate **breathing strategies**

This is not an all-inclusive list in that essentially all therapeutic exercise interventions can affect posture and movement. Because posture and movement are components of the intervention model, every activity or technique should promote optimal posture and movement. Generally, when teaching exercise activity or technique, the clinician should not compromise kinesiologic standards of posture and movement unless modification is necessary as a result of the disease, pathology, or physiologic or anatomic impairment. However, the clinician may decide to allow the patient to exercise and move in nonoptimal patterns to demonstrate comprehensive capacity and develop confidence that he/she can tolerate less than ideal movement without provoking symptoms. Of course, strict adherence to optimal posture and movement is indicated under the following conditions:

- Postacute injury to protect damaged tissue
- High load activities
- Interruption of posture and movement habits associated with pain
- Temporary changes to desensitize the ecosystem
- Respect for adaptation

Identifying and prioritizing the subsystems of the movement system, combined with knowledge of the physiologic status of the component impairments, can help to determine the activities or techniques needed, including the posture, movement, and mode parameters. Dosage parameters depend on the component impairment (e.g., ROM, muscle length, joint mobility, and muscle performance), stage of motor control, and physiologic status of the tissue being addressed.

To illustrate these points, consider a patient with a mild lower trapezius strain with thoracic kyphosis and abducted, anterior tilted, and downwardly rotated scapulae at rest (**Fig. 9-19**). The patient uses excessive scapular abduction, medial rotation, and anterior tilt during forward-reaching activities. Prevention of these impairments is preferable, and there should be careful scrutiny of any posture, activity, or technique that allows further stretching of the lower trapezius. The ideal length of periarticular structures and myofascial tissue helps to maintain ideal

FIGURE 9-19 This figure illustrates abduction and downward rotation of the right scapula relative to the left.

posture alignment with a minimum of muscular effort. When these tissues become overstretched, they fail to offer adequate support, the joint(s) deviate(s) from the neutral position, posture becomes faulty, and muscular effort or excessive passive tension is required to maintain ideal alignment. In this case, it is possible that the lower trapezius is strained by overstretching, and that the posture (thoracic kyphosis), scapula alignment (abducted and downwardly rotated), and movement patterns (scapula abduction, anterior tilt, and medial rotation) perpetuate this condition. Treatment of passive properties (i.e., short range support [i.e., taping—see Chapter 25], active strengthening of the lower trapezius) coupled with biomechanical alterations (i.e., reduced thoracic kyphosis, altered workstation ergonomics), and neural factors (train reaching patterns without excessive scapula abduction, anterior tilt, or medial rotation) is indicated. Combining interventions to passive, active, and neural subsystems is more powerful and time efficient than focusing on any one subsystem in isolation.

With respect to the active subsystem, the goal is to improve muscle performance by altering length–tension properties of the lower trapezius. This component of muscle performance impairment is often overlooked but is critical to achieving muscle balance to restore healthy and efficient posture and movement. The tendency may be to stretch the opposing short pectoralis minor and major (also contributing to impairment of scapula posture and movement). However, if attention is focused *only* on stretching the short muscle without supporting and strengthening the lengthened muscle, equilibrium about the joint cannot be achieved. Another example of this principle is in the case of a person with an anterior pelvic tilt and lumbar lordosis. If the hip flexors are stretched without adaptive shortening of the abdominal muscles (see Chapter 17), the pelvis does not assume a neutral position in relaxed standing.

One activity that may be useful in this situation is to strengthen the adaptively lengthened muscles in the shortened range. The premise of this intervention strategy is to improve the strength of the lengthened muscle in the short range, where it has the greatest difficulty creating tension. If the focus of the exercise is on strengthening without attention to the ability to create tension in the shortened range, the exercise may reinforce muscle imbalance by increasing strength in the lengthened range. Careful decisions must be made regarding the stage of motor control, posture, mode, movement, and dosage parameters to provide the optimal stimulus for strengthening without overloading the target muscle or promoting substitution of a dominant synergist (i.e., upper trapezius) or antagonist (i.e., pectoralis minor or major). The physiologic status of the tissue (i.e., length-associated changes or degree of strain) must be considered when determining each of these parameters.

Stability may be the starting point for the stage of motor control because strengthening is the chosen activity and specificity is critical so as not to strengthen in the lengthened range or the overused antagonist. Often, the lengthened muscle is unable to hold the limb against gravity when positioned in the short range as a result of the altered length–tension properties. Shortening the lever arm or exercising in a gravity-lessened position may be necessary for optimal strengthening (see Self-Management 25-2 in Chapter 25). As the muscle becomes stronger in the shortened range, lengthening the lever arm and exercising against gravity can modify the exercise. Submaximal isometric contractions in the short range may be ideal initially, moving toward concentric–eccentric contractions throughout the range as muscle performance and length tension improve and the tissues heal (if strain or tendinopathy is present). After stability and mobility are restored, the exercise can be progressed to controlled mobility and skill, with ultimate progression to functional movement patterns involving the total body as the final level of difficulty.

Dosage should follow the guidelines for strength training to improve muscle performance and generate hypertrophy of the lower trapezius to provide counterbalancing stiffness to the antagonists (pectoralis major and minor). Eventually, endurance dosage parameters can be applied as more functional movements are incorporated.

Simultaneous stretching of the pectoralis minor and major is not recommended due to the techniques that are often used for this type of stretching. The typical corner or doorway stretch (see Fig. 25-6) has a tendency to place excessive stress on the anterior capsule of the glenohumeral joint and thus is discouraged. In this case, the "freest segments moves," and the anterior capsule will undergo unnecessary lengthening and the pectoralis muscles will remain shortened. Progressive strengthening of the trapezius has an elongating effect on the pectoralis minor and major and is a form of "active stretch" that is highly recommended (see Self-Management 25-2 and Display 25-13).

It may also be necessary to address breathing patterns (Breathing in Thoracic in Chapter 24) if it is determined that the pectoralis minor is stiff because of overuse as an accessory muscle of respiration. Stretching addresses the passive subsystem, and breathing addresses the support subsystem. Both of these interventions can begin at the mobility stage of motor control, progressing somewhat parallel to that for the lower trapezius toward controlled mobility and skill.

Ultimately, the isolated joint function of optimal movements of the scapula must be incorporated into total-body movement patterns (i.e., controlled mobility and skill). When this stage is appropriate, movement impairments of related areas may emerge. Perhaps the scapula abducts during forward-reaching movements because of a lack of hip flexion during reaching patterns or a lack of thoracic or hip rotation during cross-body reaching patterns. The related areas may require intervention to restore normal function to the shoulder girdle.

Patient-Related Instruction and Adjunctive Interventions

Education regarding attention to postural alignment in frequently held or prolonged occupational or recreational positions is key to (a) optimizing joint position for rest and function, (b) reducing the tension placed on elongated muscles, and (c) increasing the tension placed on shortened muscles to restore muscle balance. Photographs of the patient in a typical rest posture and corrected posture can serve as powerful feedback for inducing change. Video of various movement patterns used repeatedly in ADLs and recreational activities can also serve as powerful feedback. Ergonomic modifications may be necessary to improve the patient's environment (see Patient-Related Instruction 9-1). If an on-site visit to the workplace is not feasible, a photograph of the workstation can be analyzed to provide suggestions for change. Other posture habits, including recumbent positions, can be analyzed and suggestions offered. Pillows under the head, under or between the knees, or under the waist in sidelying

FIGURE 9-20 The use of pillows under the head, under the waist, and between the knees can position the spine in optimal alignment in sidelying.

(**Fig. 9-20**) can be suggested to offer optimal support to body regions while in recumbent positions. Footwear is another topic about which the physical therapist can provide recommendations (see Chapter 21).

Adjunctive interventions such as supportive devices (e.g., corsets, bracing, orthotics, taping) can be used temporarily to assist in creating length-associated and proprioceptive changes or used permanently to provide partial or complete correction of impairments of body structures. For example, taping can be used temporarily in the thoracic region to provide proprioceptive input for a patient about his or her kyphotic posture (**Fig. 9-21**). Every time the patient moves into excessive thoracic flexion, the tape serves as a reminder. Conversely, a permanent supportive device such as a corrective orthotic may be necessary to improve alignment throughout the kinetic chain and gait kinetics and kinematics in an individual with structural forefoot varus (see Chapter 21).

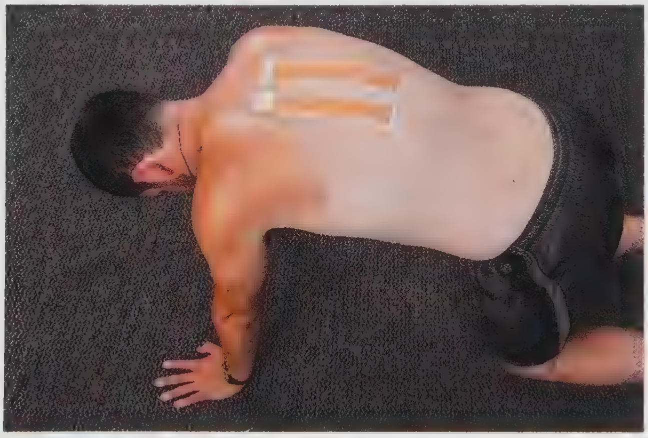


FIGURE 9-21 Taping along the thoracic spine can serve as biofeedback to discourage excessive thoracic flexion. The tape is best applied with the patient in a quadruped position, with the thoracic spine in a neutral position.

KEY POINTS

- Despite our intuition, strong correlations between posture, movement, pain, function, and activity participation do not exist in the literature.
- Posture and movement matter when alterations to the patterns reduce or eliminate pain, the patient is recovering from acute injury to protect damaged tissue, activities are performed under high load conditions or for prolonged periods of time, or you are choosing to use the activity for tissue adaptation or desensitization .
- Be cautious of creating a nocebo effect by placing too much emphasis on the "right" way to move. Instill a level of confidence in comprehensive capacity and focus on variability versus one right way to move.
- We have kinesiological standards to guide evaluation and treatment.
- Evaluation of posture and movement impairment requires identification of deviations in posture and movement from acceptable standards and assessment of contributing factors such as impairments in body functions and environmental, structural, developmental, and emotional factors.
- Therapeutic exercise intervention for posture and movement impairment involves prioritization of the subsystems of the movement system and related impairments, careful determination of the appropriate activities or techniques and stage of motor control, and accurate prescription of dosage parameters for a successful outcome.
- Successful treatment of impaired posture and movement can directly affect the kinesiopathologic factors responsible for the development, perpetuation, or recurrence of MPS.

CRITICAL THINKING QUESTIONS

1. How are posture and movement impairments related to MPS?
2. Define ideal posture as it relates to surface landmarks from a side view.
3. Consider Case Study No. 9 in Unit 7.
   a. Given this patient's posture alignment, what muscles would you predict to be too long? What muscles would you predict to be too short?
   b. List the passive, active, and neural subsystems of the movement system that contribute to this patient's movement impairment.
   c. Develop an initial list of exercises, posture education, and movement retraining for this patient. Progress one of the listed exercises with respect to the stages of motor control.

LAB ACTIVITIES

1. Assess your laboratory partner's posture from the front, side and back views. Given your partner's alignment, which muscles would you predict to be too long or short?
2. Design an exercise program that stretches muscles that may be too short and strengthens muscles that are too long.
3. Assess your partner's strategy of rising from sit to stand. Break the movement into component parts. Assess the feet, ankles, knees, hips, pelvis, and lumbar, thoracic, and cervical spine about all three axes of motion during each component of the movement.
4. How would you provide feedback to change your partner's motor control strategy in rising from sit to stand? What verbal, tactile, and visual cues would you provide? What passive and active impairments may be contributing to the movement impairment?
5. Assess your partner's strategy of balancing on one limb. How does your partner move his or her center of mass over the base of support? What happens at the foot, knee, hip, pelvis, and spine? Do you think your partner uses a correct strategy? If not, what is faulty? Is one side different from the other? What contributing factors may be responsible for the faulty movement strategy? Develop hypothesis as to what impairments you would further identify. (i.e., Trendelenburg stance and its relationship to hip girdle strength)

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CHAPTER

10

Pain

LORI THEIN BRODY

Pain is a psychosomatic experience that is affected by cultural, historic, environmental, and social factors. The prevalence of chronic pain increases from ages 18 to 70, and approximately 23% of patients in their seventh decade report chronic pain.[1] It is more common in women than in men. Unlike impairments such as motion or strength loss that can be observed and measured with tools such as goniometers and dynamometers, pain is elusive. Although limited motion produces observable activity limitations or participation restrictions, pain produces activity limitations and participation restrictions that are not always observable by the outsider. This situation produces anxiety for the patient and can be a source of conflict with spouses, family members, friends, and coworkers. The clinician must recognize the far-reaching impact of pain on the patient and provide him or her with strategies to manage the pain.

DEFINITIONS

Pain is a component of most musculoskeletal conditions seen in the clinic and oftentimes, the main reason the patient is seeking medical care. The International Association for the Study of Pain (IASP) defines pain as "an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage."[2] This definition has been reviewed but remains unchanged since its publication in 1994.[3] **Acute pain** is associated with muscle strains, tendinitis, contusions, surgery, or ligamentous injuries. Although it is important to acknowledge and treat acute pain, this pain is usually short-lived. Most individuals can tolerate this type of pain because they know that it is temporary. Acute pain is often successfully treated with nonnarcotic analgesics such as nonsteroidal anti-inflammatory drugs (NSAIDs) and agents such as ice.

Chronic pain is pain that persists after the noxious stimulus has been removed. It includes persistent pain after healing of an acute injury and pain with no known cause. It is not simply acute pain that has persisted too long. There may be no relationship between the extent of pathology and the intensity or anatomic location of the pain. Chronic pain produces profound changes in the physical, emotional, psychological, and social aspects of the patient's life (**Display 10-1**). Chronic pain is a major component of problems such as fibromyalgia, chronic fatigue syndrome (CFS), myofascial pain syndrome, autoimmune diseases, and low back pain. Physical therapy focuses on treating the pain, the motion and muscle impairments, and the activity limitations and participation restrictions that result.

DISPLAY 10-1

Characteristics of Chronic Pain Syndrome*

1. Use of prescription drugs beyond the recommended duration and/or abuse of or dependence on prescription drugs or other substances.
2. Excessive dependence on health care providers, spouse or family
3. Secondary physical deconditioning attributable to disuse and/or fear–avoidance behaviors
4. Withdrawal from social activities, including work, or recreation
5. Failure to return to preinjury function after a period of disability, resulting in inability to return to usual roles in work, family, recreation
6. Development of psychosocial sequelae after the incident, including anxiety, fear–avoidance, depression, or nonorganic illness behaviors

Three or more characteristics required for diagnosis.[4,5]

Referred pain is pain felt at a site far distant from the location of the injury or disease. Although the pain is felt elsewhere, the pain is still very real. Examination and evaluation can become difficult in the absence of understanding common pain referral patterns. The therapist should always consider other distant sources of pain when examining the patient with acute or chronic pain.

PHYSIOLOGY OF PAIN

Pain is a complex sensory experience. The physiology of pain is far too complex to be covered in detail in this text. However, this brief overview provides an understanding of the physiology of pain and the scientific basis of interventions used to treat it.

Sources of Pain

Acute pain results from microtraumatic or macrotraumatic tissue injury. **Microtrauma** is defined as a long-standing or recurrent musculoskeletal problem that was not initiated by a single precipitating event. Microtrauma is exemplified by the overuse injury where repetitive activity exceeds the tissue's ability to repair and remodel according to the imposed loads. The athlete playing in a weekend tennis tournament and the worker putting in overtime are prone to microtraumatic injuries. **Macrotrauma** is defined as an immediately noticeable injury involving sudden, direct, or indirect trauma.[6] Macrotrauma can produce pain through direct injury of tissues. Joint dislocations injure the joint capsule and periarticular connective tissue, and ligament or tendon injuries damage the respective collagenous tissues. Microtrauma and macrotrauma result in an inflammatory response that secondarily produces pain. Macrotrauma also produces pain directly through damage to the **nociceptors**, which are high-threshold sensory receptors of the peripheral somatosensory nervous system. Nociceptors are capable of transducing and encoding noxious stimuli.[3]

Chronic pain can arise suddenly or develop very gradually. It has strong psychological, emotional, and sociological effects.[7,8] Individuals with chronic pain tend to have significant sleep disturbances, depressive symptoms, appetite changes, and decreased activity and socialization.[5,9,10] Theories about the source of chronic pain suggest increased sensitization of nociceptors and spinal level changes that perpetuate positive feedback loops in the pain-spasm cycle.[11] This phenomenon is termed **central sensitization**. Central sensitization is defined as "increased responsiveness of nociceptive neurons in the central nervous system (CNS) to their normal or subthreshold afferent input."[3] It is theorized that central hypersensitivity arises from adjacent diseased tissues.[12–14]

This hypersensitivity can arise from local pathology (i.e., disk herniation, facet pathology, stenosis) or from inflammation in conditions such as osteoarthritis and rheumatological which sensitize the dorsal horn neurons to the inflammation. This pathology of a joint or muscle drives afferent input to the spinal cord, increasing the activity of the dorsal horn, spinothalamic tract, and thalamic neurons. The elevated activity increases the frequency of background firing of dorsal horn neurons and increases sensitivity to noxious and nonnoxious peripheral stimulation and joint motion. Repetitive stimulation with progressive buildup of the response in the dorsal horn neurons is termed "windup" and is a critical concept in understanding chronic pain[15] (**Table 10-1**).

When damage to the central nociceptive system occurs, *nonnociceptive* afferent activity becomes capable of eliciting pain.[16] Stimuli that were previously innocuous (i.e., active movement, touch, temperature, pressure) become painful. This is referred to as nonnociceptive pain (NNP). These nonnociceptive afferents are not abnormal, but are working with a sensitized CNS. Bennett[15] describes four clinical features of NNP. They can be found in **Display 10-2**. The pathophysiology of NNP includes central sensitization of ongoing or past nociception, convergence of nociceptive and nonnociceptive inputs on the same secondary neuron in the dorsal horn, the experience of pain on wide dynamic range (WDR) neurons, and an expansion of the receptive fields, extending pain beyond the original boundaries.[15]

TABLE 10-1

Characteristics of Central Sensitization

1. Sensory processing changes in the brain (pain as well as other inputs)
2. Dysfunction of antinociceptive descending opioid pathways
3. Facilitation of descending pain promoting pathways
4. Increased activity in the brain in areas involved in acute pain sensations
5. Additional brain activity in areas not typically involved in acute pain sensations
6. Expansion of painful areas
7. Associated central symptoms such as fatigue, sensitivity to light and other usually nonnoxious stimuli, sensitivity to stress
8. Cognitive deficits

From Bennett RM. Emerging concepts in the neurobiology of chronic pain: evidence of abnormal sensory processing in fibromyalgia. Mayo Clin Proc 1999;74:385–398; Nijs J, Kosek E, Van Oosterwijck J, et al. Dysfunctional endogenous analgesia during exercise in patients with chronic pain: to exercise or not to exercise? Pain Phys 2012;15(3, Suppl):Es205–Es213; Seifert F, Maihofner C. Central mechanisms of experimental and chronic neuropathic pain: findings from functional imaging studies. Cell Mol Life Sci 2009;66(3):375–390; Nijs J, Van Houdenhove B, Oostendorp RA. Recognition of central sensitization in patients with musculoskeletal pain: application of pain neurophysiology in manual therapy practice. Manual Ther 2010;15(2):135–141;Staud R, Craggs JG, Robinson ME, et al. Brain activity related to temporal summation of C-fiber evoked pain. Pain 2007;129(1/2):130–142; Coppieters I, Ickmans K, Cagnie B, et al. Cognitive performance is related to central sensitization and health-related quality of life in patients with chronic Whiplash-associated disorders and fibromyalgia. Pain Phys 2015;18(3):E389–E401.

DISPLAY 10-2

Characteristics of Nonnociceptive Pain

1. Pain appears to be inappropriate compared with tissue pathology, or no tissue pathology may be evident
2. Hyperalgesia, where pain is greater than expected given the stimulus
3. Allodynia, where normally nonnoxious stimuli produce pain
4. Painful region extends beyond expected based on original tissue pathology (but is not referred pain)

Patients often report progressively increasing areas of pain. The pain seems to spread from the originally painful area to adjacent areas. The peripheral receptive field of dorsal horn neurons increases in response to chronic pain and may be responsible for this enlarging painful area.[17] The basis for some of these changes may be an increased sensitization of WDR neurons from nociceptive input, causing them to respond more intensely to more nonnociceptive input and to afferent input from a larger area.[16] After being sensitized to nociceptive input from peripheral nerves, the WDR neurons will respond to nonnoxious stimuli as intensely as they had to other stimuli before sensitization.[15] Chronic pain that seems to spread along a limb or to adjacent areas may result from:

- Increased receptive field area
- Increased background firing
- Increased sensitivity to mechanical stimuli after acute or chronic inflammation

Referred pain is considered to be an error in perception. For example, pain originating from deep visceral tissues may refer to the cutaneous region with the same segmental innervation. Pain originating from the genitourinary system may refer to the low back because of the common T11–L2 segmental origin. Cardiac pain refers to the shoulder because of the common T1–T2 segments. As afferent input from the visceral receptors synapse in the dorsal horn, information is also incoming from skin afferents. Convergence of this incoming information in the dorsal horn results in the sense that the pain is originating from the skin. This same principle underlies the use of electrical stimulation at remote sites to decrease visceral pain.

Pain Pathways

Pain is transmitted from nociceptor and nonnociceptor afferents in the periphery. Nociceptors in the periphery are activated by mechanical stimuli such as strong pressure, irritants such as chemicals (e.g., bradykinin, substance P, histamine), or noxious elements such as excessive heat or cold.

Nociceptors in peripheral tissues transmit pain information through A-delta and C fibers. **A-delta fibers** are small, myelinated fibers carrying information about pain and temperature. The information is carried to the spinal cord at an approximate speed of 15 m per second.[18] The A-delta fibers are most responsive to mechanical stimuli and probably are responsible for the sensation of pain in acute injuries. **Type C fibers** are slow, unmyelinated fibers carrying information about dull aching or burning pain from polymodal receptors. **Polymodal receptors** are receptors that respond to a variety of stimuli such as temperature and pressure. Type C polymodal fibers are found in the deeper layers of skin and in virtually all other tissues except the nervous system itself. They are also known as "free nerve endings" and are responsive to thermal, chemical, and mechanical stimuli. Type C fibers probably are responsible for the continued sensation of pain after the noxious stimulus has been removed. Transmission speed to the spinal cord is approximately 1 m per second.

At the spinal cord level, A-delta fibers enter the dorsal roots sending collateral fibers that ascend and descend several segments before entering the gray matter. These fibers terminate on the cells of laminae I and V. The slower C fibers also enter the dorsal root and then enter the gray matter and synapse at the level of entry or ascend or descend a level or two before entering the substantia gelatinosa at laminae II and III. Some processing of information occurs in the spinal cord before the information is transmitted to higher levels. Important receptors at the termination of the primary nociceptive afferents in the dorsal horn have been found, in particular *N*-methyl-D-aspartate (**NMDA**), which are activated and placed in a state ready for activation.[19] Activation of the NMDA receptors causes spinal cord neurons to be more receptive to all inputs. These receptors are a primary mechanism in the development of windup, central sensitization, and changes in peripheral receptive fields.

Going further into the spinal cord, we find three types of interneurons within the dorsal horn that are categorized by their response to peripheral stimulation:

- Low-threshold mechanosensitive, responding only to innocuous stimuli such as touching the skin
- Nociceptive-specific, responding only to high-threshold noxious stimuli
- WDR, responding to a wide variety of noxious and non-noxious stimuli

Within the spinal cord, additional contributors to perpetuation of chronic pain include:

- Changes in the firing patterns of the WDR interneurons
- Convergence of stimuli from various receptors in the dorsal horn (the theoretical basis underlying the gate control theory)
- Presence of substance P, a neuromodulator shown to be responsible for the transmission of noxious information in the spinal cord.[17] It lowers the synaptic excitability threshold, sensitizing second-order spinal neurons. Substance P also facilitates the expansion of receptive fields and the activation of WDR interneurons by nonnociceptive afferent impulses.[15]

From the dorsal horn, these signals ascend through the contralateral spinothalamic tract **(ascending pathway)** in the ventrolateral white matter of the spinal cord to the ventral posterolateral nucleus of the thalamus. The spinothalamic tract transmits noxious and thermal information. The spinothalamic tract also sends collateral branches to the periaqueductal gray (PAG) nucleus of the brain stem. Synapses in this pathway are morphine-sensitive and are an important component of the pain-modulating system. Stimulation of the PAG nucleus has produced analgesia. The thalamus is capable of some conscious awareness of pain before this information reaches the postcentral gyrus of the cerebral cortex.[20] In addition to the spinothalamic tract, some noxious stimuli ascend in the ipsilateral dorsal column of the spinomedullary system (**Fig. 10-1**).

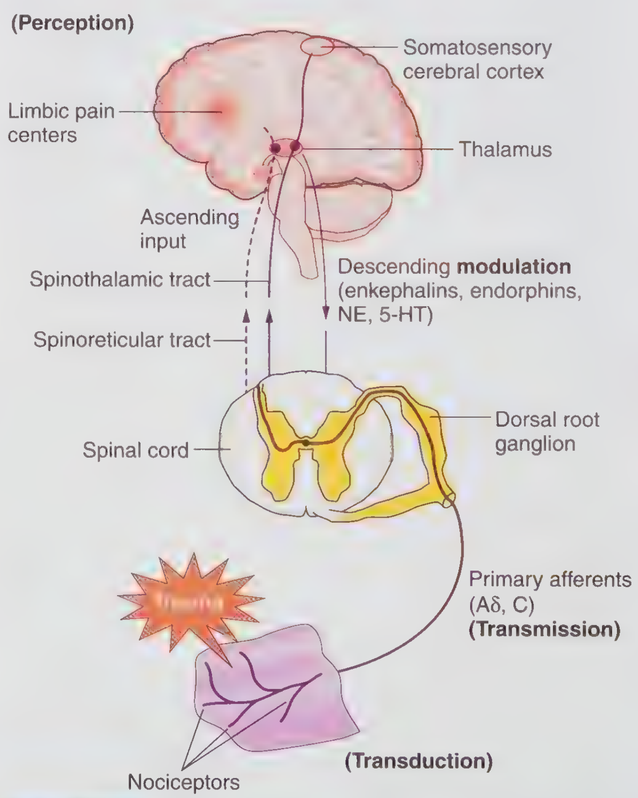


FIGURE 10-1 Diagram of the ascending and descending pain-related pathways. (From DeLeo JA. Basic science of pain. J Bone Joint Surg Am 2006;88(Suppl 2):58–62. doi:10.2106/JBJS.E.01286.)

Descending impulses also influence pain perception. The individual who continues to play sports despite a broken bone or the grandmother who lifts a car to save a child are examples of these descending influences at work. These systems are complex, and the relationships of the system components are being investigated. An overview is given to explain the rationale for some pain control interventions.

Descending pain control occurs through opiate and nonopiate systems. Release of *endogenous opiates* from the brain stem related to exercise has gained widespread publicity in the popular press. The "runner's high" that occurs with long-distance running has been attributed to the release of β-endorphin and methionine-enkephalin from CNS higher centers. Location of these opiates varies among the PAG, hypothalamus, thalamus, substantia gelatinosa, and midbrain structures.[11] Input to the enkephalinergic interneurons in the substantia gelatinosa comes from fibers descending from the midbrain (i.e., PAG) that use serotonin as the transmitter. Injection of opiates into the spinal cord inhibits noxious stimulus-elicited dorsal horn neuron activity.[11] Other neurons descending from the midbrain use noradrenaline as their transmitter and provide an analgesic action through direct inhibition of dorsal horn nociceptive neurons, rather than through the enkephalinergic interneurons.[18]

The analgesic effect of endogenous opiates does not extend to all patients with chronic pain.[21–24] Whereas exercise in healthy individuals induces the release of endogenous opioids from the pituitary and hypothalamus, exercise in patients with chronic pain has shown dysfunction of the inhibitory endogenous pain control mechanisms.[22,24,25] The cause of this dysfunction in some patients with chronic pain is still unknown, although heritability may be a factor.[26] Additionally, patient expectations regarding analgesia appear to impact descending inhibition.[27] Even when patients expected analgesia and reported decreased pain, the levels of spinal activity suggested continued inhibitory endogenous dysfunction.[28] This dysfunction in the descending inhibitory system may be the reason for "flares" in some individuals following exercise. This dysfunction appears to be limited to those with clear evidence of central sensitization[25] (**Evidence and Research 10-1**). Exercise prescription in patients with chronic pain should be highly individualized and flexible. Continued research in the area of descending influences in patients with chronic pain may provide more effective pain control interventions and better guidance regarding therapeutic exercise in the future.

EVIDENCE and RESEARCH 10-1

Patients with central sensitization may do poorly with an exercise program, experiencing postexercise flares owing to lack of descending opioid influences. However, clinicians may be able to use exercise in other body regions to treat pain. Anderson et al.[29] found that treating pain in one region of the body reduced sensitivity to pressure in other body parts. Patients may be able to exercise body parts that are nonpainful in order to address the central sensitization. In their review paper, Daenen et al.[30] suggest that aerobic exercise is best for migraine prevention, whereas specific neck and shoulder exercises are more effective in tension-type headaches. They also note that there is a lack of endogenous analgesia in some patients with chronic pain, reinforcing the notion of individualized programming. Additionally, sufficient recovery strategies are highly recommended.

Pain Theory

Melzack and Wall proposed the gate theory of pain in 1965, with revisions added in 1982.[11] This theory replaced previously held pain theories such as the specificity and patterning theories.[11] The cornerstone of the gate theory is the convergence of first-order neurons and associated second-order neurons within the substantia gelatinosa (**Fig. 10-2**). The system has four components, namely, afferent neurons, internuncial neurons within the substantia gelatinosa, transmission cells (T cells), and descending control from higher centers.[31] The activity of T cells is regulated by the balance of large- and small-diameter fiber input from the periphery and by descending control from higher cells. This balance regulates the transmission of pain information.

The substantia gelatinosa modulates incoming information (i.e., regulates position of the gate) presynaptically, before information is passed to second-order neurons. When incoming information increases substantia gelatinosa activity, presynaptic inhibition occurs, closing the gate. Information is not passed from first- to second-order neurons for further transmission to higher centers. If peripheral receptors associated with large-diameter myelinated fibers are stimulated, activity in the substantia gelatinosa may close the gate to the slower C fiber pain information transmission.

This theory provides the rationale for interventions to "close the gate" to pain transmission. Several peripheral stimuli can close the gate to pain.

- Input from thermal modalities such as heat and cold can successfully "block" pain transmission from slower fibers at the substantia gelatinosa and decrease pain.
- Electrical impulses from transcutaneous electrical nerve stimulation (TENS) application can preferentially block pain impulse transmission (discussed in the "Adjunctive Therapies" section).
- Exercise can successfully decrease pain by stimulation of joint afferent receptors. These signals travel along A-beta fibers, which have larger diameters and carry information at higher speeds (30 to 70 m per second) than the slower pain fibers.
- Mechanical stimulation of peripheral receptors can be achieved through tissue massage.

Further revision of the gate theory of pain continues, because descending control from higher centers also influences the transmission of pain information. Although many of these interventions provide temporary relief, there is little evidence

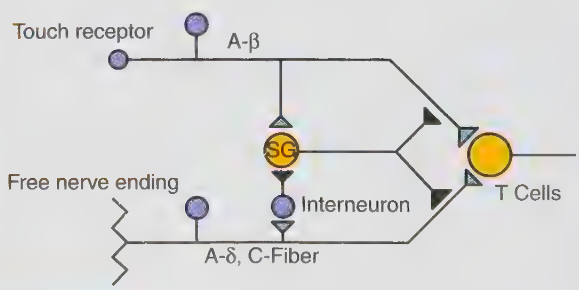


FIGURE 10-2 The gate control theory of pain. T cells, central transmission cells; SG, substantia gelatinosa.

for long-term significant improvements in chronic pain with these interventions.

EXAMINATION AND EVALUATION

A variety of tools help the clinician assess and monitor the patient's pain level. Tools such as the McGill Pain Questionnaire (MPQ) assess affective qualities of pain, whereas the visual analog scale (VAS) is a nominal scale assessing pain intensity. Because of the multifaceted nature of pain, assessment should include information on the pain's intensity, location, and pattern over a 24-hour period (i.e., quantity of pain) and descriptors assessing the affective aspects (i.e., quality of pain). The impact of pain (i.e., activity limitations and participation restrictions) on the patient's life should be determined. Frequently, tools such as the Beck depression and Beck anxiety questionnaires are used to assess the psychological aspects of the patient's pain.

Clinicians perform examinations to determine the source of the patient's pain. This examination directs the subsequent treatment program to the source of pain. Structures within the musculoskeletal system have different levels of pain sensitivity. The periosteum of the bone is a highly pain-sensitive structure, whereas the joint capsule, ligaments, tendons, and muscle are less pain sensitive. Interestingly, research has found that in healthy subjects, isometric muscle contraction normally increases the pain threshold, whereas in patients with fibromyalgia, the pain threshold actually decreases.[32] Additionally, compared with skin receptors, sensory input from muscle is a more potent catalyst of central sensitization.[15] Fibrocartilage and articular cartilage are not pain-sensitive structures, although injury or damage to these structures can produce a synovitis that results in pain. Perform a thorough evaluation to determine the source of the pain and to assess the characteristics of that pain. However, remember the pathophysiology of chronic pain and realize that the pain region and intensity may extend beyond discernible tissue pathology.

Pain Scales

The VAS (0 = least pain and 10 = worst pain) is used to assess pain intensity. The simplest clinical tool consists of asking the patient to rate his or her pain on a 0 to 10 scale and recording this in the medical record. Follow-up visits ask the same question to determine the response to treatment. This type of scale has advantages and disadvantages. The clearest **advantage** is the ease of use. The patient is not burdened with forms to fill out or multiple questions to answer. Language and cultural barriers do not affect the use of this simple scale. The **disadvantage** is the minimal information acquired with such a tool. Only pain-intensity information is gathered. Information regarding the affective aspects of pain, pattern of pain, and the impact of the pain on the patient's life is absent. The patient is likely to remember the previous pain score, which reduces the reliability of this type of measurement. This type of scale presumes equal intervals between successive levels (i.e., the difference between a 1 and a 2 is equal to the difference between a 3 and a 4), and this may not be the case for the patient. Be sure to clarify the question being asked.

- Are you interested in the patient's current pain level or average pain level over the last 24, 48, or 72 hours?
- Are you interested in the worst pain and best pain in the last 24 hours?
- or in the last 7 days?

Clarifying the question is critical because of the variable nature of the patient's pain. Pain is often mediated by multiple factors such as time of day, activity level, and medication use. Consistency in collecting and interpreting these data is essential when using them to assess the efficacy of an intervention.

The VAS can be administered in several different forms (**Fig. 10-3**). A line with words placed at intervals along the line commonly is used. A single word may be used at each end, such as "no pain" and "worst pain," or several words may be placed along the continuum. The more words and lines dividing the continuum, the more likely the patient is to recall previous answers. Improve the reliability of a VAS by eliminating division marks and only marking both ends of the scale. The patient then places a mark along the scale corresponding to his or her current pain level. The distance from the left or right can be measured to assess progress. The direction of the scale should be altered occasionally. Reverse the "no pain" and "worst pain" sides of the scale or turn the scale from horizontal to vertical to minimize patient recall.[33] Combine these scales with other assessments, such as the location of pain (using a body diagram) and subjective descriptions of the quality of pain (see **Building Block 10-1**).

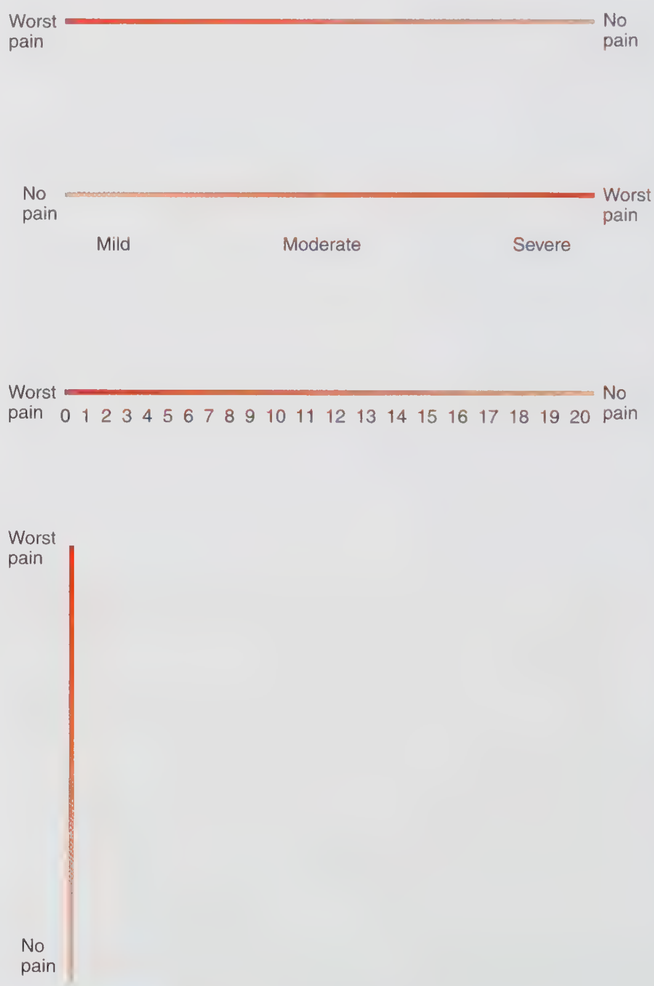


FIGURE 10-3 Variations of a visual analog scale.

BUILDING BLOCK 10-1

A 36-year-old woman with chronic neck pain and posttraumatic stress disorder has been coming to physical therapy weekly for soft-tissue mobilization. The first week she reports her pain level at 8 on a 0 to 10 scale. On subsequent visits, she reports her pain ranging from 5 to 9 on a 0 to 10 scale. Please provide recommendations on ways to gather pain information that would guide and inform her plan of care (primary goal: pain reduction).

McGill Pain Questionnaire

The MPQ is one of the most widely used tests for the measurement of pain, and several forms of the questionnaire have been developed.[34–38] This pain questionnaire consists primarily of three classes of word descriptors to assess the subjective aspects of pain. The MPQ also contains an intensity score, a body diagram, and an assessment of pain relative to activities and pain patterns. The three major measures are the pain rating index (PRI), the number of words chosen (NWC), and the present pain intensity (PPI).

Part 1 contains word descriptors classified as three categories (i.e., sensory, affective, and evaluative) and 20 subcategories. Subcategories contain two to six words that are qualitatively similar but of increasing intensity. For example, one subcategory assesses the thermal aspects of pain through the descriptors "hot," "burning," "scalding," and "searing." Each word is assigned a numeric value. The patient is allowed to choose only one word from each subcategory and is not required to select an item from every category. The values are summed and the mean determined; the mean is the PRI score. The total number of subcategories selected is summed as the NWC score (**Fig. 10-4**).

McGill - Melzack Pain Questionnaire

Patient's Name ____________ Date ____________ Time ________ am/pm
Analgesic(s) ____________ Dosage ____________ Time Given ________ am/pm
____________ Dosage ____________ Time Given ________ am/pm

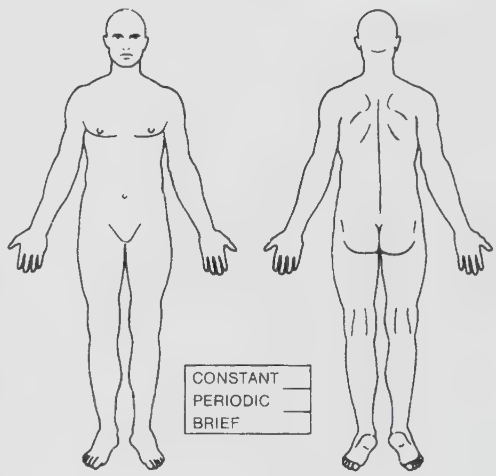
Analgesic Time Difference (hours): +4 +1 +2 +3

PRI: S ______ (1-10) A ______ (11-15) E ______ (16) M(S) ______ (17-19) M(AE) ______ (20) M(T) ______ (17-20) PRT(T) ______ (1-20)

1 FLICKERING, QUIVERING, PULSING, THROBBING, BEATING, POUNDING
2 JUMPING, FLASHING, SHOOTING
3 PRICKING, BORING, DRILLING, STABBING, LANCINATING
4 SHARP, CUTTING, LACERATING
5 PINCHING, PRESSING, GNAWING, CRAMPING, CRUSHING
6 TUGGING, PULLING, WRENCHING
7 HOT, BURNING, SCALDING, SEARING
8 TINGLING, ITCHY, SMARTING, STINGING
9 DULL, SORE, HURTING, ACHING, HEAVY
10 TENDER, TAUT, RASPING, SPLITTING
11 TIRING, EXHAUSTING
12 SICKENING, SUFFOCATING
13 FEARFUL, FRIGHTFUL, TERRIFYING
14 PUNISHING, GRUELLING, CRUEL, VICIOUS, KILLING
15 WRETCHED, BLINDING
16 ANNOYING, TROUBLESOME, MISERABLE, INTENSE, UNBEARABLE
17 SPREADING, RADIATING, PENETRATING, PIERCING
18 TIGHT, NUMB, DRAWING, SQUEEZING, TEARING
19 COOL, COLD, FREEZING
20 NAGGING, NAUSEATING, AGONIZING, DREADFUL, TORTURING

PPI
0 No pain
1 MILD
2 DISCOMFORTING
3 DISTRESSING
4 HORRIBLE
5 EXCRUCIATING

PPI ______ COMMENTS:



CONSTANT ___
PERIODIC ___
BRIEF ___

ACCOMPANYING SYMPTOMS: NAUSEA, HEADACHE, DIZZINESS, DROWSINESS, CONSTIPATION, DIARRHEA
COMMENTS:

SLEEP: GOOD, FITFUL, CAN'T SLEEP
COMMENTS:

FOOD INTAKE: GOOD, SOME, LITTLE, NONE
COMMENTS:

ACTIVITY: GOOD, SOME, LITTLE, NONE
COMMENTS:

FIGURE 10-4 The McGill-Melzack Pain Questionnaire. (From Melzack R. The McGill Pain Questionnaire: major properties and scoring methods. Pain 1975;1:277–299.)

The PPI is determined by use of a 5-point scale, asking about the current pain level and the level of pain when it is at its worst and at its best. Part 2 categorizes the pattern of pain as constant, periodic, or brief and asks about activities that increase or relieve pain. A body diagram allows the patient to mark where the pain is located. The patient marks *E* for external pain and *I* for internal pain and then uses a VAS to document the quantity of pain.

The MPQ better assesses the many dimensions of pain with greater sensitivity than a VAS. The disadvantage is the time required to complete the questionnaire. A short form of the MPQ has been developed to address this issue. This form has been validated in various patient populations.[19,20]

Disability and Health-Related Quality of Life Scales

A variety of tools have been developed to assess pain and the impact of pain and resulting disability on patients' lives. Research into chronic musculoskeletal pain found that the International Classification of Functioning, Disability and Health (ICF) components of Mobility and Community life were the most impacted in patients who were admitted to a multidisciplinary rehabilitation program for chronic pain.[39] Most tools broadly assess physical, social, and psychological function. Some tools assess health perceptions, satisfaction, and various impairments. Each tool taps into these domains in a different way and at a different level. The tool must be matched to the population of interest.

The scales are classified in several ways but are broadly categorized into disease-specific and generic measures. Disease-specific scales are specific to a particular disease and are more responsive to issues of that particular population. Generic tools are applied across a variety of disease categories; the information has little relevance to a specific disease, and other important issues may not be tapped. However, use of these tools allows comparisons among disease or injury categories.

Commonly used generic tools are the Quality of Well-Being scale (QWB), the Sickness Impact Profile (SIP), the Duke Health Profile (DUKE), and the Short Form-36 (SF-36). The QWB taps five health concepts (i.e., physical functioning, mental health including psychological distress, social or role functioning, mobility or travel, and physical or physiologic symptoms), and the SIP measures 12 concepts. Neither of these tools assesses pain directly. The DUKE measures seven health concepts, including self-esteem, health perceptions, and pain. The SF-36 is a derivative of the Medical Outcomes Study-149, a 149-item tool used as a generic assessment. The SF-36 is a 36-item tool measuring seven health concepts, including pain. Use caution when choosing a generic health assessment tool to ensure that critical parameters are being measured. The tool's range must allow for improvement or decline in the patient's status without exceeding the upper or lower limits of the measure (**Fig. 10-5**).

One way to minimize some of the potential problems associated with generic tools is to use a disease-specific tool in combination with a generic measure. The Oswestry Low Back Disability Questionnaire, the Waddell Disability Index, and the Disability Questionnaire are used for individuals with back pain; and the McMaster-Toronto Arthritis Patient Reference Disability Questionnaire, the Arthritis Impact Measurement Scales (AIMS), the Health Assessment Questionnaire, and the Functional Capacity Questionnaire are used for individuals with arthritis (**Fig. 10-6** on page 251). These disease-specific tools must match the population tested. Reliability of the tool must be determined for the population being evaluated. For example, if the AIMS reliability has been established for Caucasian women who are 65 or older, this tool may not be reliable or valid when applied to men between the ages of 40 and 60.

Other tools tap some of the psychosocial aspects of the pain experience. A large body of literature has developed around the issue of anxiety, fear and avoidance of pain in patients with chronic pain.[40–42] Fear–anxiety–avoidance models of pain and tools attempting to measure these constructs have been developed and tested.[43–51] The fear–anxiety–avoidance models were originally developed to explain the transition from acute to chronic pain. Now these models and measurement tools are used to formulate multidimensional treatment plans for patients with chronic pain, as well as to determine the effectiveness of different interventions. Frequently, physical activity and rehabilitative exercises are a component of these intervention plans, as providers guide patients through structured activities to minimize their fear of movement.[52,53] The Fear–Avoidance Beliefs Questionnaire is commonly used to assess the patient's response and accommodations to the pain. Similar tools such as the Pain Anxiety Symptoms Scale (PASS), the Anxiety Sensitivity Profile, and the Fear of Pain Questionnaire attempt to determine how fear and anxiety impact a patient's function.[43,44,54–56]

The literature on **fear–anxiety–avoidance** models suggests that anxiety and fear are separate cognitive constructs, with fear being a present-oriented emotive state associated with an imminent threat, whereas anxiety is a more general, future-oriented emotive state existing without an imminent threat.[43] It has been suggested that the pain-related fear is more disabling than the pain itself.[57] Although this may be an oversimplification of the problem and true in only a small subsample of patients, the statement highlights the importance that fear-anxiety–avoidance models have in patients with pain. The fear–avoidance beliefs can impact the transition from acute to chronic pain, and have been studied in patients with low back pain. Heightened focus on pain-related fear during the acute phase increased the risk of future chronic low back pain and disability.[45,51,58] Moreover, people with higher fear–avoidance beliefs who were currently pain free had a greater risk of future low back pain.[59,60]

Fear–anxiety–avoidance behaviors can have a profound impact on a patient's physical, psychological, and social well-being. Avoidance behaviors are aimed at preventing a situation from occurring.[61] For patients with chronic pain, it is not possible to avoid pain, so these patients tend to avoid activities that they perceive will increase their pain. This may manifest as complete avoidance of some activities or decreased performance of activities. Pain-related fear has been associated with decreased walking speed,[62] decreased muscle performance,[63,64] and decreased physical task performance.[65] Patients may begin to avoid social situations that they fear will increase their pain. This can lead to increasing social isolation and decreased physical activity. The decreased physical activity associated with

SF-36 HEALTH SURVEY

Instructions: This survey asks for your views about your health. This information will help keep track of how you feel and how well you are able to do your usual activities.

Answer every question by marking the answer as indicated. If you are unsure about how to answer a question, please give the best answer you can.

1. In general, would you say your health is:

(circle one)

Excellent	1
Very good	2
Good	3
Fair	4
Poor	5

2. Compared to one week ago, how would you rate your health in general now?

(circle one)

Much better now than one week ago	1
Somewhat better now than one week ago	2
About the same as one week ago	3
Somewhat worse now than one week ago	4
Much worse than one week ago	5

3. The following items are about activities you might do during a typical day. Does your health now limit you in these activities? If so, how much?

(circle one number on each line)

ACTIVITIES	Yes, Limited A Lot	Yes, Limited A Little	No, Not Limited At All
a. **Vigorous activities** such as running, lifting heavy objects, participating in strenuous sports	1	2	3
b. **Moderate activities**, such as moving a table, pushing a vacuum cleaner, bowling, or playing golf	1	2	3
c. Lifting or carrying groceries	1	2	3
d. Climbing **several** flights of stairs	1	2	3
e. Climbing **one** flight of stairs	1	2	3
f. Bending, kneeling, or stooping	1	2	3
g. Walking **more than a mile**	1	2	3
h. Walking **several blocks**	1	2	3
i. Walking **one block**	1	2	3
j. Bathing or dressing yourself	1	2	3

FIGURE 10-5 The SF-36 assessment tool. (From Medical Outcomes Trust; Boston, MA, 1992.)

(Continued on next page)

4. During the past week, have you had any of the following problems with your work or other regular daily activities as a result of your physical health?

(circle one number on each line)

	Yes	No
a. Cut down on the **amount of time** you spent on work or other activities	1	2
b. **Accomplished less** than you would like	1	2
c. Were limited in the **kind** of work or other activities	1	2
d. Had **difficulty** performing the work or other activities (for example, it took extra effort)	1	2

5. During the past week, have you had the following problems with your work or other regular daily activities as a result of any emotional problems (such as feeling depressed or anxious)?

(circle one number on each line)

	Yes	No
a. Cut down on the **amount of time** you spent on work or other activities	1	2
b. **Accomplished less** than you would like	1	2
c. Didn't do work or other activities as **carefully** as usual	1	2

6. During the past week, to what extent has your physical health or emotional problems interfered with your normal social activities with family, friends, neighbors, or groups?

(circle one)

Not at all 1

Slightly 2

Moderately........ 3

Quite a bit........ 4

Extremely........ 5

7. How much bodily pain have you had during the past week?

(circle one)

None 1

Very mild 2

Mild 3

Moderate 4

Severe 5

Very severe 6

8. During the past week, how much did pain interfere with your normal work (including both work outside the home and housework)?

(circle one)

Not at all 1

A little bit 2

Moderately........ 3

Quite a bit........ 4

Extremely........ 5

FIGURE 10-5 *(continued)*

9. These questions are about how you feel and how things have been with you during the past week. For each question, please give the one answer that comes closest to the way you have been feeling. How much of the time during the past week—

(circle one number on each line)

	All of the Time	Most of the Time	A Good Bit of Time	Some of the Time	A little of the Time	None of the Time
a. Did you feel full of pep?	1	2	3	4	5	6
b. Have you been a nervous person?	1	2	3	4	5	6
c. Have you ever felt so down in the dumps that nothing could cheer you up?	1	2	3	4	5	6
d. Have you felt calm and peaceful?	1	2	3	4	5	6
e. Did you have a lot of energy?	1	2	3	4	5	6
f. Have you felt downhearted and blue?	1	2	3	4	5	6
g. Did you feel worn out?	1	2	3	4	5	6
h. Have you been a happy person?	1	2	3	4	5	6
i. Did you feel tired?	1	2	3	4	5	6

10. During the past week, how much time has your physical health or emotional problems interfered with your social activities (like visiting with friends, relatives, etc.)?

(circle one)

All of the time.......... 1

Most of the time 2

Some of the time.......... 3

A little of the time.......... 4

None of the time.......... 5

11. How TRUE or FALSE is each of the following statements for you?

(circle one number on each line)

	Definitely True	Mostly True	Don't Know	Mostly False	Definitely False
a. I seem to get sick a little easier than other people?	1	2	3	4	5
b. I am as healthy as anybody I know	1	2	3	4	5
c. I expect my health to get worse	1	2	3	4	5
d. My health is excellent	1	2	3	4	5

FIGURE 10-5 *(continued)*

Health Concepts, Number of Items and Levels, and Summary of Content for Eight SF-36 Scales and the Health Transition Item

Concepts	No. of Items	No. of Levels	Summary of Content
Physical Functioning (PF)	10	21	Extent to which health limits physical activities such as self-care, walking, climbing stairs, bending, lifting, and moderate and vigorous exercises
Role Functioning Physical (RP)	4	5	Extent to which physical health interferes with work or other daily activities, including accomplishing less than wanted, limitations in the kind of activities, or difficulty in performing activities
Bodily Pain (BP)	2	11	Intensity of pain and effect of pain on normal work, both inside and outside the home
General Health (GH)	5	21	Personal evaluation of health, including current health, health outlook, and resistance to illness
Vitality (VT)	4	21	Feeling energetic and full of pep versus feeling tired and worn out
Social Functioning (SF)	2	9	Extent to which physical health or emotional problems interfere with normal social activities
Role Functioning Emotional (RE)	3	4	Extent to which emotional problems interfere with work or other daily activities, including decreased time spent on activities, accomplishing less, and not working as carefully as usual
Mental Health (MH)	5	26	General mental health, including depression, anxiety, behavioral-emotional control, general positive affect
Reported Health Transition (HT)	1	5	Evaluation of current health compared to one year ago

FIGURE 10-5 *(continued)*

avoidance behaviors can also lead to further physical decline. Decreased aerobic fitness and decreased trunk mobility and muscle activation patterns have been found in patients with chronic low back pain.[66]

When treating patients with acute or chronic pain, the therapist must give consideration to all components of pain. Although patients with acute pain may not exhibit all components of the fear–anxiety–avoidance models, researchers and clinicians are attempting to determine which factors in the acute pain situation might predict those patients who will go on to develop chronic pain.[45,49,50,67]

Generic, psychosocial, and disease-specific tools can be administered together to strengthen the information obtained. For example, the SF-36 may be combined with the Oswestry Low Back Disability Questionnaire for individuals with low back pain. A major concern about combination application is the burden placed on the patient who must fill out a number of questionnaires.

THERAPEUTIC EXERCISE INTERVENTION FOR PAIN

Although many commonalities exist, the approaches to treating acute pain differ from the approaches to chronic pain. Application of acute pain interventions in the case of chronic pain will lead to frustration for the caregiver and the patient. Some combination of exercise and manual therapy is used; specific choices depend on the patient's circumstances. The treatment program should be tailored to each patient and be responsive to the pain pattern. For example, muscle stretching exercises are advocated for treating patients with myofascial pain resulting

INSTRUCTIONS

Check only one box in each section which best applies to you. We realize you may consider that two of the statements in any one section relate to you, but please just mark the box which most closely describes your problem.

SECTION I - PAIN INTENSITY

- ❑ I can tolerate the pain I have without having to use pain killers.
- ❑ The pain is bad but I can manage without taking pain killers.
- ❑ Pain killers give complete relief from pain.
- ❑ Pain killers give moderate relief from pain.
- ❑ Pain killers give very little relief from pain.
- ❑ Pain killers have no effect on the pain and I do not use them.

SECTION II - PERSONAL CARE (Washing, Dressing, Etc.)

- ❑ I can look after myself normally without causing extra pain.
- ❑ I can look after myself normally but it causes pain.
- ❑ It is painful to look after myself and I am slow and careful.
- ❑ I need some help but manage most of my personal care.
- ❑ I need help every day in most aspects of self care.
- ❑ I do not get dressed, wash with difficulty and stay in bed.

SECTION III - LIFTING

- ❑ I can lift heavy weights without extra pain.
- ❑ I can lift heavy weights but it gives extra pain.
- ❑ Pain prevents me from lifting heavy weights off the floor, but I can manage if they are conveniently positioned, e.g., on a table.
- ❑ Pain prevents me from lifting heavy weights, but I can manage light to medium weights if they are conveniently positioned.
- ❑ I can lift only very light weights.
- ❑ I cannot lift or carry anything at all.

SECTION IV - WALKING

- ❑ Pain does not prevent me from walking any distance.
- ❑ Pain prevents me from walking more than 1 mile.
- ❑ Pain prevents me from walking more than 1/2 mile.
- ❑ Pain prevents me from walking more than 1/4 mile.
- ❑ I can only walk using a stick or crutches.
- ❑ I am in bed most of the time and have to crawl to the toilet.

SECTION V - SITTING

- ❑ I can sit in any chair as long as I like.
- ❑ I can only sit in my favorite chair as long as I like.
- ❑ Pain prevents me from sitting for more than 1 hour.
- ❑ Pain prevents me from sitting for more than 30 minutes.
- ❑ Pain prevents me from sitting for more than 10 minutes.
- ❑ Pain prevents me from sitting at all.

FIGURE 10-6 The Oswestry Low Back Disability Questionnaire. (Adapted from Fairbank JCT, Davies JB, Couper J, et al. The Oswestry Low Back Pain Disability Questionnaire. Physiotherapy 1980;66:271–273.)

(Continued on next page)

from shortening of sarcomeres found with sustained muscle fiber tension. However, resistive exercises are contraindicated in the early phases because of the early fatigue and lengthy recovery in muscle with active trigger points.[68]

As with many other medical conditions, the science of caring for people with acute or chronic pain is constantly growing. Clinicians must be aware of new research and literature that can provide strong evidence for interventions chosen. The American College of Occupational and Environmental Medicine regularly revises its recommendations for the treatment of various work-related disorders and includes a chapter on chronic pain (www.acoe.org). Progressive resistive exercise programs are the cornerstone of intervention programs for workers with chronic pain.

Acute Pain

The typical patient with acute pain has recently sustained an injury or undergone a surgical procedure. The pain is related to the acute trauma of an initial injury or an exacerbation of

SECTION VI - STANDING

- ❑ I can stand as long as I want without extra pain.
- ❑ I can stand as long as I want but it gives me extra pain.
- ❑ Pain prevents me from standing for more than 1 hour.
- ❑ Pain prevents me from standing for more than 30 minutes.
- ❑ Pain prevents me from standing for more than 10 minutes.
- ❑ Pain prevents me from standing at all.

SECTION VII - SLEEPING

- ❑ Pain does not prevent me from sleeping well.
- ❑ I can sleep well only by using tablets.
- ❑ Even when I take tablets I have less than six hours sleep.
- ❑ Even when I take tablets I have less than four hours sleep.
- ❑ Even when I take tablets I have less than two hours sleep.
- ❑ Pain prevents me from sleeping at all.

SECTION VIII - SEX LIFE

- ❑ My sex life is normal and causes no extra pain.
- ❑ My sex life is normal but causes some extra pain.
- ❑ My sex life is nearly normal but is very painful.
- ❑ My sex life is severely restricted by pain.
- ❑ My sex life is nearly absent because of pain.
- ❑ Pain prevents any sex life at all.

SECTION IX - SOCIAL LIFE

- ❑ My social life is normal and gives me no extra pain.
- ❑ My social life is normal but increases the degree of pain.
- ❑ Pain has no significant effect on my social life apart from limiting my more energetic interests, e.g. dancing, etc.
- ❑ Pain has restricted my social life and I do not go out as often.
- ❑ Pain has restricted my social life to my home.
- ❑ I have no social life because of pain.

SECTION X - TRAVELING

- ❑ I can travel anywhere without extra pain.
- ❑ I can travel anywhere but it gives me extra pain.
- ❑ Pain is bad but I manage journeys over two hours.
- ❑ Pain restricts me to journeys of less than one hour.
- ❑ Pain restricts me to short necessary journeys under 30 minutes.
- ❑ Pain prevents me from traveling except to the doctor or hospital.

FOR OFFICE USE
Total Score

Therapist's Signature and Date	Patient's Signature and Date

FIGURE 10-6 *(continued)*

a preexisting injury. Pain medication may be taken for a short time after the injury or surgery. Acute pain is expected to resolve substantially over the course of a few days. Although some residual pain may continue for weeks after the injury or surgery, most pain is expected to resolve with only minimal discomfort remaining.

Acute pain of this type is treated with a combination of medication (i.e., prescription or over-the-counter medication at the patient's discretion), gentle exercise, and ice. Ice is preferred over heat in the first 24 hours, and may be changed to heat thereafter depending upon the injury acuity and patient preference. Exercise is prescribed on the basis of the specific injury or surgery and is directed at restoring the motion, strength, and function of the injured body part. Rehabilitation of the injured area is the prime focus and provides the framework for exercise prescription. Exercise in this phase is directed toward the primary joint and at prevention of injury at adjacent joints because of compensation. Include patient education about pain-relieving postures or positions (i.e., sleeping positions) and skills to fulfill the activities of daily living and the instrumental activities of daily living (see **Patient-Related Instruction 10-1** and **Building Block 10-2**).

Chronic Pain

Treatment of chronic pain requires a team approach because of the multidimensional nature of the pain. Chronic pain is disabling and interferes with all aspects of the person's life. The clinician must work closely with the physician, psychologist, vocational counselor, social worker, alternative health care providers, and the patient. In this way, a comprehensive treatment program can be established to ensure all aspects of the pain are being addressed. Many adjunctive treatments and alternative therapies are often explored by the patient, often because of the protracted course of improvement in chronic pain.[42,69] Herbal remedies, acupuncture, reflexology, and other therapies are often part of a patient's complete treatment program. An open dialogue with the patient ensures a thorough understanding of all therapies occurring simultaneously.

Patient-Related Instruction 10-1

Management of Acute Pain

An increase in acute pain is a sign of doing too much. This may disrupt the healing process. In this situation, you should do the following:

1. Find a position of comfort that decreases or eliminates your pain. Your clinician can help you learn what these positions are.
2. Use a pain-relieving treatment such as ice for 10 to 15 minutes every hour.
3. In the short term, use an assistive device such as crutches, a cane, or a walker if your leg is involved; a sling or splint for your upper extremity; or a corset for your back. These devices reduce the stress on the injured area.
4. Take your medications as prescribed.

BUILDING BLOCK 10-2

A 15-year-old track runner strained the hamstring muscle yesterday while running the hurdles. The athlete and his parents present to a Saturday morning injury clinic. They would like advice on how to manage this acute injury.

Therapeutic Exercise Guidelines for Patients with Chronic Pain

Therapeutic exercise is a major component of the treatment plan,[70–72] and has been shown to be effective in improving impairments and activity limitations in patients with chronic pain.[73–78] Different types of therapeutic exercise programs, including those focused on strength training, aerobic conditioning, or flexibility appear to be successful in improving patient symptoms.[25,30] Given the individual nature and complexity of chronic pain, some guidelines for its prescription are warranted (**Display 10-3**). Realize that these are broad, general guidelines. The specific cases of fibromyalgia and CFS will be addressed later in the chapter.

A critical component of chronic pain treatment is a realistic understanding of the goals of the treatment plan. Patient education is a key component; the clinician must explain the likely source of pain, activity modifications or postures to minimize pain, and the expected outcomes of intervention to the patient at a level the patient can comprehend. Patient expectations about the outcomes of interventions, particularly those related to pain relief, can have measurable physiologic effects at both the brain and spinal cord levels.[27,28] The goals of the therapeutic exercise program extend beyond treatment of impairments. Activity limitations and participation restrictions related to depression, sleep, and appetite are also of concern. Improvements in sleep patterns, mental state, and appetite may be the first markers of successful intervention, improving before any change in impairment measures (see **Patient-Related Instruction 10-2** and **Building Block 10-3**). Ultimately, the goal is to return patients to the highest level of function while independently managing their pain.

DISPLAY 10-3

Guidelines for Therapeutic Exercise Prescription for Patients with Chronic Pain

1. Understand and clarify goals with the patient to ensure appropriate expectations.
2. Prioritize goals emphasizing both impairments and activity limitations as well as primary, secondary, and tertiary prevention.
3. Consider the patient's current physical state and whether exercise will increase or decrease pain.
4. Consider the patient's current psychological status and whether exercise will be a stress reliever or stress producer.
5. The exercise program must allow sufficient recovery to prevent symptom escalation.

Patient-Related Instruction 10-2

Why You Should Exercise When You Have Chronic Pain*

You should exercise when you have chronic pain, because exercise can:

1. Improve problems such as inflexibility, loss of mobility, or weakness, which contribute to your pain.
2. Decrease pain by inhibiting transmission of pain impulses.
3. Improve your sleep at night.
4. Control weight gain, which often occurs from inactivity and can have negative physical and psychological consequences.
5. Prevent secondary musculoskeletal complications of pain such as further weakness, immobility, and flexibility at other joints.
6. Prevent secondary cardiovascular changes such as increases in blood pressure, elevated cholesterol levels, or diabetes complications.
7. Enhance your sense of well-being, self-esteem, and accomplishment.

* Not all people with chronic pain respond in the same way to exercise. Be sure to discuss your exercise program with your health care provider.

BUILDING BLOCK 10-3

A 48-year-old woman comes to physical therapy for multiple joint problems. She has a history of undifferentiated spondyloarthropathy, s/p L chest wall nonmalignant tumor resection, ankylosing spondylitis, s/p L hip labral tear resection, R knee pain, CFS. She is unable to do any work at all. She can walk <1/8 mile, and can stand <30 minutes without significant pain. Pain averages 6 on a 0 to 10 scale. Her sleep ranges from being mildly disturbed to completely disturbed. She complains of falling, especially when moving backward.

Considering the number of problems this patient faces on a daily basis, what are some priorities in goal setting that you might discuss with this patient?

Program goals and design must consider the primary complaint(s) and potential secondary problems that must be prevented.[68] Direct the therapeutic exercise program toward the source of the pain, musculoskeletal impairments that directly relate to activity limitations and participation restrictions. In addition, consider potential secondary problems that must be prevented.[45] Identify the multiple sources involved in the production of pain in order to facilitate prioritization of interventions. Interventions to inhibit pain input or to facilitate nonnociceptive input are incorporated while simultaneously addressing associated impairments and activity limitations. Therapeutic exercise can: (1) affect the pain directly through endogenous opiates; (2) indirectly affect pain through facilitation of nonnociceptive input; and (3) treat the associated impairments and activity limitations. Exercise programs similar in design may have very different goals from one patient to the next: although the specific program may appear to be straightforward, the clinical decision-making process underlying that exercise prescription is complex in this patient population. For example, some pain or discomfort may be necessary to achieve pain inhibition through endogenous opiates in some patients, whereas exercising into discomfort or pain may be contraindicated in others.[30] This type of intervention requires ongoing communication regarding the purpose of the exercise and alternative options to ensure that the intervention is meeting patient needs and thereby improving program adherence.

When designing the therapeutic exercise program, consider the current physical status of the patient and determine whether therapeutic exercise is likely to increase or decrease pain. Therapeutic exercise can reduce pain and improve function in patients with osteoarthritis, rheumatoid arthritis, chronic low back pain, neck pain, headaches, and fibromyalgia.[79–82] However, not all patients with the same diagnosis will respond similarly to an exercise program; for example, patients with fibromyalgia who have central sensitization may have a very different prognosis with exercise than those who do not.[30] Tailor the therapeutic exercise prescription to the specific physical needs and status of the individual patient. See Table 10-1 for exercise guidelines for individuals with dysfunctional endogenous analgesia.

The psychosocial component of the patient's pain can significantly impact participation and response to the therapeutic exercise program. Exercise is considered a stress, and this stress can be positive, producing improved resilience and function, or it can be negative, contributing to the cycle of pain and dysfunction. Too much stress, whether physical or psychological, can trigger the neuroendocrine responses of the adrenal–hypothalamic–pituitary-axis (HPA) to further nociceptive sensitization, increasing pain sensitivity[12,83–86] (for a complete discussion of the HPA and the role of cortisol in pain and stress, see Hannibal and Bishop[86]) (**Fig. 10-7**). Therefore, the decision to exercise or not, as well as the mode of exercise, the dosage, and recovery strategies, must be carefully considered.[25,30]

Recovery strategies are an integral component of the exercise program and stress management program. All patients with chronic pain need recovery strategies to maintain homeostasis and balance with the stress producers in their lives. Because exercise is a stress, insufficient recovery can worsen rather than alleviate pain. Many individuals can manage their pain-related and non–pain-related stress if sufficient recovery is available. Researchers have described the importance of recovery in maintaining balance and preventing overtraining in athletes.[87–89] Many of the same principles can be applied to patients with chronic pain. Recovery is multidimensional and includes both within (physiologic and psychological) and between (social) individual components.[30] Recovery strategies can take many forms and are not necessarily time dependent. Because recovery plays such a critical role in successful management of chronic pain, it is the responsibility of the therapist to educate the patient regarding adequate recovery. General characteristics of recovery can be found in **Display 10-4**.

General Recommendations for Activity and Mode for Patients with Chronic Pain

The activity chosen to treat the individual with chronic pain depends on the source of the pain and results of the evaluation process. In addition to the specific interventions chosen to treat the source of the pain, other activities can help the patient. In particular, active movement (vs. passive treatment) is of benefit. Patients with chronic low back pain who were

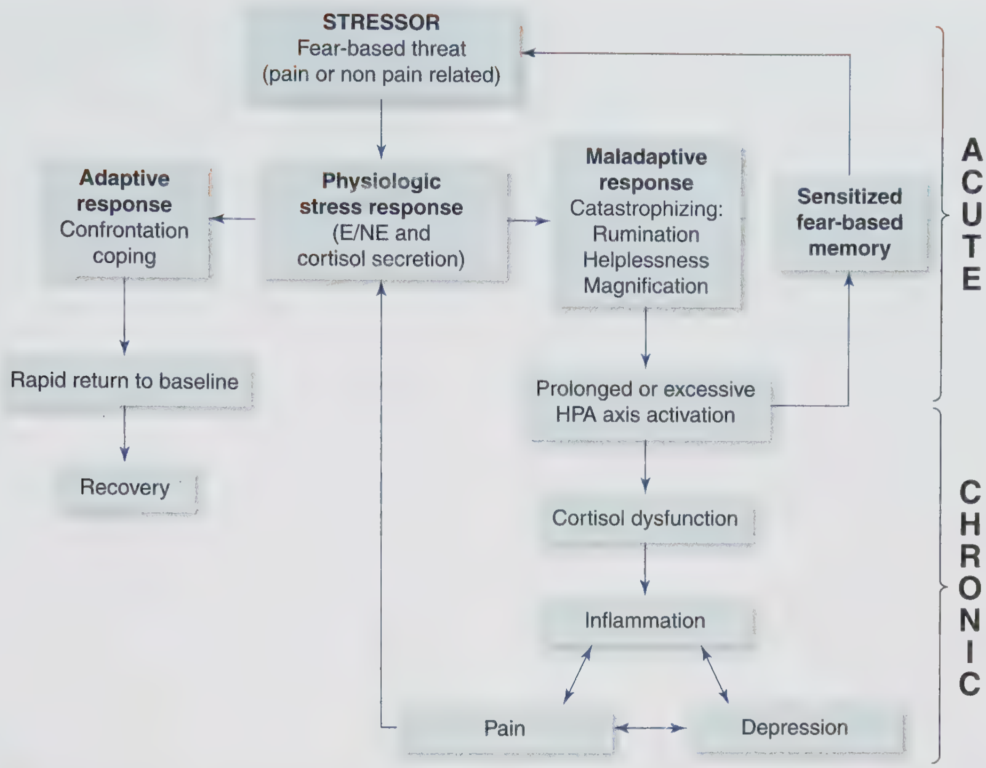


FIGURE 10-7 Proposed role of stress-related hypothalamic–pituitary–adrenal (HPA) axis activation in the transition from acute to chronic pain. (From Hannibal KE, Bishop MD. Chronic stress, cortisol dysfunction, and pain: a psychoneuroendocrine rationale for stress management in pain rehabilitation. Phys Ther 2014;94(12):1816–1825,with permission.)

randomly assigned to active rehabilitation compared with passive (massage and heat) treatment had significantly improved back pain intensity, functional disability, and lumbar endurance measured at a 1-year follow-up.[90] In addition, individuals in pain are susceptible to changes in posture and movement patterns. These changes can perpetuate the original symptoms or cause secondary impairments or activity limitations. Regardless of the activity chosen, the therapeutic focus should be on awareness and use of proper posture and movement patterns (**Evidence and Research 10-2**).

DISPLAY 10-4
General Characteristics of Physical and Psychological Stress Recovery Processes*

1. Recovery needs depend upon the type, magnitude, and duration of stress.
2. Recovery requires a complete break from, a reduction of, or a change from the stress.
3. Recovery strategies and needs are highly individual.
4. Recovery is intentional and self-initiated with the goal of restoring homeostasis.
5. Each individual needs a certain quality and/or quantity of recovery activities to balance stress levels. Individuals should have more than one strategy available.
6. *Disturbed recovery*, or impaired recovery, processes can occur if the recovery process is interrupted.
7. Recovery is closely associated with situational conditions (i.e., sleep, socialization, work, etc.).

**Adapted from Daenen L, Varkey E, Kellmann M, Nijs J. Exercise, not to exercise, or how to exercise in patients with chronic pain? Applying science to practice. Clin J Pain 2015;31(2):108–114; Kellmann M, Kallus, K. The Recovery-Stress Questionnaire for Athletes: User Manual. Vol 1. Champaign, IL: Human Kinetics; 2001; Kellmann M. Preventing overtraining in athletes in high-intensity sports and stress/recovery monitoring. Scand J Med Sci Sports 2010;20(Suppl 2):95–102.*

EVIDENCE and RESEARCH 10-2

Ongoing deep lumbar muscle dysfunction despite resolution of pain has been suggested as a factor in recurrent low back pain.[91] Electromyographic changes in the deep lumbar muscle responsible for spine stabilization show altered firing patterns, even after symptom resolution. Muscle activation patterns in patients with low back pain differed from healthy controls during core stabilization exercises, suggesting that muscle dysfunction may be an impairment remediated by physical therapy intervention.[81] Impaired motor control of the transversus abdominis and internal oblique muscles along with primary motor cortex changes are associated with chronic low back pain, and deep muscle training along with peripheral neurostimulation can remediate these impairments.[92]

Movement therapies such as Feldenkrais, Ai Chi, T'ai Chi, and yoga are helpful in restoring appropriate movement patterns (**Fig. 10-8**). Total-body movement patterns are often more successful than isolated joint movement when treating individuals with chronic pain. Rhythmic activity of large muscle groups and/or nonpainful limbs should be the activity of choice.

Using a therapeutic ball allows a variety of large muscle group activities to be carried out along with increasing posture awareness (**Fig. 10-9**). Many of these activities are done in a group setting or individually at home, providing flexibility to suit the needs of each patient (see **Self-Management 10-1**). Group treatment of patients with fibromyalgia resulted in improved function and decreased tender points.[93] Balance these activities with specific exercises to address the individual patient's impairments and activity limitations.

Diagonal patterns used in proprioceptive neuromuscular facilitation (PNF) techniques (see Chapter 15) are useful for teaching the patient position and posture awareness although still using multisegmental movement. In addition to assisting in movement awareness, PNF patterns can increase mobility and muscle performance together with ensuring proper muscle recruitment during movement. Substitution patterns often are difficult to observe but are easily palpated during PNF exercises. Bilateral, symmetric patterns are particularly helpful when one side is involved and needs retraining through the uninvolved side. If moving the involved limb is too painful, movement of the opposite limb can have positive central effects. Bilateral patterns that emphasize trunk flexion and extension or rotation and sidebending are effective for normalizing specific movement patterns. These same patterns can be performed in a pool (see **Self-Management 10-2**).

In addition to performance of land-based exercise, the pool is a useful tool in the application of therapeutic exercise for those with chronic pain (see Chapter 16). The advantages include unweighting from the buoyancy and the warmth and contact of the water on the skin. Unweighting the sore limb or painful back allows movement with less pain and provides the opportunity for correct posture and movement patterns during activity or stretching (**Fig. 10-10**; see **Self-Managements 10-3**,

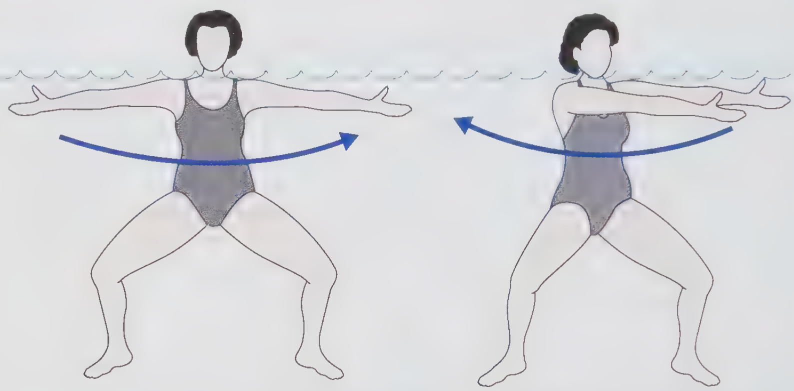


FIGURE 10-8 Ai Chi exercise as a form of mobility and strength exercise.

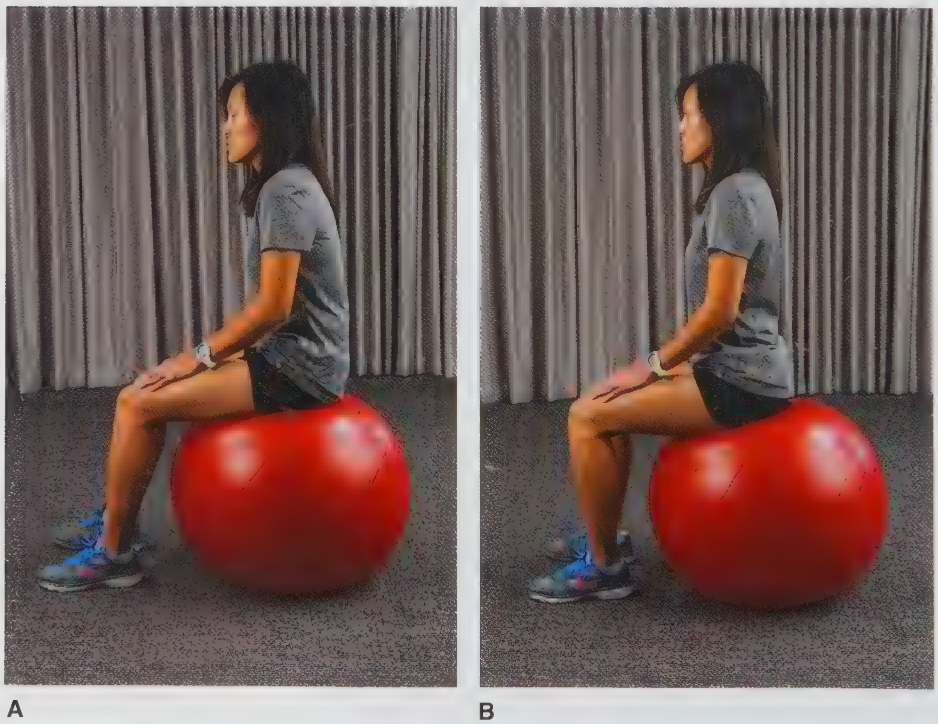


FIGURE 10-9 Therapeutic ball exercises such as pelvic rocking can be performed at home and in the clinic. **(A)** Start position. **(B)** End position.

SELF-MANAGEMENT 10-1
Yoga Exercise

Purpose: To promote relaxation and pain relief and to increase mobility in the low back and hips.

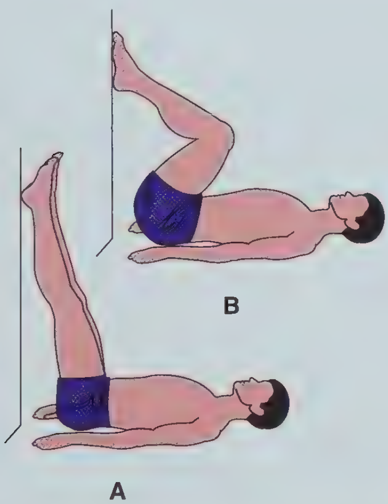
Position: Lying supine, with legs elevated on the wall (**Fig. A**).

Movement Technique: Let the knees and hips bend, sliding the leg down the wall to a comfortable position (**Fig. B**). Hold 10 to 15 seconds, and return to the starting position.

Dosage:

Repetitions: ______________________________

Frequency: ______________________________



SELF-MANAGEMENT 10-2
Proprioceptive Neuromuscular Facilitation Postural Technique

Purpose: To improve postural control while moving the arms and sitting on an unstable surface.

Position: Sitting on a therapeutic ball, with both feet flat on the floor, grasp wrist or a resistive band with both hands over one shoulder (**Fig. A**).

Movement Technique: Level 1: Keeping your arms straight, rotate your trunk and shoulders down past your opposite hip (**Figs. B** and **C**).

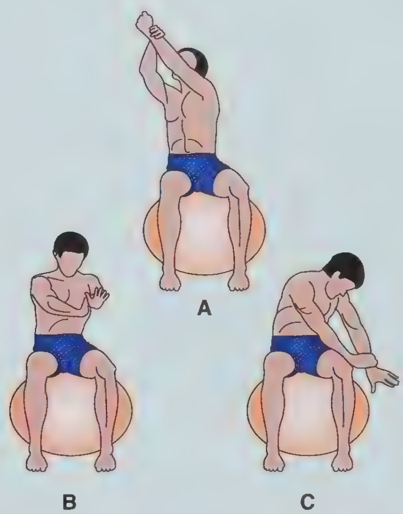
Level 2: Increase the resistance.

Level 3: Perform with one foot off the floor.

Dosage:

Repetitions: ______________________________

Frequency: ______________________________



10-4, and **10-5**). Movements that are too painful to perform on land are performed with greater ease and less pain in the water (**Fig. 10-11**). Disadvantages include pool access, difficulty in determining proper muscle recruitment and movement patterns as a result of distortion from the water's refraction, and resistance caused by the water's viscosity. The viscosity of water provides enough resistance to exacerbate some chronic pain conditions. Choose positions and movement patterns to minimize resistance caused by turbulence (i.e., controlling the speed of movement) and viscosity (i.e., minimizing the surface area; see **Self-Management 10-6**). Palpation and tactile cueing while in the water can ensure proper muscle recruitment.

Aerobic exercise is effective for treating chronic pain and is frequently recommended in the treatment of conditions such as fibromyalgia. The pool can also be used for aerobic exercise, keeping in mind the effects of viscosity and turbulence (see **Self-Management 10-7** and **10-8**). This resistance can produce muscle fatigue before reaching aerobic exercise levels.

FIGURE 10-10 Deep water bicycling.

SELF-MANAGEMENT 10-3
Hip External Rotation Stretch

Purpose: To increase mobility of the hips.

Position: While facing the ladder, set the foot of the hip to be stretched on a step of the ladder. Slide the foot across to the edge of the step. Keeping your foot there, let your knee roll out. Hold for 10 to 15 seconds.

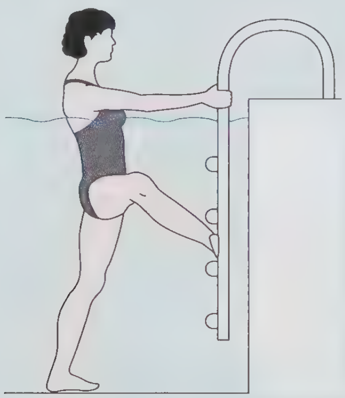
Movement Technique: Level 1: Assume the position just described until you feel a gentle stretch in your hip.

Level 2: Assume the position just described until you feel a gentle stretch in your hip. Use your hands to push your knee farther into rotation.

Dosage:

Repetitions: ______________________

Frequency: ______________________



SELF-MANAGEMENT 10-4
Deep Water March with Barbell

Purpose: To increase mobility through the low back, hips, and knees.

Position: In water depth equal to your height or deeper, use a barbell or other buoyant equipment to support yourself.

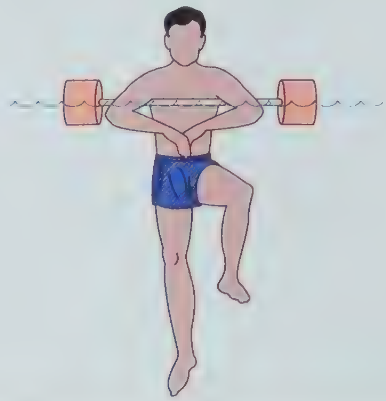
Movement Technique: Level 1: March in place through a comfortable range of motion at a comfortable speed.

Level 2: Add buoyant equipment to feet and ankles, increase the speed of marching, or do both.

Dosage:

Repetitions: ______________________

Frequency: ______________________



SELF-MANAGEMENT 10-5
Elbow Flexion Extension

Purpose: To increase mobility in the elbows, increase muscle strength and endurance in the upper extremities, and increase trunk stability.

Position: Standing in shoulder-deep water, with your feet in a comfortable stance and arms at the sides.

Movement Technique: Level 1: Flex and extend the elbows with thumbs pointing up.

Level 2: Turn your palms up.

Level 3: Add gloves or other resistive equipment.

Dosage:

Repetitions: ______________________

Frequency: ______________________

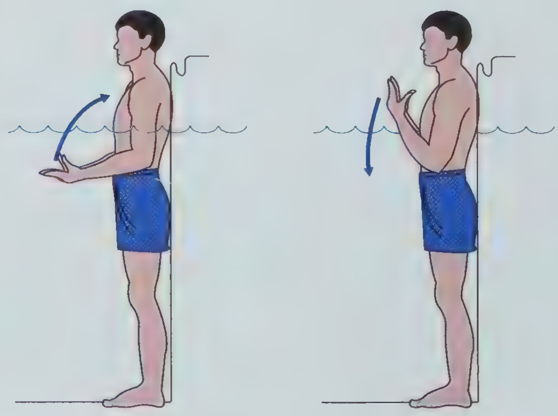


FIGURE 10-11 Knee lifting is an active, core exercise that is non-weight bearing.

SELF-MANAGEMENT 10-6
Water Walking, Forward and Sideways

Purpose: To increase mobility throughout the trunk, arms, and legs; increase trunk stability; and increase muscular strength and endurance in the arms, legs, and trunk.

Position: Stand in water between waist and shoulder deep; deep water provides more resistance to walking.

Movement Technique: Level 1: Step sideways, raising your arms out to the sides as you step and bringing back down to the sides as you bring your feet together.

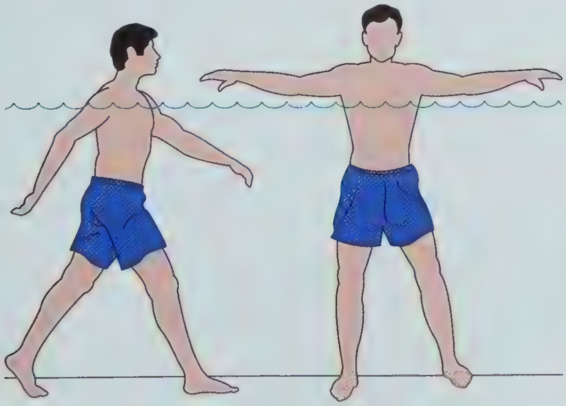
Level 2: Walk forward with the opposite arm and leg reaching forward together. Be sure to walk normally using a heel-to-toe pattern.

Level 3: Add resistance gloves to hands.

Dosage:

Repetitions: ______________________

Frequency: ______________________



SELF-MANAGEMENT 10-7
Supine Kicking with Optional Arm Movements in a Pool

Purpose: To increase strength and endurance of the neck, trunk, hip, and leg extensor muscles and to increase cardiovascular endurance.

Position: Supine with arms in a comfortable position overhead or at the side

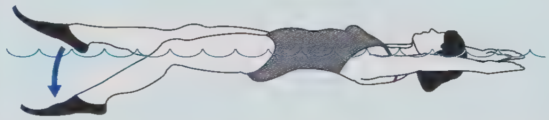
Movement Technique: Level 1: Rhythmic, repetitive kicking, keeping knees relatively straight and kicking from the hips; large or small fins may be used.

Level 2: Add arm movements in an underwater backstroke pattern. Bring arms up along the sides of your body to the shoulders, extend them straight out to the sides, then pull back down toward your sides.

Dosage:

Repetitions: ______________________

Frequency: ______________________



Intensity levels of 70% of the maximum aerobic capacity is necessary to trigger endogenous pain inhibitory mechanisms.[94] However, in patients with chronic pain, the exercise may need to begin at a much lower, tolerable level to avoid increasing central sensitization of pain. On land, walking is a simple form of continuous exercise that can be performed by many persons. Walking is particularly effective because it can be performed for several short bouts several times each day. A stationary bicycle or other aerobic equipment preferred by the patient can be included in a cross-training manner. Other exercises enjoyed by the individual and viewed as stress-relieving, such as aerobic dance, recreational dance, or traditional lap swimming, should be incorporated.

Dosage

Exercise dosage depends on the specific component of the movement system being treated and the purpose of the exercise, but some generalities about exercise and pain should be considered. Although discomfort can be expected, the exercise dosage should not increase the pain that caused the patient to seek medical attention in the first place. The chosen speed, repetitions, intensity, and duration should not increase pain within the exercise session, nor should symptoms increase after exercise.

SELF-MANAGEMENT 10-8
Jumping Jacks in a Pool

Purpose: Increase strength in shoulder and hip abductor muscles, initiate gentle impact, and initiate exercise using large muscle groups.

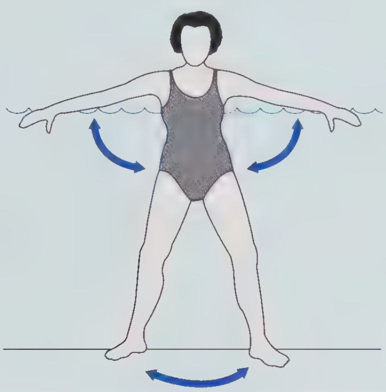
Position: Start in chest-deep water, with feet together and arms at sides.

Movement Technique: Bring both feet out to the sides while simultaneously bringing arms out to the side, shoulder height. Return to the starting position.

Dosage:

Repetitions: ____________________

Frequency: ____________________



If using aquatics as the exercise medium, the water's resistance can be a concern. Keep the first session brief (5 to 7 minutes) to assess the response to this intervention. As tolerance is demonstrated, the intensity or the duration may be increased (see **Patient-Related Instruction 10-3**). The overarching goal is to increase the total volume of exercise (see Chapter 5). Initially, exercise volume might remain stable, whereas variables within the total volume (i.e., sequence, contraction type, etc.) are changed. When the optimum combination of variables is achieved, exercise volume can be slowly expanded (see **Building Block 10-4**).

BUILDING BLOCK 10-4

The patient in Building Block 10-3 has been performing a therapeutic aquatic exercise program of slow-speed single plane shoulder movements, single plane hip movements, walking, and abdominal muscle isometrics. She exercises for 30 to 40 minutes and is tired at the end of the program, but has no increase in pain. She is doing the exercise program 4 days per week. How might her program be progressed?

Patient-Related Instruction 10-3

How Often and Hard Should You Exercise with Chronic Pain

1. Ideally, you should do something every day, at least once per day. Your clinician can give you further guidelines.
2. Many people do well by performing several short bouts of exercise spread throughout the day. These sessions may be only 5 to 10 minutes long.
3. Any aerobic activity should be continuous, working up to 10 to 20 minutes over time.
4. Stretches should be intense enough to feel a gentle pulling sensation.
5. Other exercises should be performed slowly until slight fatigue is felt or as otherwise instructed by your clinician.
6. If you feel any sharp, stabbing pain or numbness or tingling as a result of the exercise, discontinue the exercise. Use your pain-relieving measures, and tell your clinician.
7. You may feel some discomfort during or for a short time after exercise. This discomfort should not be confused with the pain that brought you to the clinic. Avoid exercises that increase this pain, but you may continue to exercise with some of the discomfort.
8. Ask your clinician if you are unsure about what to feel with your exercise program.

The frequency is determined by the activity type and purpose and by the quantity of exercise performed before pain is experienced. For example, if only a few repetitions of activity at a low intensity for a short duration can be performed before experiencing pain, the exercises may be performed with greater frequency. Availability also affects frequency. A pool may not be available more than once each day or even less often. The frequency must be balanced against the intensity and duration of an activity. Some exercise should be performed daily, and matching a land-based exercise program to complement the pool program is necessary. Be sure to consider the patient's other daily activities (work, ADLs, IADLs), and still allow sufficient recovery to prevent perpetuating the pain-activity cycle.

After the pain-free dosage is determined, progress the exercise parameters to those best suited to treat the patient's underlying pathology, impairments, or activity limitations. Advance the activity to a functional progression aimed at decreasing or abolishing participation restrictions.

ADJUNCTIVE AGENTS

Adjunctive agents are essential in the treatment of pain. In the case of chronic pain, more agents are used. The disabling nature of chronic pain leads individuals to seek out any other potentially pain-relieving therapy such as medications, chiropractic, massage therapy, relaxation techniques, acupuncture, biofeedback, and psychological care.[68] Acupuncture, herbal remedies, dietary changes, and a host of other therapies may be employed. In particular, real acupuncture has proven better than sham acupuncture for relieving pain, improving global ratings, and decreasing morning stiffness.[68] It has been recommended as an adjunctive treatment in the management of fibromyalgia, chronic low back pain, myofascial pain, and osteoarthritis. Continuous communication with the patient and other health care providers ensures optimal treatment and avoids conflicting interventions. Remain open-minded and supportive as the patient searches for solutions to his or her pain.

Transcutaneous Electrical Nerve Stimulation

Transcutaneous electrical nerve stimulation has been proven useful in the treatment of some types of pain.[95] Stimulation of the posterior tibial nerve and sciatic nerve was performed to see the effect on WDR neurons in the spinal cord. Results showed that electrical stimulation of peripheral nerves leads to inhibitory input to the pain pathways at the spinal cord.[96] One mechanism of pain relief with the application of an electric current is based on the gate theory of pain. Application of TENS selectively activates large A-alpha and A-beta fibers, which are stimulated at lower thresholds than the smaller C fibers. These impulses travel to the dorsal horn of the spinal cord, where facilitation of the small interneurons of the substantia gelatinosa inhibits pain transmission through presynaptic inhibition. Activation of these large-diameter fibers closes the gate to small-diameter fiber transmission.

Other theories suggest that TENS may function through antidromic (i.e., conducting impulses in a direction opposite to normal) stimulation of afferent neurons. Antidromic stimulation may decrease pain by blocking the nociceptive input to the spinal cord, and it may stimulate release of substance P, resulting in vasodilation. Vasodilation can decrease pain by increasing local circulation, which removes metabolic waste products and supplies oxygenated blood for healing. The increased local circulation may decrease local ischemia enough to decrease pain.[31]

TENS may affect the opiate pain-modulating system. Ascending projections from small-fiber afferents reach the PAG, which is rich with opiates. The PAG provides descending input to the dorsal horn, which probably is opiate-mediated. TENS may provide some analgesia through opiate-mediated activation of the brain stem. TENS can be used in a variety of ways that increase a patient's function. It can be worn continuously, during activity, or after activity.

The parameters for TENS application are varied. Consult any appropriate textbook for discussion of the benefits of different parameter settings.

Heat

Heat is commonly used as a primary or adjunctive agent to decrease pain. Trauma can produce a pain-spasm cycle that activates nociceptors. The nociceptors detect pain that produces reflex muscle activity that, if prolonged, results in muscle ischemia. The ischemia excites muscle nociceptors that perpetuate the muscle spasm. Chemical release at the time of injury or resulting from inflammation can also stimulate nociceptors. Vasoconstriction associated with a sympathetic response or vasoconstriction resulting from muscle spasm can produce pain. The application of heat can decrease pain from any of these sources.

According to the gate theory, heat application can decrease pain directly. Thermal sensations are carried to the dorsal horn of the spinal cord through large-diameter myelinated fibers. These impulses can close the gate, blocking the transmission of pain impulses through small-diameter fibers. The thermal sensations are transmitted to conscious levels preferentially over pain sensations. The increased circulation resulting from heat application decreases pain through two mechanisms. First, pain resulting from ischemia decreases as the local circulation is increased. The increased circulation may break the pain-spasm cycle as pain decreases and the muscle is provided with oxygenated blood. Second, the increased circulation may remove noxious chemicals associated with injury or inflammation, thereby decreasing pain.

Superficial heat in the form of hot packs is commonly used in the clinic and home to decrease pain and as a precursor to therapeutic exercise. Local heat application increases the extensibility of tissue, preparing it for subsequent exercise. Immersion in a warm pool or whirlpool can also decrease pain, although the water temperature is significantly lower than that of a hot pack because of the size of the area heated. The warmth and buoyancy effects of the water combine to decrease pain sensation. Ultrasound or diathermy can increase the heat's depth of penetration. Any of these modalities can provide valuable assistance in the reduction of pain. However, it is important to remember that the best way to heat a muscle is to exercise it.

Cold

Cold treatments are commonly used to decrease pain. Cold decreases pain through some of the same mechanisms as heat. Cold sensation is carried to the dorsal horn of the spinal cord through large-diameter afferent fibers and is capable of closing the gate to pain signals through smaller-diameter fibers. The drop in tissue temperature blocks synaptic transmission of any input, rendering the gate inactive. The decrease in pain may help to break the pain-spasm cycle. In acute injury, the vasoconstriction produced by cold may prevent edema that produces pain. Because the application of cold is somewhat noxious, the afferent input to the brain stem through the PAG could cause the release of endorphins at the spinal level; the decrease in pain would be modulated by higher centers.

Cold usually is applied by means of ice in the form of packs, bags, or ice massage. The length of application depends on the size of the area to be cooled, the area of the body to be cooled, the mode of application, local circulation, and patient sensitivity.

Medication

Drug therapy is commonly prescribed for individuals with acute or chronic pain. Many medications are available and act through different mechanisms and at different sites to relieve pain. Medications are administered orally, by intramuscular injection, by injection into other structures, or by intravenous infusion. The dosage necessary to produce analgesia varies among individuals and for various medications.

Acting peripherally, NSAIDs are commonly prescribed. Several chemical classes exist, all of which inhibit the synthesis or release of prostaglandins.[97] Analgesia generally occurs within

24 hours of NSAID administration, and anti-inflammatory responses occur with continued administration. The major side effect of NSAIDs is gastrointestinal upset. Many NSAIDs are enteric-coated and long acting, decreasing the frequency of administration. Local injections of anesthetic agents can provide relief from pain in localized areas. Trigger-point injections with an anesthetic agent are commonly performed in individuals with chronic pain, particularly pain arising from myofascial tissues. Recently, botulinum toxin type A has been effective in reducing pain as measured by VAS, palpable muscle firmness, and pressure pain thresholds when compared with saline (placebo) injections.[68]

Cyclooxygenase (COX)-selective drugs are another classification of nonopioid analgesic medications. The COX-2 selective drugs (e.g., celecoxib, rofecoxib) work by inhibiting the synthesis of prostaglandins. These medications may decrease pain and inflammation with less gastric irritation.

At the spinal cord and higher levels, a variety of medications can be administered. When treating centrally mediated pain, the preferred first line of medications includes the tricyclic antidepressants, serotonin-selective reuptake inhibitors (SSRIs), and the anticonvulsive medications gabapentin and pregabalin. Antidepressant medications have analgesic effects, and administration may relieve pain at levels below those necessary to achieve antidepressant effects. These medications may be used at levels that have analgesic and antidepressant benefits. SSRIs typically cause less cardiovascular or anticholinergic side effects than tricyclics.[98] Side effects of the SSRIs include headache, nausea, tinnitus, insomnia, and nervousness. Tricyclic antidepressants also have significant side effects, including orthostatic hypotension, potentially predisposing patients to falling. The tricyclics also have a significant impact on the cardiovascular system, including altered heart rate, rhythm, and contractility, particularly in patients with existing cardiac disease.[98] Therefore, SSRIs are generally preferred to tricyclics in patients with known cardiac disease.

Anticonvulsive medications such as gabapentin are used to treat neuropathic pain. Pregabalin has also been successfully used to treat neuropathic pain.[99] A recent study showed that the use of pregabalin (Lyrica) was cost neutral compared to "usual care" and resulted in a small but significant increase in the quality of life in patients with peripheral neuropathic pain.[100] Other medications such as muscle relaxants like benzodiazepines also act as analgesics. Moreover, they help patients relax and sleep, which significantly improves their quality of life.

Narcotics acting at opioid receptors are also used to treat pain. Side effects of opioids include postural hypotension, sedation, and confusion. These effects may lead to a risk of falls, which should be considered in any rehabilitation program. Morphine and other strong narcotics are commonly used to relieve end-of-life pain and cancer pain. Bennett[15] suggests that opiates are the most effective medications for managing chronic pain and should not be withheld because of fear of addiction. Addiction is the use of medication for its mind-altering properties with manipulation of the medical system to acquire them. This is very different from the physical dependence seen in patients who need these medications to obtain pain relief.

Some patients receive inadequate pain control from traditional administration methods because of individual differences in absorption and metabolism of drugs or because of fluctuating plasma levels of the drugs or their metabolites. In this situation, patient-controlled analgesia (PCA) may be indicated. The PCA system infuses a drug in a desired location on demand or at a continuous rate.[101] Opioid analgesic drugs such as morphine, meperidine, and hydromorphone are commonly used.[101] In an on-demand system, a small button on the PCA system releases a preset dose of medication. The constant-rate infusion delivers a small but continuous dose to maintain steady plasma levels of the analgesic. A variety of safety features (i.e., the pump is programmed to prevent an overdose) are included in the system. Chronic pain from cancer, surgery, or labor and delivery is a common reason for the use of PCA.

SPECIAL CONSIDERATIONS IN CHRONIC PAIN: COMPLEX REGIONAL PAIN SYNDROME, FIBROMYALGIA, AND CHRONIC FATIGUE SYNDROME

Significant impairments exist in patients with fibromyalgia syndrome (FMS), including widespread pain,[102] decreased joint range of motion,[103] and impaired respiratory[104] and cardiovascular status.[93] Patients frequently decrease work hours and change tasks,[105–107] and they develop significant conflicts about life roles.[108] Twenty-five percent of patients with CFS are bedridden or unable to work.[109] Complex regional pain syndrome (CRPS) is a painful and debilitating condition of unknown origin, which profoundly affects patients and their families. These disabilities have negative economic and quality of life effects. Patients with FMS, CRPS, and CFS are being seen increasingly in the physical therapy clinic because carefully prescribed exercise has been shown to be of value in improved aerobic performance, tender point pain, well-being, pain levels, and self-efficacy.[110–116] Unfortunately, these conditions are poorly understood by the public and many health professionals. An understanding of the problems these patients encounter will provide a basis for a solid rehabilitation program.

Complex Regional Pain Syndrome

Complex regional pain syndrome is a term used to describe a cluster of signs and symptoms, including pain disproportionate to the injury, vasomotor and trophic changes, stiffness, swelling, and decreased function. Other terms for CRPS have included reflex sympathetic dystrophy (RSD), sympathetically maintained pain, causalgia, sympathetic dystrophy without pain, shoulder–hand syndrome, and Sudeck atrophy. The uncertain role of the sympathetic nervous system in CRPS led the IASP and the American Pain Association to recommend the use of the term CRPS to replace the term RSD.[117]

CRPS is three to four times more common in women, is found more frequently in the upper extremity, and peaks in the 50 to 70 age group.[118] The diagnostic rates for CRPS have decreased approximately 50% since the IASP revised their diagnostic criteria.[119,120] Most acute cases, defined as diagnosis <1 year (also called "warm" CRPS), tend to resolve with conservative care, with reports of resolution of CRPS type I of 74%.[121] Patients with chronic CRPS (diagnosis >1 year, also called "cold" CRPS) have a poorer prognosis; at 6 years postdiagnosis, 30% reported being completely recovered, 16% reported decline, and 54% considered their disease as stable.[120]

Etiology

As with other forms of chronic pain, CRPS has a complicated and unclear etiology. CRPS develops most frequently after trauma, including fractures (accounting for ~45% of cases), crush injuries, sprains, contusions, and surgical procedures.[117] Although a few cases develop without a known antecedent event, the fact that trauma was involved implicates the inflammatory process as key in the early phase, and anti-inflammatory measures are recommended in the early phase.[122–124] It has been considered as a type of neuropathic pain by some, but not by others.[119,123] Some have suggested that genetic factors may predispose some individuals to CRPS.[119,124] Other research suggests that CRPS may be a type of autoimmune disease.[120] Most consistently, CRPS follows the same pattern as other forms of chronic pain, with a complex interplay of peripheral and central mechanisms that result in central sensitization and its sequelae. Central changes at the cortical and spinal cord levels involving ascending and descending pathways, NMDA receptors, windup and allodynia, which have been previously discussed, are also implicated in CRPS.

Signs and Symptoms

Several common features and two major classifications of CRPS have been identified. The common features are local tissue damage or nerve damage that initiates a reflex response in the peripheral nervous system and CNS. Several disorders with the same abnormal clinical findings share these criteria with CRPS. The two types have been classified by the absence or presence of nerve involvement (see **Display 10-5**). A third type has been added for coding purposes:

- CRPS Type I: resembling RSD (without nerve involvement).
- CRPS Type II: equivalent to causalgia (with nerve involvement).[117]
- CRPS- NOS: patients who partially meet the CRPS criteria. Developed to capture those previously diagnosed with CRPS who do not meet the updated criteria.[42]

Several impairments are associated with CRPS and may include pain and inflammation, swelling, stiffness, vasomotor disturbances, trophic changes, bone demineralization, and dystonia.[117] Initial activity limitations are numerous and are based on pain-limited use of the extremity. An ADL checklist is helpful to monitor even small improvements in functional tasks.

Pain disproportionate to injury severity is the primary clinical feature of CRPS. In the upper extremity, pain is found throughout a large part of the arm, from the upper arm distally to and fully including the hand. In the lower extremity, pain can begin in the foot and spread proximally up the leg. The pain is often described as burning initially and eventually changing to pressure, aching, and binding sensations. Pain is often constant, starting locally at the original injury site and spreading throughout the extremity. The pain often leads to disuse and self-immobilization of the extremity, along with the known consequences of this response. In addition to constant pain, hypersensitivity to touch occurs, with extreme sensitivity to any kind of tactile stimulation. Occasionally, sympathetic and trophic changes occur with minimal complaints of pain or pain related only to motion of stiff joints.

Excessive swelling at the injury site is often the first objective sign noticed in the early phase. Swelling can subsequently spread throughout the distal upper extremity. Initially, it has a fusiform and pitting appearance, but it later takes on a hard and brawny character that contributes to joint stiffness. In the hand, periarticular thickening is observed at the interphalangeal (IP) joints. Edema is difficult to control even with otherwise successful intervention techniques.

Joint restriction with CRPS is often more profound than expected for the associated diagnosis. Unlike the traditional joint stiffness experienced after injury that decreases with ROM and functional use, individuals with CRPS tend to lose motion over time and seem to be refractory to improvement with traditional active and passive exercises and dynamic splinting. Fibrosis of

DISPLAY 10-5
Clinical Diagnostic Criteria for Complex Regional Pain Syndrome

1. Continuing pain, which is disproportionate to any inciting event.
2. Must report at least one symptom in three of the four following categories:
   - Sensory: Reports of hyperalgesia and/or allodynia.
   - Vasomotor: Reports of temperature asymmetry and/or skin color changes and/or skin color asymmetry.
   - Sudomotor/Edema: Reports of edema and/or sweating changes and/or sweating asymmetry.
   - Motor/Trophic: Reports of decreased range of motion and/or motor dysfunction (weakness, tremor, dystonia) and/or trophic changes (hair, nails, skin).
3. Must display at least one sign* at the time of evaluation in two or more of the following categories:
   - Sensory: Evidence of hyperalgesia (to pinprick) and/or allodynia (to light touch and/or deep somatic pressure and/or joint movement).
   - Vasomotor: Evidence of temperature asymmetry and/or skin color changes and/or asymmetry.
   - Sudomotor/Edema: Evidence of edema and/or sweating changes and/or sweating asymmetry.
   - Motor/Trophic: Evidence of decreased range of motion and/or motor dysfunction (weakness, tremor, dystonia) and/or trophic changes (hair, nails, skin).
4. There is no other diagnosis that better explains the signs and symptoms.

**A sign is counted only if it is observed at the time of diagnosis.*

***Research criteria for CRPS are recommended that are more specific, but less sensitive than the clinical criteria; they require that four of the symptom categories and at least two sign categories be present.*

From: International Association for the Study of Pain. White paper on Classification and Diagnostic Criteria for Pain [whitepaper], 2015. http://iasp.files.cmsplus.com/Content/ContentFolders/Publications2/ClassificationofChronicPain/Part_II-A.pdf. Accessed August 14, 2015.[125]

ligaments limits motion about joints, and adhesions in tendon sheaths limit the gliding properties of the tendon, producing inflammation and pain. These changes contribute to the vicious circle of pain and inflammation. Palmar and plantar fasciitis can be seen, and nodules and thickening of the fascia can be palpated. In the hand, this stiffness contributes to limited metacarpophalangeal (MCP) and IP extension.

Discoloration of various degrees occurs with vasomotor instability. Pallor results from vasoconstriction of the arterial and venous systems. Redness is evident when there is dilation of both sides of the vascular tree. Blueness (cyanosis) is usually present with vasoconstriction of the venous system.[126] Sudomotor changes include hyperhidrosis (excessive sweating) in the early stages and dryness in later stages.

Bone demineralization is a reliable sign of CRPS and assists in making the diagnosis. Although some demineralization takes place with immobilization, the bulk of calcium loss results from increased blood flow in the periarticular bone.[126] Sudeck[127] described the condition as "inflammatory bone atrophy." Untreated cases progress from "spotty" osteoporosis to diffuse osteoporosis.

Trophic changes in the skin are initially caused by swelling and later by nutritional changes in the hand. The skin appears glossy or shiny, and evidence of subcutaneous tissue atrophy is present. Excessive and dark hair growth may be present. The nails become coarse, rigid, and curved.[127]

Interventions for CRPS

Interventions for CRPS are changing as new information on the etiology and prognosis are better understood. Previously, when the primary etiology was believed to be sympathetic nervous system dysfunction, sympathetic blocks were standard of care. However, as new information arises, other interventions are being tested. Ketamine, a NMDA antagonist, has been effective in decreasing CRPS pain.[120,128–130] Drugs or medications that address free radicals have been researched by some and suggested to be effective (vitamin C, oral corticosteroids, topical dimethyl sulfoxide, calcium channel blockers).[120] Graded motor imagery, mirror therapy, and physical and occupational therapy have evidence for positive effects.[129] Physical therapy is particularly effective in acute cases and addresses the impairments (pain, edema, mobility, strength) and activity limitations experienced by the patient.[120]

Therapeutic exercise must be approached practically and cautiously. Traditional exercises for restricted joints are often painful and exacerbate the pain cycle and vasomotor instability. Pain must be controlled before progressing to other treatment techniques. Modalities such as heat and cold may be helpful in reducing pain but must not aggravate the vasomotor tone. Elevation and moist heat before edema massage and exercise can improve tissue extensibility and tolerance to exercise.

Fibromyalgia Syndrome

Fibromyalgia syndrome is characterized by widespread body pain (in all four quadrants and the axial skeleton) and tenderness, fatigue, and morning stiffness.[1] These patients are highly sensitive to both painful and nonpainful stimuli, including touch, temperature, chemical, light, sounds, and smells.[131] Although the cause of FMS is uncertain, it tends to predominately affect females (80% to 90% of patients). Patients typically are between 20 and 60 years of age,[132] although there have been reports of children being affected.[133,134] The prevalence of fibromyalgia is about 2% of the general population, affecting approximately 5 million adults in 2005.[135] Persons with FMS are estimated to constitute about 7% of the patients seen in general medical practices and up to 20% of the patients in general rheumatology practices.[132,135] Patients with fibromyalgia account for nearly 2.2 million ambulatory care visits annually.[136,137] Fibromyalgia has a significant impact on quality of life, with these patients scoring the lowest on 7 of 8 subscales of the SF-36 compared to patients with other chronic diseases, and having a 3.4 times greater likelihood of being diagnosed with major depression compared with age-matched peers without fibromyalgia.[138–140]

Etiology

One of the characteristics of FMS is the absence of consistent, positive laboratory findings.[102] Because its symptoms mimic those of other diseases (e.g., rheumatic diseases, multiple sclerosis, malignancies, hypothyroidism, anemia), a thorough medical evaluation is necessary to exclude other possible causes of the presenting complaints.[141] Onset of FMS can be insidious; it may occur after a viral infection[142–144] or trauma.[143–145] It may also be related to stress[146]; sleep disruption such as occurs in sleep apnea, sleep myoclonus, and alpha-delta sleep[147,148]; or be related to CNS mechanisms.[149] Increased excitability of spinal cord neurons after an injury, increased receptive field size of the neurons, and reductions in pain threshold are indicative of progressive central sensitization.[131] It seems likely that multiple factors contribute over time until a threshold is reached such that a final event appears to be the precipitating factor.[150]

Many researchers have attempted to identify the causative factors of FMS, but the pathomechanics remain elusive. Historical references to FMS-like symptoms are found as far back as Hippocrates.[151,152] Straus[152] cites the treatise of an 18th-century physician who describes such a disorder found predominately "among women. . . who are sedentary and studious," and that he felt was "precipitated by antecedent causes including grief and intense thoughts." In the 1800s and early 1900s, muscle inflammation (giving rise to the term *fibrositis*) was considered a cause. The term fibrositis has generally been disregarded for want of histological evidence of inflammation in the muscles of patients with FMS.[153,154] Later research into the possible causes of FMS has focused on peripheral (muscle physiology) and central (CNS function) phenomena.

Peripheral Origin Aggressive exercise is not well tolerated by patients with FMS and often results in increased perception of pain and fatigue.[155–158] Muscle adaptation to decreased activity has been hypothesized to be at least partially responsible for the adverse reaction to overexertion, and muscle morphology and physiology in patients with FMS have been investigated[159] (**Evidence and Research 10-3**). It is not clear whether localized metabolic or morphological changes in muscle can account for the pain and fatigue associated with FMS. Peripheral changes may contribute to increased pain signals to the spinal cord, contributing to windup and central sensitization.[131] Even low levels of nociceptive input from the periphery can maintain the central sensitization. It is likely that peripheral mechanisms interact with central to increase central sensitization.

EVIDENCE and RESEARCH 10-3

A large body of research has examined the muscle morphology in FMS for the etiology of this syndrome. No muscle morphological changes specific to FMS have been found, but the muscles of patients with FMS have the appearance of inflammatory infiltrates, muscle pH changes related to ischemia, reduced oxidative capacity, and fiber changes.[131,154] In very few muscle samples, evidence suggesting a mitochondrial disorder and possibly microcirculation compromise was documented, but these changes were not widespread in the muscle.[153,160–162] Neither muscle energy metabolism[163,164] nor enzyme levels[156] vary from those of controls, although a recent study showed decreased use of phosphorous metabolites at maximal work levels.[165] Reports of decreased exercise-induced muscle blood flow in patients with FMS[166] were not, however, accompanied by the expected decrease in capillary density that this finding suggested.[161]

Epidural blockade does reduce FMS tender points,[167] and there is evidence of increased nociceptor reactivity in patients with FMS,[168] which suggests that peripheral pain may be a contributor. Electromyographic studies suggest that the muscle itself is capable of normal work but that there may be a central mechanism limiting that work by producing symptoms of FMS and CFS, which the patient interprets as pain and fatigue (**Evidence and Research 10-4**).

EVIDENCE and RESEARCH 10-4

Muscles of patients with FMS do not show a drop in surface electromyographic activity during short pauses between muscle contractions, which may be a response to perceived pain and fatigue.[169] Studies found that patients with FMS or CFS do not sustain repeated muscle contractions at the same intensity as controls.[170–172] Other studies show that they do.[173–174] However, when electrical stimulation of muscles accompanied repeated contractions, the contraction intensity and duration matched those of controls.[175]

Central Nervous System Origin Pain modulation may be disrupted in FMS at the spinal cord level or in higher CNS centers. Although endorphin levels have been found to be normal,[176–178] lowered levels of serum tryptophan[179] and elevated levels of substance P[180] may amplify pain perception. Blunting of the hypothalamic–pituitary axis to stressors is also a factor.[131]

Pituitary hormone secretion changes have been found in patients with FMS.[181–183] Growth hormone is adversely affected by sleep deprivation.[184] The production of an FMS-like state in healthy volunteers through alpha-delta sleep induction[185] may point to a role for abnormal growth hormone secretion in FMS symptom production.[161]

The limbic system has also been implicated as a contributor to FMS. This area affects sensory gating and processing of sensory input.[186] Autonomic nervous system dysfunction has also been suggested by the results of several studies.[156,187] An inverse relationship between sympathetic reactivity and pain sensitivity has been found. Stress and anxiety associated with FMS would be expected to increase sympathetic tone, but the expected commensurate increase in plasma and urinary catecholamines was not found.[188] A lowered level of sympathetic activation has been postulated, and may be a source of increased pain sensitivity in patients with FMS.[189]

Like other patients with chronic pain, central sensitization and "windup" occur in patients with FMS.[131] Patients with chronic pain described their pain as dull, aching, or burning; these symptoms are transmitted by the unmyelinated C fibers. When this type of pain is evoked, the perceived pain is greater for patients with FMS than for controls.[131] In patients with FMS, fibers that previously had no association with pain stimuli now begin transmitting pain, furthering the central sensitization phenomenon.[131]

There may be a genetic predisposition to FMS because first-degree relatives of patients with FMS have a higher than expected frequency of FMS. It has been proposed[190,191] that FMS can occur with exposure of genetically susceptible individuals to any one or a combination of the triggers associated with FMS onset.[132–134,141,176]

Signs and Symptoms

FMS is a chronic condition in which symptoms wax and wane but are typically unrelenting. In addition to pain and fatigue, this population experiences lowered respiratory function,[104] joint range of motion, decreased muscle strength and endurance,[93,192–194] and below average cardiovascular fitness levels.[93] FMS is listed in the American College of Rheumatology (ACR) classification of rheumatic disease as an extraarticular disorder. In a multicenter study,[102] which established the 1990 ACR criteria for definition of FMS, the most common symptoms of patients with FMS were:

- Fatigue, sleep disturbance, and morning stiffness (73% to 85% of patients)
- Pain all over, paresthesia, headache, and anxiety (45% to 69% of patients)
- Irritable bowel syndrome
- Sicca syndrome (i.e., dry eyes and mouth)
- Raynaud phenomenon (<35%)

In this same study, factors found to affect the musculoskeletal symptoms of patients with FMS included cold, poor sleep, anxiety, humidity, stress, fatigue, weather changes, and warmth, as they did to a lesser degree in control subjects. These are still the accepted guidelines for the classification of fibromyalgia.[134]

The diagnostic criteria for FMS were developed from this study (**Display 10-6**). The diagnosis is based on finding at least 11 of 18 tender points (**Fig. 10-12**) in the presence of widespread pain (i.e., pain in all four quadrants of the body, including at least part of the axial skeleton) persisting for at least 3 months' duration. Tender points were defined as anatomically discrete and reproducible areas of heightened pain perception in patients with FMS. Diagnosis may also be made when the full 11 of 18 tender points are not present but other features commonly found in the study are.[150]

Activity Limitations

Several studies have examined the effect of FMS on everyday life. Fifty-five percent of working patients were found to have changed work tasks and to work shorter hours than before the illness. Motor tasks were reported as being more difficult to perform than before FMS onset, and 67% reported no or short pain-free periods.[105]

The lack of objective findings in light of the patients' perception of their illness is stressful and can lead to feelings of rejection and of being misunderstood or disbelieved. These feelings compromise their ability to cope with the illness. Daily routines are disrupted, conflicts about life roles emerge and

DISPLAY 10-6

Classification of Fibromyalgia*

1. History of widespread pain.
   Definition: Pain is considered widespread when ALL of the following are present: pain in the left side of the body, pain in the right side of the body, pain above the waist, and pain below the waist. In addition, axial skeletal pain (cervical spine or anterior chest or thoracic spine or low back) must be present. In this definition, shoulder and buttock pain is considered as pain for each involved side. Low back pain is considered lower segment pain.
2. Pain in 11 of 18 tender point sites on digital palpation.
   Definition: Pain on digital palpation must be present in at least 11 of the following 18 tender point sites:
   Occiput: bilateral, at the suboccipital muscle insertions
   Low cervical: bilateral, at the anterior aspects of the intertransverse spaces at C5–7
   Trapezius: bilateral, at the midpoint of the upper border
   Supraspinatus: bilateral, at origins, above the scapula spine near the medial border
   Second rib: bilateral, at the second costochondral junction, just lateral to the junctions on upper surfaces
   Lateral epicondyle: bilateral, 2 cm distal to the epicondyles
   Gluteal: bilateral, in upper outer quadrants of buttocks in the anterior fold of muscle
   Greater trochanter: bilateral, posterior to the trochanteric prominence
   Knee: bilateral, at the medial fat pad proximal to the joint line
   Digital palpation should be performed with an approximate force of 4 kg. For a tender point to be considered "positive," the subject must state that the palpation was painful. *Tender* is not to be considered *painful.*

**For classification purposes, patients are said to have fibromyalgia if both criteria are satisfied. Widespread pain must have been present for at least 3 months. A second clinical disorder does not exclude the diagnosis of fibromyalgia.*

From Wolfe F, Smythe HA, Yunus MB, et al. The American College of Rheumatology 1990 criteria for the classification of fibromyalgia. Arthritis Rheum 1990;33:160–172.

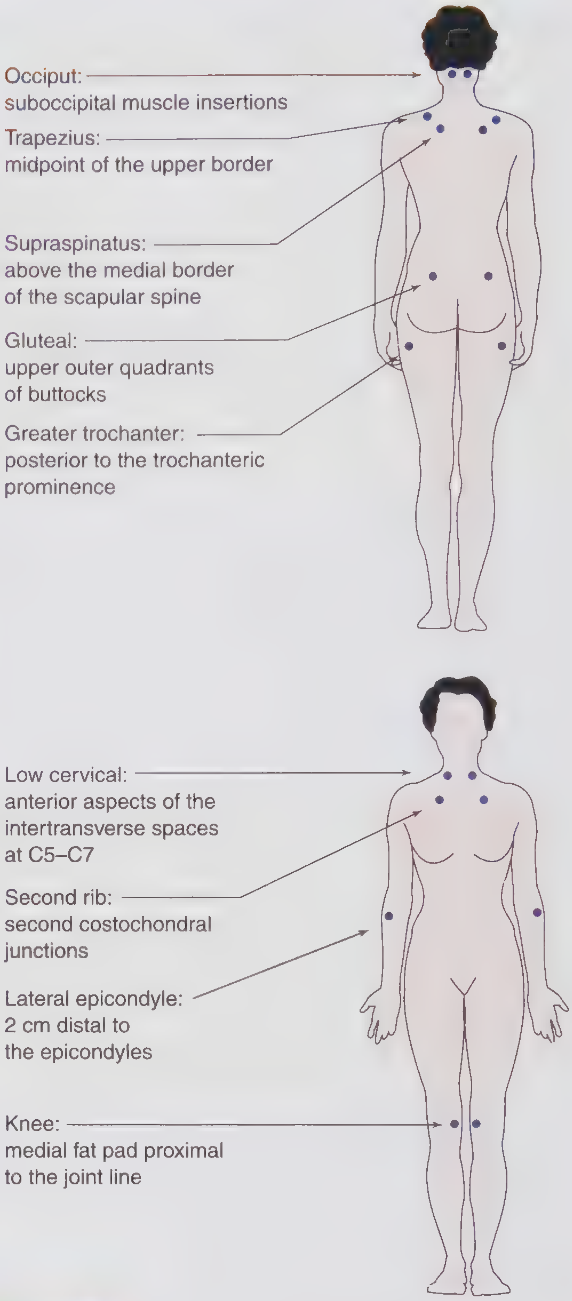


FIGURE 10-12 Location of 18 tender points.

lead to further stress, and loss of physical fitness and loss of future opportunities occur. Patients need early and adequate information, along with acknowledgment of the conditions to minimize psychosocial consequences.[108]

Chronic Fatigue Syndrome

Chronic fatigue syndrome is characterized by profound fatigue. Descriptions of similar illnesses are found throughout the medical literature.[151,152] These disorders include neurasthenia, myalgic encephalomyelitis, and chronic Epstein–Barr virus infection (i.e., "yuppie flu"). With an estimated incidence of 0.1%, CFS is much less prevalent than is FMS, and studies suggest that CFS affects both sexes and occurs across almost all races and ethnic groups.[195]

Etiology

Various studies have looked for the causes of CFS.[196,197] Neuroendocrine changes, especially in hypothalamic hormone production or release of corticotrophin-releasing hormone, have been found.[198] Patients with CFS also have widespread pain with characteristics of central sensitization similar to patients with FMS.[199,200] Up to 70% of patients with CFS simultaneously present with FMS.[135] Involvement of the HPA axis facilitates the inflammatory pathways and combined with the oxidative pathways (associated with mitochondrial dysfunction) produce pain, fatigue, cognitive impairments, and depression.[201,202] Mitochondrial dysfunction has been found in patients with CFS.[203–205]

Signs and Symptoms

The onset of CFS is typically sudden, and the fatigue is profound. Twenty-five percent of patients with CFS are bedridden or unable to work, and 33% can work only part-time.[109] Patients with CFS may tolerate exertion at first, but 6 to 24 hours later, symptoms often increase.

In 1994, the Centers for Disease Control and Prevention (CDC) published a working case definition of CFS[206] (**Display 10-7**). This definition is still current.[207] Unexplained, debilitating fatigue of at least 6 months' duration that is unalleviated by rest, and four of eight listed symptoms are required for case definition.

Among the eight symptoms detailed by the CDC, sleep disruption is reported by about 95% of patients with CFS. Other common complaints include neurocognitive difficulties, muscle weakness, frequent need for naps, dizziness, shortness of breath, and adverse responses to stress.[107] Comparison of the diagnostic criteria for FMS and CFS shows a broad overlap, and their exact relationship is in question.[195]

> **DISPLAY 10-7**
>
> **The Centers for Disease Control and Prevention Working Case Definition of Chronic Fatigue Syndrome**
>
> Fatigue criteria and four of eight symptom criteria must be present to fulfill the case definition.
>
> **Fatigue Criteria**
>
> 1. Persistent or relapsing fatigue that
>   a. Has been clinically evaluated
>   b. Is of definite onset
>   c. Is not the result of exertion
>   d. Results in substantial reduction in activity
> 2. Other conditions that explain the fatigue have been excluded, including:
>   a. Active medical conditions (e.g., untreated hypothyroidism)
>   b. Previously diagnosed medical condition whose resolution has not been clinically documented (e.g., treated malignancies)
>   c. Past or present psychotic or melancholic depression, bipolar disorder, schizophrenia, delusional disorders, dementia, anorexia nervosa, bulimia
>   d. Alcohol or substance abuse within 2 years of the onset of fatigue or anytime thereafter
>
> **Symptom Criteria**
>
> Persistent or recurrent symptoms lasting more than six consecutive months:
>
> 1. Self-reported impairment in short-term memory or concentration, which causes substantial reduction of occupational, educational, social, or personal activities
> 2. Sore throat
> 3. Tender posterior cervical, anterior cervical, or axillary lymph node pain
> 4. Muscle pain
> 5. Multijoint noninflammatory arthralgias
> 6. New or different headaches
> 7. Unrefreshing sleep
> 8. Prolonged (at least 24 hours) generalized fatigue after previously tolerable levels of exercise
>
> *From Buchwald D. Fibromyalgia and chronic fatigue syndrome. Similarities and differences. Rheum Dis Clin North Am 1996;22:219–243.*

THERAPEUTIC EXERCISE INTERVENTIONS FOR COMMON IMPAIRMENTS

Clinical manifestations of FMS and CFS include evidence of impairments that affect functioning. Studies carried out over the past 10 years[110–112,208–212] and reviews of treatment approaches for FMS and CFS[113,195,213] support the need for multidisciplinary intervention in the treatment of these impairments. Pharmacology, psychotherapy, education, and aerobic exercise are used successfully in many cases.[214–216]

Therapeutic exercise can address six main areas of impairment:

1. Muscle power functions
2. Exercise tolerance functions (impaired aerobic capacity)
3. Mobility of joint functions (impaired ROM)
4. Muscle endurance functions (impaired posture)
5. Emotional functions (impaired response to emotional stress)
6. Pain

There will be overlap in the impairments addressed within any given session, but it is advisable to start with an emphasis on the less demanding regimens (e.g., relaxation and muscle stretching) early in the course of treatment to build patient confidence in exercise and a greater acceptance of more aggressive exercise later. As treatment progresses, increase the intensity and difficulty of the intervention, monitoring patient response and adjusting (and teaching the patient to monitor and adjust) appropriately, working toward functional goals (**Table 10-2**). Therapeutic intervention for a structured return to physical activity is suggested for patients with CFS because complete inactivity appears to promote fatigue.[195] Although little literature exists on the effect of exercise for CFS,[162] one study showed improvement in global self-assessment scores for patients with CFS after aerobic exercise training.[212] Treatment of FMS-like symptoms of CFS could follow the FMS protocols suggested in the next sections, and physical symptom exacerbation should guide progression of the program.

Impaired Muscle Power Functions

Muscle performance in patients with FMS declines compared with the case in controls. Perception of pain and fatigue may limit production of muscle contraction force and eventually affect functional activities of the patient because of resulting deconditioning. Once existing muscle imbalances are successfully addressed, patients can begin to direct their energy toward general strengthening routines for conditioning, especially if this goal is a priority for them. There is evidence that increasing general strength levels affects FMS symptoms positively.[116,215]

The same conditions apply to exercise prescription for general strengthening as to treatment of specific movement faults. The program should start with low-resistance and low-repetition work, avoid static holding, monitor symptoms, and progress slowly. Allowing the patient to choose the form of exercise may increase enjoyment and compliance. Exercise can be isometric or isotonic. If isometric activities are chosen, avoidance of

TABLE 10-2

Exercise for Patients with Fibromyalgia

Early Phase

- Goal: stress and pain management
- Progressive relaxation
- Diaphragmatic breathing
- Visualization
- Active movement of nonpainful areas
- Stretch

Midphase

- Goal: musculoskeletal balance
- Self-mobilizations
- Active movement involving more joints
- Strain–counterstrain
- Muscle system balance exercises
- Core stabilization
- Functional movements
- Early aerobic exercise: recumbent bike, unloading equipment, easy exercises in water

Late Phase

- Goal: transition to wellness
- Stretch
- Musculoskeletal balance
- General strength: resistance tubing, machines, free weights
- Aerobic exercise: non–weight-bearing to weight-bearing and nonjarring activities (elliptical, stepper, seated stationary bike, treadmill) and water exercises (aerobics, flotation belt)

TABLE 10-3

Sample Strengthening Program

Water Program: 3 d/wk

- Warm-up: slow walking forward, backward, sideways: with or without arm movement depending upon upper extremity involvement (approximately 5 min)
- Slow-speed arm movements with short lever arm and decreased surface area (5–10 repetitions)
- Flexion/extension
- Horizontal abduction/adduction
- Abduction/adduction
- Rotation
- Slow-speed leg kicks into flexion and abduction (5–10 repetitions)
- Squats or stepping exercise
- Bicycling with legs
- Gentle stretching and walk for cool down

Land Program: 3 d/wk

- Walking in home or around neighborhood
- Abdominal muscle strengthening (e.g., pelvic tilts, bridging, stabilization)
- Stepping exercise (such as wall slide, squat, stair step exercise)
- Upper extremity exercise with very light resistance (1–2 lb or less)
- Gentle stretching exercise

prolonged static holding is important. Contractions should not be held longer than 3 to 5 seconds, with three to six repetitions of the exercise performed three times each week, a level that has been demonstrated to increase periarticular muscle strength.[217]

In dynamic exercise, slow movement through full range with return to the lengthened range allows a slight muscle stretch between contractions. Resistance exercise using free weights, tubing machines, or the water's viscosity are all useful if dosed properly, including appropriate recovery time. Aquatic therapy has been shown to be very effective for strengthening and aerobic exercise for patients with FMS.[216] Closed chain lengthening exercises such as T'ai Chi, Pilates, or yoga are useful when the patient is ready for active movement. If no prior weight training has been done by the patient, calibrating the response by starting with three to five repetitions of three to five exercises at the lightest weight and monitoring the response over 24 to 48 hours can provide the baseline of the patient's tolerance. Patience is important in introducing exercise to decrease setbacks. **Table 10-3** provides a sample program.

Exercise Tolerance Functions: Impaired Aerobic Capacity

Because aerobic exercise may have a positive effect on some of the impairments seen in patients with FMS and CFS, including endurance, pain, and flexibility, it should be introduced as soon as possible. Patients with FMS who participate in an aerobic exercise have been shown to improve overall well-being, improve ability to perform aerobic exercise, decrease tender point pressure pain, and reduce overall pain.[214] Exercise programs were performed for at least 20 minutes per day, 2 to 3 days per week and included strength training. The exercise should progress to being of moderate intensity.[215]

Initially, only a few minutes of the activity should be allowed (2 to 5 minutes, unless the patient is already active for longer periods without symptom flares) to allow the gradual buildup of tolerance. By the late phase of rehabilitation, the patient may be ready to work on elevation of the heart rate to 50% to 60% of the maximum heart rate. Monitoring techniques including the training index, pulse determination, and use of the perceived exertion scale[218] should be discussed, so pacing and progress can be monitored. The patient should keep a record of exertion and symptoms to facilitate this. A variety of electronic equipment is available to make tracking activity simpler.

During the first session, it may be a good idea to make a contract with the patient to start preaerobic activities of daily walking, even if only one-half of a block. For the patient who is able to walk more than one-fourth of a mile, a high school track offers several advantages. Typically, it has a shock-absorbing surface; it is a safe place to use headphones without worrying about traffic, which may make it more enjoyable; accurate distance estimates are possible, so progress in distance and rate can be tracked; and the patient who fatigues part way through can usually walk back to a car rather than all the way home or have to ask someone to come for him or her. It is important to consider the patient's interests and goals in designing a walking program and in suggesting a particular environment. Initially, the rate of walking should be slow and comfortable until tolerable levels, without a flare of symptoms, can be established.

Another approach to introducing exercise gently is to have the patient exercise on a recumbent bike or walking in a swimming pool. During the first session, the patient should walk or pedal about 2 to 3 minutes; 1 to 2 minutes can be added each session (at first not more than once a day) until, by the late phase of treatment, the patient may reach 15 minutes. After the patient is able to exercise on the bike or pool for 20 to 25 minutes, it should be possible to allow the patient to choose some other form of nonjarring aerobic exercise that is personally enjoyable. Community pool programs with classes for patients with fibromyalgia have the added benefit of social contact. For some patients with FMS, socializing has been markedly decreased because of fatigue and pain. Nonjarring sources of aerobic exercise for slightly more advanced patients may include a treadmill, ski machine, seated push–pull arm and leg machines, rowing ergometer, and minitramp (see **Selected Intervention 10-1**).

SELECTED INTERVENTION 10-1

Treatment of the Patient with Fibromyalgia

See Case Study No. 7

Although this patient requires comprehensive intervention, as described in the patient management model, one exercise is described.

ACTIVITY: Hand-to-knee pushes

PURPOSE: To increase abdominal and hip flexor muscle strength; improve single-leg balance and trunk stability; and increase upper quarter strength through closed chain activity.

RISK FACTORS: No appreciable risk factors

STAGE OF MOTOR CONTROL: Stability

POSTURE: Standing position on a single leg. The opposite hip and knee are flexed to 90 degrees. The opposite hand of the flexed leg pushes isometrically against the movement of hip flexion. A neutral spine is maintained, and concentration on abdominal muscle contraction is emphasized.

MOVEMENT: Isometric contraction of the abdominal, hip flexor, and contralateral upper quarter muscles.

SPECIAL CONSIDERATIONS: Ensure proper posture of the trunk, pelvis, and weight-bearing limb. Cue for an abdominal muscle contraction, using palpation as necessary. This exercise is contraindicated when an isometric muscle contraction is contraindicated.

DOSAGE: Hold contraction for 3 to 6 seconds at a comfortable intensity that does not cause hip flexor or shoulder fatigue. Repeat on the opposite side.

TYPE OF MUSCLE CONTRACTION: Isometric

Intensity: Submaximal

Duration: Hold for up to 6 seconds

Frequency: During each pool session

RATIONALE FOR EXERCISE CHOICE: This exercise addresses the many components of fibromyalgia, including trunk stability, single-leg stance stability, abdominal muscle endurance, and upper and lower quarter muscle endurance.

EXERCISE GRADATION: This exercise is progressed to greater intensity and more repetitions. More advanced stabilization exercises incorporating upper and lower extremity movements with resistance are then added.

When introducing aerobic exercise routines, the therapist should let the patient know that continuous monitoring and pacing are important. During periods of symptom flares, the patient should be encouraged to modify exercise intensity appropriately and not discontinue altogether (**Evidence and Research 10-5**). It is easy for patients to become discouraged and stop a program. Their records and the encouragement of the clinician may help them push through this difficult time and allow them to comply with what appears to be one of a few treatment approaches with a positive impact on FMS.

EVIDENCE and RESEARCH 10-5

In several studies of the effects of aerobic exercise on FMS, the first 10 to 12 weeks were problematic for musculoskeletal symptom flares and for adherence.[110,115] A systematic review of exercise in FMS[219] reports adherence to exercise and attrition in study subject numbers (25% average in the studies cited) was a problem. Some patients complained of a flare of pain or fatigue during and after exercise, and it is pointed out that positive findings reported with exercise in these studies might be attributable to attrition bias. Mengshoel,[115] however, maintains that patients can perform low-intensity dynamic exercise without a flare of symptoms.

Mobility of Joint Functions: Impaired Range of Motion

Restrictions in joint ROM may exist at any joint held for prolonged periods in abnormal alignment. Joints particularly affected by static poor posture can include craniovertebral, cervicothoracic, scapulothoracic, glenohumeral, radiohumeral, midthoracic, lumbopelvic and pelvofemoral, and subtalar joints. Intervention with soft-tissue and joint mobilization techniques where deemed appropriate should always be supported with exercises designed to balance muscles around the affected joints. Patient efficacy and responsibility with self-treatment in this chronic condition is an important part of patient education for self-management.

Where joint hypermobility or poor proximal stability is present, concurrent use of stabilization training (e.g., in craniovertebral flexion during self-stretch of suboccipital muscles, uptraining of longus capitis, and downtraining of scalenes and sternocleidomastoid muscles) is necessary for the preservation of good joint alignment.

Flexibility exercises should be graded for exertion and time. The typical 20- to 30-second hold during stretching may be too long when effort is required to hold a limb. Passive support or decreased time may be necessary. Stretching should never be painful. Breathing instruction during training is important as breath holding can be a characteristic of patients with FMS[104] (see **Self-Managements 10-9**, **10-10**, and **10-11**).

Muscle Endurance Functions: Impaired Posture

The biomechanical faults resulting from poor postural alignment can contribute to FMS pain,[113,149] and poor postural alignment can play into the reduced respiratory capacity of patients. Postural

SELF-MANAGEMENT 10-9

Neuromuscular Relaxation of Suboccipital Muscles

Purpose: To restore normal length to one group of suboccipital muscles and to decrease craniovertebral compression and possibly relieve headache.

Position: Lie on your back with your knees bent, feet flat on the floor, and neck supported on a small pillow or towel roll.

Movement Technique: Gently tuck your chin without lifting your head.

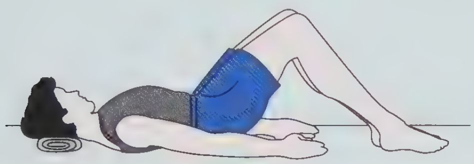
Hold for 6 seconds.

Relax.

Dosage:

Repetitions: ______________________

Frequency: ______________________



SELF-MANAGEMENT 10-10

Neuromuscular Relaxation of a Second Set of Suboccipital Muscles

Purpose: To restore normal length to a second set of suboccipital muscles and to decrease cranio-vertebral compression and possibly relieve headache.

Position: Lie on your back with your knees bent, feet flat on the floor, and neck supported on a small pillow or towel roll.

Movement Technique: Glide your head to the right without bending your neck.

With one fingertip on the bone behind your right ear, gently push your head to the left, but resist isometrically with your muscles on the right side of your neck.

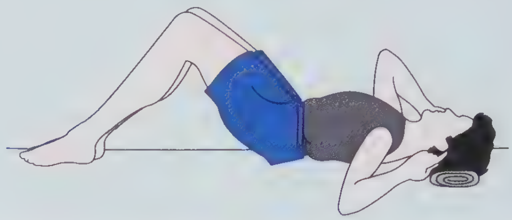
Hold for 6 seconds.

Repeat on the opposite side.

Dosage:

Repetitions: ______________________

Frequency: ______________________



SELF-MANAGEMENT 10-11

Neuromuscular Relaxation of a Third Set of Suboccipital Muscles

Purpose: To restore normal length to a third set of suboccipital muscles and to decrease cranio-vertebral compression and possibly relieve headache.

Position: Lie on your back with your knees bent, feet flat on the floor, and neck supported on a small pillow or towel roll.

Movement Technique: Lift your chin about one-eighth of an inch, so your head tips back.

Bring your right ear toward your right shoulder one-eighth of an inch, so your head tips to the right.

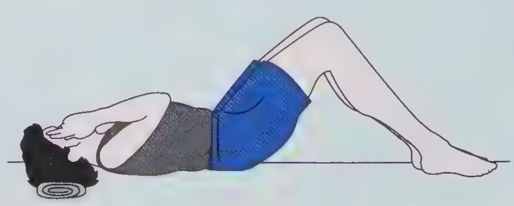
Turn your head one-eighth of an inch to the right, so your head rotates to the right.

With one fingertip on the right temple, gently push your head back to the left, but use your neck muscles to resist, so no motion occurs.

Dosage:

Repetitions: ______________________ times on each side (do not alternate)

Frequency: ______________________



assessment in all postures typical for the patient (standing, sitting, resting, and static or repetitive work postures) is important. Instruction regarding appropriate adaptation of standing, sitting, and lying surfaces with shock-absorbing pads, supports, and equipment realignment may be needed. And, often, verbal and manual cueing for proper muscle recruitment to maintain good alignment is necessary.

Along with stretching, strengthening for muscle balance around affected joints is necessary. The Sahrmann approach to muscle balance (see Chapter 9) appears to be an especially effective and well-tolerated approach to treating patients with FMS. These exercises are specific and can be progressed slowly, allowing pacing to minimize overexertion. Most do not require resistance equipment and are easily related to functional tasks (e.g., reaching overhead without shoulder or back pain, standing without back or hip pain).

Static posture is a starting point for return to function where dynamic activity against gravity is required. Stabilization exercises for trunk and proximal limb girdle muscles are useful when muscle weakness or joint hypermobility impairments exist and proximal control during functional tasks with the limbs is compromised. This is especially true for spinal segmental dysfunction. An approach that has been nonstressful for patients is the use of graded-resistance tubing attached to the wall or door, with the performance of scapular strengthening exercises while neutral trunk alignment is maintained (**Fig. 10-13**). This exercise can be progressed in difficulty by adding movement of the entire body (e.g., stepping) against resistance while holding a neutral alignment.

Stability control is an important part of functional activity, one that is frequently lost in deconditioned patients. Closed-chain activities and movement therapies, including T'ai Chi Chuan, Feldenkrais, and low-level therapeutic ballet classes, are exercise strategies that may help restore periarticular muscle balance and function and stimulate vestibular balance (**Fig. 10-14**). These classes may be more enjoyable for patients, and may increase adherence. Introduction of these strategies should be slow, probably after successful introduction of concentric forms of exercise, and always according to the patient's tolerance and carefully monitored for progression of intensity, duration, and frequency.

FIGURE 10-14 T'ai Chi is an excellent exercise strategy to help restore control and balance to the movement patterns of deconditioned patients. The teacher should have experience working with patients with joint problems or chronic illness.

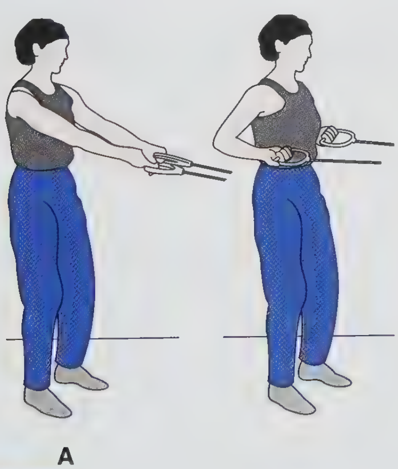


FIGURE 10-13 The use of graded-resistance tubing attached to the wall, with performance of upper extremity PNF diagonals provides a nonstressful stabilization exercise. **(A)** Holding onto the tubing, the patient crosses her wrists with her palms facing downward. **(B)** Maintaining her hand at waist level, the patient bends her elbows as she turns her palms upward.

Emotional Functions: Impaired Response to Emotional Stress

If the evaluation indicates a need for stress management, it should be initiated in the early phase of treatment, probably within the first or second visit. Stress management may include an exercise program with relaxation, deep breathing, and stretching exercises. These are unlikely to be stressful to most patients and usually provide benefits that are immediately obvious and typically pleasurable. This approach can provide a positive introduction to the benefits of exercise and offer an opportunity to demonstrate that exercise does not have to mean maximal exertion to be beneficial. Progressive relaxation, autogenic deep breathing, and visualization exercises (see Chapter 24) can be taught, or tapes can be made available to patients for use at home. In addition, patients may benefit from referral to an appropriate mental health professional for related services.

Instruction in diaphragmatic and lateral costal expansion breathing (see Chapters 22 and 24) can help respiratory function and is a good adjunct to any treatment requiring soft-tissue or joint mobilization of the thoracic cage (see **Self-Management 10-12**). Relaxation in a warm pool along with

SELF-MANAGEMENT 10-12

Neuromuscular Relaxation of Tight Rib Joints

Purpose: To decrease tightness at the rib joints and decrease posterior costovertebral pain.

Position: With the help of your therapist or after you are experienced, push on the rib in the front that corresponds with the level of pain on the back.

Even though this might not have seemed painful to you until you touched it, it will feel almost like a red-hot type of pain if it is the correct level. The place you push in front is on the same side as the back pain and near where the rib attaches to the sternum.

After you have located the spot, place the fist of the same-side hand flat against the spot.

Press the opposite hand on top of your fist; your elbow on the side of the pain sticks out.

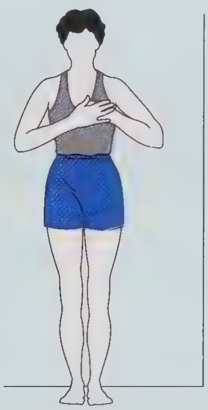
Movement Technique: Stand next to a wall or have a partner gently resist that elbow as it starts to elevate from your side.

Hold for a slow count of 6. *Be very gentle with resistance.*

Dosage:

Repetitions: ________________
times on each side (do not alternate)

Frequency: ________________



diaphragmatic breathing while immersed provides resistance to the muscles of inspiration. General stretching following accepted guidelines (see Chapter 7) can be prescribed if no joint instability has been identified. It is often necessary to make the patient aware of the distinction between stretch and pain, which can be difficult when generalized pain and aching is chronic and patients have learned to disregard these signals. If static stretching is uncomfortable, consider gentle dynamic mobility to begin.

In introducing these exercises, it may be useful to suggest that the patient choose a pleasurable place at a time when interruptions are minimal. Ensure proper recovery time so that the stress and recovery components stay in balance, maintaining homeostasis.

PRECAUTIONS AND CONTRAINDICATIONS

Exercise can be a two-edged sword for patients with FMS or CFS. Overexertion can lead to a relapse or exacerbation of symptoms.[110,115,162,208,211] Because most persons with FMS or CFS have experienced this phenomenon, they may resist the idea of exercise, and adherence to an exercise program may be difficult (see Chapter 3).

Pacing

Pacing is crucial for patients who are chronically fatigued.[220] For people who have been active exercisers before the onset of the disease, the inability to meet previous exercise goals may be a source of grief or frustration. Others may fear that exercise means lap swimming or jogging. The concept of therapeutic exercise and the importance of pacing need to be carefully explained.

Most patients have experienced symptom flares with overexertion. Initiating an exercise routine requires starting slowly, with few repetitions (three to five may be enough the first time), light resistance (none to very minimal), and a limited number of exercises (usually, three are enough). Feedback 24 to 48 hours after exercise is necessary for pacing the progression of the program. Exacerbations of FMS were triggered in one study that looked at the effects of repetitive dynamic muscle contraction and sustained static muscle contractions in patients with FMS and in sedentary, healthy control subjects. It was found that, 24 hours after exercise, exercise-induced extremity pain had not returned to preexercise levels in patients with FMS.[158] Patients need sufficient recovery time and strategies, and these will vary from one individual to the next. The training index is one form of monitoring that can be used to help the patient in pacing. The training index was originally introduced for use in cardiac patients by Hagberg[221] and modified by Clark[222] for use in patients with FMS. This is a quantitative measure of exertion based on simple calculations using pulse rate and the duration of exercise. The training index provides target values for basic cardiovascular fitness, which may be used by patients to track their progress toward these goals. Some patients may find it helpful to keep a diary of daily activities to monitor possible correlations between symptoms and activity levels, and this may also be a useful pacing tool.

Pharmacological and Psychological Intervention

Pharmacological therapy is based on findings of neurohormonal alterations and sleep disruption in CFS and FMS and on treating associated symptoms (e.g., fever in CFS, muscle pain, and gastrointestinal irritation in CFS and FMS). Low-dose tricyclic medications, which in much larger doses act as antidepressants, may be beneficial in addressing pain and sleep disruption. Selective serotonin-uptake inhibitors may help the fatigue component.[213] Buchwald[195] points to anecdotal reports of antiviral and immunomodulating drugs in the treatment of CFS. Simms[213] offers a complete review of the pharmacological treatment of FMS.

The association of pain, fatigue, depression, and disordered sleep of FMS and CFS is a sign of central sensitization.[151,223–225] These symptoms are additionally stressful for many patients and those around them.[108] The effects of these chronic, long-term conditions can be profound.[105,108] Various types of psychotherapeutic and educational interventions aimed at teaching coping strategies and lifestyle adjustments have been found to be beneficial. These include cognitive behavior therapies as well as self-management techniques such as mindful meditation.

One study[226] showed a 63% rate of return to work by patients with CFS after 1 year of cognitive behavioral therapy, and a study by Buckelew et al.[227] correlated higher self-efficacy with less pain and impairment in physical activities for patients with FMS. Self-efficacy can be defined as a belief that one can successfully do a thing. Self-efficacy has been shown to impact behavior, motivation, thoughts, and emotions.[227] A meditation-based stress-reduction program was also shown to be effective in improving physical symptoms.[228] Because CFS and FMS may be long-term, life-changing conditions, individual and group psychotherapy may be beneficial. In a review of programs using education for self-management of FMS, Burkhardt and Bjelle[229] concluded that self-efficacy and life quality can be enhanced for patients who undergo even short-term intensive treatment, with improvement lasting beyond the end of the program. Several organizations sponsor support groups and education classes throughout the United States and Canada (see **Patient-Related Instruction 10-4**).

Patient-Related Instruction 10-4

Organizations for Information About Fibromyalgia Syndrome and Chronic Fatigue Syndrome

For information about fibromyalgia or CFS, contact one of these organizations:

- The Arthritis Foundation is an excellent source of information, has support groups, and provides leadership training. Phone numbers of local chapters can be found in phone books.
- Fibromyalgia Alliance of America provides patient information and support group resources (FMAA, PO Box 21990, Columbus, OH 43221-0990, (614) 457-4222).
- Chronic Fatigue Immune Deficiency Syndrome Association of America, Inc., provides patient information, support group resources, and data on research, treatment, and conferences (CFIDS Assoc., PO Box 220398, Charlotte, NC 28222-0398, (800) 848-7373).

KEY POINTS

- Pain impairment occurs with most musculoskeletal conditions and must be treated as a primary impairment along with any secondary limitations that may result.
- Nociceptors, or pain receptors, transmit impulses from the periphery to the dorsal horn of the spinal cord and higher CNS levels.
- Pain information is transmitted through A-delta and C fibers, which are small, unmyelinated neuronal fibers.
- Information is processed within the spinal cord and then ascends through the contralateral spinothalamic tract to the thalamus.
- The gate theory of pain states that incoming information from nonpain receptors (e.g., thermal, mechanical) can close the gate to pain information.
- Chronic pain may result from increased sensitization of nociceptors and spinal level changes that perpetuate positive feedback loops in the pain-spasm cycle.
- Descending impulses can influence pain perception through several mechanisms, including endogenous opiates.
- Pain can be assessed through direct measurement tools such as the VAS or MPQ questionnaires or through quality of life scales such as the SF-36.
- Fear–anxiety–avoidance models help explain transitions from acute to chronic pain and can be measured with different tools.
- Therapeutic exercise is a cornerstone of treatment for chronic pain. It can remedy pain (through gating mechanisms and descending influences), secondary limitations caused by pain, and associated impairments and activity limitations.
- FMS and CFS are increasingly recognized in clinic patient populations, have widespread effects, and limit functioning.
- Exercise appears to be one of a few effective treatments for FMS and possibly for CFS.
- Because of the fatigue and ease of symptom exacerbation with exertion, exercise prescription must be done carefully and thoughtfully, tracking responses continuously.
- Exercise for the treatment of FMS and CFS can be expected to address stress, posture, and mobility impairments; impaired muscle performance; and cardiovascular endurance.
- Exercise should be introduced slowly and progressed from exercises likely to lead to success to those that may be more stressful. Relaxation, breathing, stretching exercises, and gentle, limited walking exercises can progress to strengthening and to slowly progressing aerobic exercises.
- Physical therapy treatments should always attempt to model the concepts of pacing and limiting overexertion and overcommitment as they apply to daily activities of the patient and in therapeutic exercise.
- The physical therapist should attempt to encourage good communication and establish mutually acceptable goals in an attempt to contribute to the patient's adherence to the exercise program.
- Aerobic exercise should be progressed slowly, be nonjarring, and be pleasurable if possible.
- During physical therapy treatment, patients often are undergoing adjunctive treatments from other medical disciplines, which may stress them in terms of energy, time, and resources. The therapist should be aware of the other commitments and help the patient prioritize realistically.

- The use of physical agents for pain control should be taught as self-treatment techniques, because using clinic time for their application may not be the best use of the patient's resources.
- Patients should be taught appropriate self-mobilization or neuromuscular techniques to cope with chronic biomechanical faults so that they have tools to manage their condition independently.

CRITICAL THINKING QUESTIONS

1. Consider Case Study No. 5 in Unit 7.
   a. This patient has pain with standing and walking. What interventions may improve this patient's ability to stand and walk without pain?
   b. This patient has pain with lumbar extension. How does your therapeutic exercise intervention address this problem?
   c. What suggestions can you give this patient to allow her to participate in social activities without pain?
2. Consider Case Study No. 7 in Unit 7.
   a. Design an exercise program to prevent further decline of her general deconditioning, with consideration of her overall fatigue and daily demands.
   b. Provide this patient with suggestions for energy-reducing measures to allow her to complete daily tasks without increasing pain or fatigue.
3. Outline the questions you would ask in the subjective portion of an evaluation of a patient with FMS. Be sure you cover the areas of their presentation that may affect development of the condition and that may contribute to its exacerbation.
4. What physical tests and measurements would you perform in the objective portion of the evaluation?
5. What forms of exercise would you need to introduce over time to the patient with FMS?
6. List the order in which you would probably introduce the various types of exercise over the course of treatment of the FMS patient.
7. Discuss special considerations for introducing exercise.
8. List the functional goals of physical therapy treatment that would be appropriate for this clinical population.

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Special Physiologic Considerations in Therapeutic Exercise

UNIT **3**

CHAPTER 11

Soft-Tissue Injury and Postoperative Management

LORI THEIN BRODY

Most musculoskeletal problems resolve with conservative management. Patients who develop overuse injuries, or have mild sprains, strains, or contusions, can expect to return to full function within a matter of days or weeks. For example, most patients with acute low back pain recover within 12 weeks without surgery.[1] However, some musculoskeletal problems do not resolve with conservative management alone. In these cases, surgical intervention may be necessary to return the patient to optimal function. Understanding the fundamentals of connective tissue physiology and response to stress forms the basis for rehabilitation programs designed for both conservative and postoperative management. Be sure to consider this information in the context of interventions used to improve mobility, aerobic capacity and muscle performance, as discussed in Chapters 5, 6 and 7. Appropriate management of acute injuries may prevent an acute injury from becoming a chronic condition (see Chapter 2).

PHYSIOLOGY OF CONNECTIVE TISSUE REPAIR

Soft tissues, including ligament, tendon, cartilage, bone, and other connective tissues, respond to injury in a relatively predictable fashion. The repair process is similar in all connective tissues, although some variability between tissues (e.g., bone) exists. Healing is also affected by age, lifestyle, and systemic factors (e.g., alcohol abuse, smoking, diabetes mellitus, nutritional status, general health) and local factors (e.g., degree of injury, mechanical stress, blood supply, edema, infection).[2,3] Understanding the healing phases helps the clinician choose interventions that are appropriate at various points in the healing process.

Microstructure of Connective Tissues

Tendon, ligament, cartilage, bone, and muscle are some of the major connective tissues in the body. The four main components of connective tissue are:

- Fibers (i.e., collagen and elastin)
- Ground substance with associated tissue fluids
- Solids (i.e., glycosaminoglycans such as proteoglycans)
- Cellular substances (i.e., fibroblasts, fibrocytes, and cells specific to each connective tissue)[3]

The function of the various connective tissues is based on the relative proportions of intracellular and extracellular components such as collagen, elastin, proteoglycans, water, and contractile proteins. At least 15 types of collagens (types I through XV) are known and differ fundamentally in the amino acid sequence of their constituent polypeptide chains, resulting in different slightly functions of each collagen (**Table 11-1**).[4,5]

Ligament is connective tissue attaching bone to bone. Water makes up nearly two-thirds of the weight of normal ligament, and collagen makes up 70% to 80% of the ligament's dry weight.[6] Nearly 90% of the collagen is type I, and 10% or less is type III collagen. Elastin is found in tiny quantities in ligaments, making up <1% to 2% of the total weight. Proteoglycans, another important solid found in ligaments, constitute <1% of the ligament's weight, but they are essential because

TABLE 11-1

Collagens of Connective Tissue

TYPE	DISTRIBUTION
I	Bone, ligament, tendon, fibrocartilage, capsule, synovial lining tissues, skin
II	Cartilage, fibrocartilage
III	Blood vessels, synovial lining tissues, skin
IV	Basement membranes
V	Pericellular region of articular cartilage when present,[a] bone, blood vessels
VI	Nucleus pulposus
VII	Anchoring fibers of various tissues
VIII	Endothelial cells
IX	Cartilage matrix[a]
X	Hypertrophic and ossified cartilage only
XI	Cartilage matrix[a]
XII	Tendon, ligament, perichondrium, periosteum
XIII	Skin, tendon

[a]Small amounts (<20%). From Walker JM. Cartilage of human joints and related structures. In: Zachazewski JE, Magee DJ, Quillen WS, eds. Athletic Injuries and Rehabilitation. Philadelphia, PA: WB Saunders, 1996:123.

of their water-binding properties.[2] This overall makeup of the ligament renders it a stiff structure with very little elongation when stressed or tensed.

Tendon is a connective tissue attaching muscle to bone. Collagen forms 70% of the dry weight of tendon, and the overall proportions are 30% collagen, 2% elastin, and 68% water.[7] The low proportion of elastin accounts for the low elasticity of tendon. If tendon were more elastic, the tendon would elongate with muscle contraction, rather than transmitting force to the bone. Muscle contraction would fail to move its insertion toward the origin, and no movement would take place. The structure provides some information about the function of this tissue.

Articular cartilage is composed of similar components, with nearly 80% of its weight from water. The high water content in articular cartilage, as in other viscoelastic tissues, is responsible for the mechanical properties of the tissue. The collagen makeup is primarily type II collagen, with small proportions of other collagen types.[5] Proteoglycans and their associated glycosaminoglycans are water-loving, or hydrophilic, molecules. Proteoglycans are responsible for the water-binding capabilities of articular cartilage, and proteoglycan loss results in a decreased water content and loss of the tissue's mechanical properties. Weight-bearing causes tissue compression and fluid extrusion from the tissue, while unweighting pulls fluid back in because of the hydrophilic nature of the proteoglycans. This action provides nutrition and lubrication for the articular cartilage. Thus, intermittent weight bearing is critical to the health of articular cartilage. As proteoglycans are lost with degenerative joint disease, the ability to resorb fluid is impaired, decreasing the ability to absorb shock or transmit loads.

Bone is composed of solid and fluid components, similar to other soft tissues of the body. Organic compounds such as type I collagen and proteoglycans constitute approximately 39% of the total bone volume.[8] Minerals contribute nearly half of the total bone volume, and fluid fills the vascular and cellular spaces comprising the remaining volume. The primary minerals found in bone are calcium hydroxyapatite crystals. These minerals differentiate bone from other connective tissue and provide bone with its distinctive stiffness.

Response to Loading

When connective tissues are loaded, the *stress* can be plotted against the *strain* providing much information about the material properties of the tissue. The relative contributions of composite materials determine the mechanical properties of the specific tissue. However, some general concepts about connective tissue responses can be determined.

Tensile loads are resisted primarily by the collagen fibrils, which respond first by straightening from their resting crimped state. This straightening requires little force (**Fig. 11-1**). In the elastic portion of the curve, the collagen fibers respond to the load in a linear fashion up to 4% elongation.[7,9] After the load is removed, the tissue returns to its original length, a characteristic of the elastic range only up to the elastic limit. Beyond this point, removal of the stress does not result in a return to the tissue's original length. If the tissue is elongated beyond approximately 4%, plastic changes begin to occur (i.e., plastic range) as the cross-links begin to fail. Permanent deformation is the chief characteristic of the plastic range. After some fibers fail, the load on the remaining fibers is increased, accelerating tissue

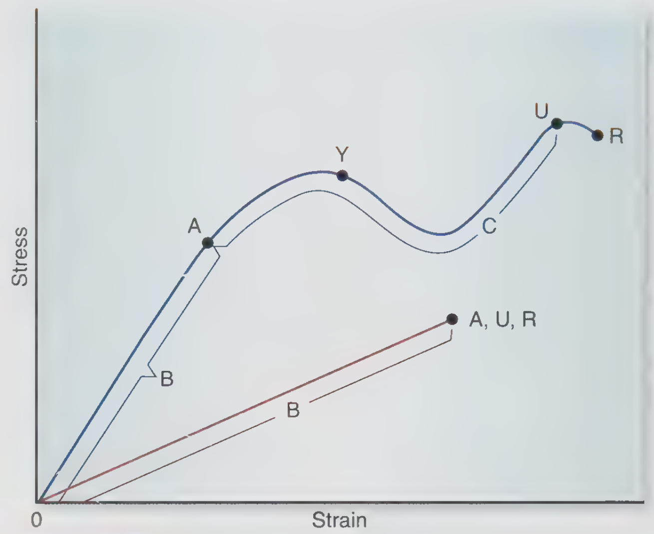

FIGURE 11-1 The stress–strain curve showing the elastic limit (A), elastic range (B), yield point (Y), plastic range (C), ultimate strength (U), and the rupture strength (R). (Adapted from Cornwall MW. Biomechanics of orthopaedic and sports therapy. In: Malone TR, McPoil T, Nitz AJ, eds. Orthopedic and Sports Physical Therapy. 3rd Ed. St. Louis, MO: Mosby, 1997:73; Rees JD, Wilson AM, Wolman. Current concepts in the management of tendon disorders. Rheumatology 2006;45:508–521.)

failure. The curve plateaus or even dips at the *yield point*. The *ultimate strength* is the greatest load the tissue can tolerate, and *rupture strength* is the point at which complete failure occurs.

The area under the curve represents the amount of strain energy stored in the tissue during loading. The viscoelastic nature of connective tissue results in an imperfect recovery after deformation, known as *hysteresis*. This difference between the loading curve and the unloading curve represents energy lost. This energy is lost primarily in the form of heat. A stretched tissue becomes warm in the process.

Other tissue qualities related to the load deformation curve are resilience and toughness. *Resilience* reflects a material's ability to absorb energy within the elastic range. As a resilient tissue is loaded quickly, work is performed, and energy is absorbed. When the load is removed, the tissue quickly releases energy and returns to its original shape. *Toughness* is the ability of a material to absorb energy within the plastic range. A critical quality of connective tissues is their ability to absorb energy without rupturing.

A relationship exists between stress and strain called the *elastic modulus*. The elastic modulus is the ratio of the stress divided by the strain and reflects the amount of stress needed to produce a given strain (i.e., deformation). The greater the stress necessary to deform the tissue, the stiffer is the material. For example, bone has a higher elastic modulus than meniscus and deforms less with a given load.

Cyclic loading alters the load deformation curve. Heat accumulates in the area of loading, disrupting the collagen crossbridges. Cyclic loading produces microstructural damage that accumulates with each loading cycle. Damage accumulates faster at higher intensities of cyclic loading.[10] Failure as a result of cyclic loading, called *fatigue failure*, is the physiologic basis underlying stress fractures. *Endurance limit* or *fatigue strength* is the stress below which fatigue cracks in bone do not begin to form.[10]

Connective tissues also demonstrate viscoelastic properties that provide these tissues with their uniquely mutable characteristics. These properties are creep and relaxation. When a tissue is held with a constant force, it begins to lengthen until equilibrium is reached or until the tissue ruptures, depending on the magnitude of the force. This property is called *creep*. When a tissue is pulled to a fixed length, a certain force is required. As the tissue is held at this length, the amount of force necessary to maintain that length decreases. This property is called *relaxation*. These properties allow connective tissues to adapt to and function in a variety of loading conditions without being damaged. Tissues pulled into tension (i.e., stretched) lengthen and relax, which provides the rationale for stretching exercises to lengthen shortened soft tissues (**Figs. 11-2** to **11-4**).

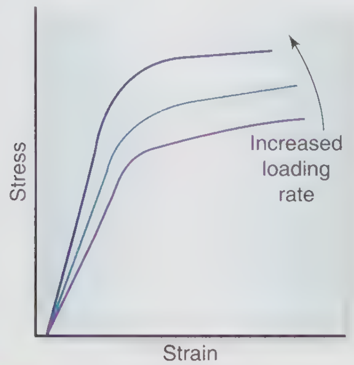

FIGURE 11-2 Three stress–strain curves for cortical bone tissues tested in tension at three different loading rates. As the testing rate increases, the slope (the elastic modulus) of the initial straight line portion increases. (Adapted from Burstein AH, Wright TM. Fundamentals of Orthopaedic Biomechanics. Baltimore, MD: Williams & Wilkins, 1994:120.)

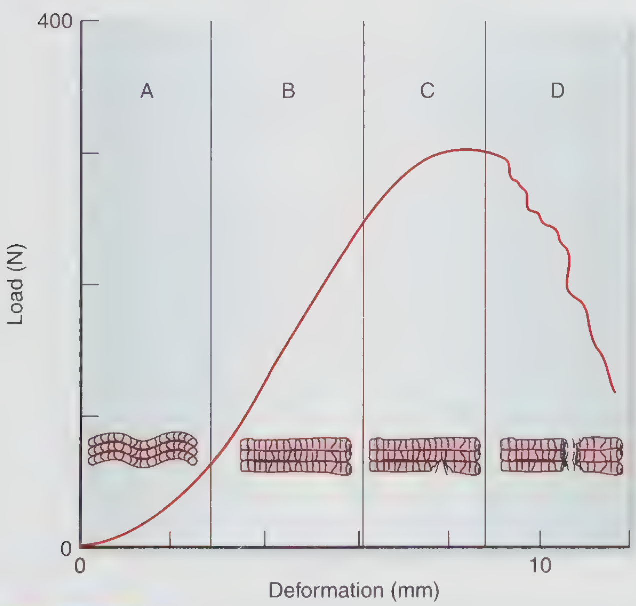

FIGURE 11-3 Stress–strain curve for ligament. As the ligament is distracted, fibers become progressively recruited into tension **(A)** until all the fibers are tight **(B)**. The parts of the ligament that are tightened first are likely to be the first to fail **(C)** as the ligament reaches the yield point. Progressive fiber failures quickly result in ligament failure **(D)**. (Adapted from Frank CB. Ligament injuries: pathophysiology and healing. In: Zachazewski JE, Magee DJ, Quillen WS, eds. Athletic Injuries and Rehabilitation. Philadelphia, PA: WB Saunders, 1996:15.)

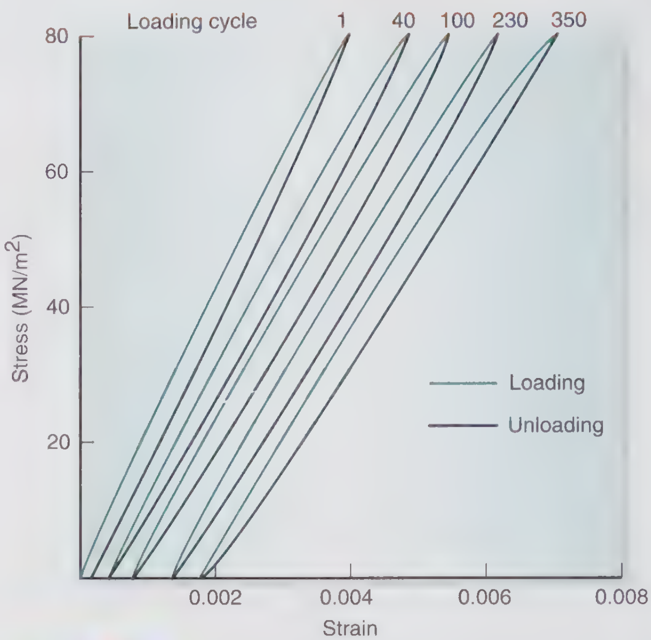

FIGURE 11-4 Effects of cyclic loading. When bone tissue is loaded cyclically to 90% of its tensile yield strength, nonreversible behavior (i.e., damage) is seen. By the 350th loading cycle, the elastic modulus has changed appreciably. (Adapted from Burstein AH, Wright TM. Fundamentals of Orthopaedic Biomechanics. Baltimore: Williams & Wilkins, 1994:125.)

Phases of Healing

The clinician must understand the phases of healing to formulate a plan of care matching the tissue's loading capabilities. The phases of healing provide a framework into which the rationale for physical therapy interventions fit. Understanding the healing process gives the clinician the tools to treat a variety of injury and surgical conditions.

Injury to the soft tissues arises from a number of sources. Physical traumas such as a sprain, strain, or contusion are most common, whereas injuries can also occur from bacterial or viral infections, heat, or chemical injury. Trauma causes direct damage to the cells in the immediate area of the injury, causing bleeding in the interstitial spaces. The bleeding initiates a cascade of events that promote healing of the injured tissue. The process can be considered in phases, although the continuum is an oversimplification of a very complex process. How the soft-tissue injury is managed is often responsible for the outcome of the injury. Any of four outcomes may result from the inflammatory process:

(a) Resolution when the injury is mild and transitory
(b) Replacement of the normal cell with fibrosis
(c) Abscess formation in the presence of an infection
(d) Progression to chronic inflammation resulting from persistent injury or individual factors (i.e., diabetes, corticosteroid use, and hematologic disease)[11]

Inflammatory Response

Healing of acute injuries passes through four major phases, beginning with the acute vascular-inflammatory response (**Fig. 11-5**). The purpose of the vascular changes is to mobilize and transport cells (white blood cells and leukocytes) to the area to initiate

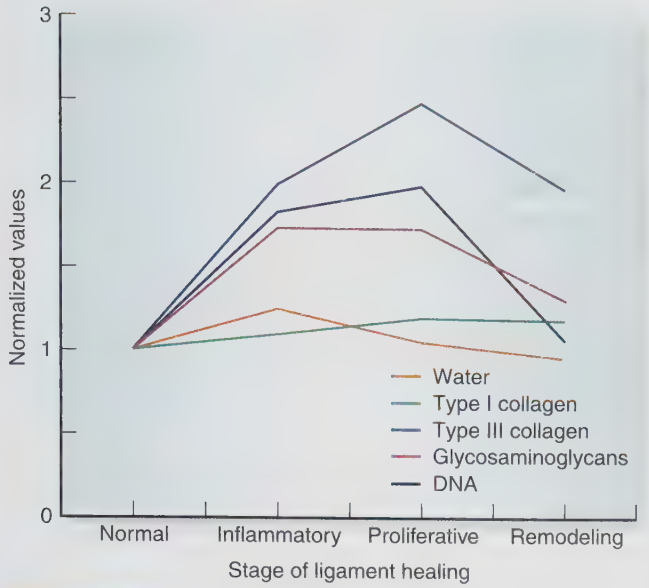

FIGURE 11-5 Changes in components of rabbit MCLs at various stages of healing. Values are normalized to that of uninjured ligament (normal = 1). (Adapted from Andriaacchi T, Sabiston P, DeHaven K, et al. Ligament: injury and repair. In: Woo SL-Y, Buckwalter JA, eds. Injury and Repair of the Musculoskeletal Soft Tissues. Park Ridge, IL: American Academy of Orthopaedic Surgeons, 1988:115.)

healing. When connective tissue is damaged, injured cells in the area release chemical substances (e.g., prostaglandins, bradykinin) that initiate the inflammatory response. The gap in the torn tissue is filled with erythrocytes and platelets.[1] The platelets form a plug to contain the bleeding and provide a scaffold for substances that will stabilize the clot. Local bleeding is a strong chemotactic stimulus, attracting white blood cells such as neutrophils and mononuclear leukocytes that help rid the site of bacteria and cellular debris through phagocytosis. Concurrently, in adjacent uninjured vessels, vasodilation occurs to increase local blood flow while capillary permeability is altered to allow greater exudation of plasma proteins and white blood cells. This produces swelling and edema in the area. In this phase, the damaged tissues and microorganisms are removed, fibroblasts are recruited, and some wound strength is provided by the weak hydrogen bonds of collagen fibers.[12] The inflammatory phase is essential in initiating the healing process. This phase is initiated immediately and lasts 3 to 5 days.[12]

Signs and symptoms observed in this phase are pain, warmth, palpable tenderness, and swelling. Pain and tenderness are caused by mechanical and chemical stimulation of nociceptors, and warmth and swelling are caused by acute inflammation. Limitations in joint or muscle range of motion (ROM) from pain or direct tissue damage are likely to occur. AROM testing usually reveals limited movement, and PROM reveals an empty end-feel, with pain limiting movement.

Focus **treatment procedures** in this phase at decreasing pain and edema while preventing a progressive chronic inflammation. Ice is effective at reducing pain and edema. Compression also controls edema by forcing fluid to areas of lower hydrostatic pressure in the capillaries and lymph vessels.[11] Maintain the mobility and strength of adjacent joints and soft tissues while the acutely injured areas are rested (see **Patient-Related Instruction 11-1**).

Patient-Related Instruction 11-1

Acute Injury Management

Take the following steps when an acute musculoskeletal injury or a flare-up of a preexisting injury occurs:

1. Ice the area for 10 to 15 minutes using cold packs or ice. Do this as often as possible throughout the day.
2. If possible, elevate the body part above the heart to decrease swelling.
3. Apply compression in the form of an elastic sleeve or bandage. Remove the compression at night for sleeping.
4. Use a supportive or assistive device (e.g., sling, splint, cane, crutches, walker) to rest the injury.
5. Contact your clinician or physician regarding the need for further examination and evaluation.
6. Resume previous program of care when instructed or able.

Proliferative/Fibroplasia Phase

The second phase, lasting from 48 hours to 6 to 8 weeks, is marked by the local presence of macrophages directing the cascade of events occurring in this proliferative phase. This phase may be referred to as the "repair-regeneration" phase, as there is a concurrent attempt at repair (replacement of the original tissue with scar tissue) and regeneration (replacement of the damaged tissue with the original tissue type).[13] Fibroblasts are actively resorbing collagen and synthesizing new collagen (primarily type III). The new collagen is characterized by small fibrils, disorganized in orientation and deficient in cross-linking.[12] Consequently, the tissue laid down in this phase is vulnerable and susceptible to disruption by overly aggressive activity. The greatest rate of collagen accumulation occurs between days 7 and 14.[13] As this phase progresses, a gradual decrease in tissue macrophages and fibroblasts occurs, and a grossly visible scar filling the gap can be seen.[14]

The warmth and edema resolve during this phase. Palpable tenderness decreases, and the tissue can withstand gentle loading. Pain is felt concurrent with tissue resistance or stretch of the tissue.

Treatment procedures in this phase include ROM exercises, joint mobilization, and scar mobilization to produce a mobile scar. These interventions are most effective during this stage of healing. Gentle resistance may be applied to maintain mobility and strength of the musculotendinous unit (**Building Blocks 11-1** and **11-2**).

BUILDING BLOCK 11-1

A 72-year-old woman with a history of left knee osteoarthritis experienced an increase in symptoms after a day of walking for the Relay for Life 3 days ago. She reports pain averaging 4 to 5 on a 0 to 10 scale during weight bearing, moderate swelling, and difficulty negotiating the stairs in her home. She is retired, but is an avid walker and enjoys weight lifting. Provide this patient with intervention strategies for this phase of treatment.

BUILDING BLOCK 11-2

Progress the 72-year-old patient from Building Block 11-1 to the next rehabilitation phase. Assume expected progress during the first phase.

In **bone**, this phase is referred to as the callus phase. Osteoclasts perform a function analogous to the macrophages in soft tissue. These cells debride the fracture ends and prepare the area for healing. The infrastructure for healing is assembled, including a capillary structure supporting callus formation. This callus bridges the gap between the fracture ends. The callus is an unorganized scaffold of cartilage that is easily deformed. Although bone repair is relatively weak at this point, limited activity is allowed. Gentle, cyclical loading promotes remodeling and maturation.

Treatment goals focus on applying light loads that will provide a stimulus for the tissue to remodel. Keep these loads within the tolerance of the newly formed tissue by monitoring signs and symptoms closely. Any increase in pain, warmth, or edema is a signal that the loads are exceeding tissue capabilities. Loads can be in the form of stretching, joint mobilization, ROM activities, light resisted exercises, or weight bearing.

Remodeling and Maturation

As healing progresses to the third phase, the remodeling stage, a shift is made to the deposition of type I collagen. This phase is characterized by decreased synthetic activity and cellularity, with increased organization of extracellular matrix. The collagen continues to increase and begins to organize into randomly placed fibrils with stronger covalent bonds. At this point, tension becomes important in providing orientation guidance to the organizing collagen. The new collagen must orient and align along the lines of stress to best accommodate the functional loads required. This tension can be imposed by stretching, active contraction (in the case of the musculotendinous unit), resistive loads, or electrical stimulation. Active tissue remodeling occurs throughout this phase up until approximately 4 months postinjury. The final end point is unknown and the tissue will continue to remodel and mature for 1 to 2 years postinjury. Although patients are discharged from formal rehabilitation by the time they reach the maturation phase, it is important for them to continue their rehabilitation exercises. The tissue will continue to mature according to the stresses placed upon it, even following completion of formal rehabilitation.

As with the remodeling-maturation phase in soft tissues, loading is important in the final phase of bone healing. In this phase of bone healing, woven bone (i.e., immature bone) is replaced by well-organized lamellar bone.[3] Normal loading is necessary to remodel the bone in accordance with the stresses that it will bear (i.e., Wolff's law). The linkage of electrical charges with mechanical loading is called the piezoelectric effect.[3] Piezoelectric effects in the calcium hydroxyapatite crystals resulting from loads orient the crystals along the lines of stress. In long, weight-bearing bones, activity differs on the concave and convex sides. On the concave side, osteoblasts lay down more bone where the bone is subject to compression (i.e., negative charge). On the convex side, osteoclasts digest bone that is subject to tension (i.e., positive charge). Imposition of normal functional loads is necessary for the final remodeling of bone. Electrical stimulation is used to enhance bone healing using the same piezoelectric effect.

PRINCIPLES OF TREATING CONNECTIVE TISSUE INJURIES

A variety of procedures are available to achieve physical therapy goals. Although detailing every situation the clinician may encounter is difficult, specific principles guide the decision-making process. These principles provide a framework and rationale for intervention choices.

Restoration of Normal Tissue Relationships

After connective tissue injury, the relationships among a variety of tissues are altered. After injury or immobilization, the tendon may fail to glide smoothly through the tendon sheath, the nerve may be adhered to surrounding tissues, folds of joint capsule may become adhered to one another, the skin may bind to underlying tissues, or fascial layers may fail to glide on one another. These normal relationships must be restored, or painful and restricted movement may result. Interventions such as active muscle contraction, passive joint motion or mobilization, modality use, or massage restore those relationships. Begin these preventive interventions as early as the healing process allows, often within the first 48 hours. Additionally, the normal length–tension relationship of the muscle must be recovered to ensure optimal function. Muscles damaged by contusion, disrupted by surgical procedures, or placed in a shortened position during immobilization are susceptible to these alterations. Use stretching techniques to restore the normal length–tension properties. For example, the Achilles tendon should be stretched regularly while a patient recovers from an ankle sprain or fracture.

Optimal Loading

After a connective tissue injury, a cascade of events facilitate the body's healing process. If this cascade is interrupted, healing is disrupted and chronic inflammation may ensue. During each of the healing phases, choose treatment procedures that aid the healing process without disrupting the normal chain of events. This requires optimal loading or choosing a level of loading that neither overloads nor underloads the healing tissue (**Fig. 11-6**). Effective application of optimal loads requires a thorough understanding of the mechanism of injured tissue loading, including which planes of movement place the greatest loads on the healing tissue (**Building Block 11-3**).

BUILDING BLOCK 11-3

While it may be obvious that the mobility of tissues adjacent to the injured area should be mobilized, what about tissues more directly involved in the injury? For example, following a lateral ankle sprain, should the peroneal muscles be mobilized? Why or why not?

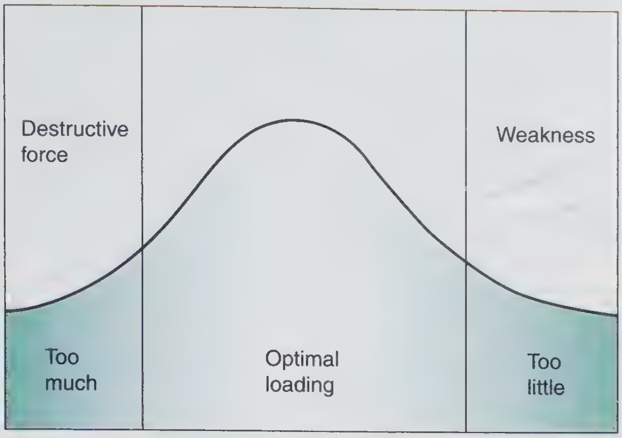

FIGURE 11-6 Optimal loading. Choose a load that neither overloads nor underloads the tissue of interest. (From Porterfield JA, DeRosa C. Mechanical Low Back Pain. Philadelphia, PA: WB Saunders, 1991:13.)

Consider the biomechanical effects of daily activities and therapeutic activities in the context of the stage of healing, and individual factors such as age, quality of the tissue, nutritional status, and fitness level. A stress that underloads a tissue in the remodeling phase probably overloads the tissue in the inflammatory phase (review Table 5-8). An exercise that underloads a young athlete after an acute fracture would probably overload an elderly individual after a pathologic fracture. The medial collateral ligament (MCL) of the knee is loaded most in the frontal and transverse planes, with the knee near terminal extension. Avoid activities that load the knee in this manner during the acute phase. However, in the late phases, when remodeling of the ligament is necessary, frontal and transverse plane loading are precisely the stimulus needed. Designing the treatment program requires consideration of all of the factors in the intervention model within the injury framework (see **Patient-Related Instruction 11-2**).

Specific Adaptations to Imposed Demands

Although the concept of optimal loading guides the *quantity* of activity (e.g., volume, intensity), the specific adaptations to imposed demands (SAID) principle expands to include the *type* of activity chosen. The SAID principle is an extension of Wolff's law, which states that a bone remodels according to the stresses that are placed on it. The SAID principle implies that soft tissues remodel according to the stresses imposed on them. Exercise is specific to the posture, mode, movement, exercise type, environment, and intensity used. For example, an exercise may be chosen to prepare the quadriceps muscle for weight bearing. The quadriceps muscle contracts eccentrically in a closed chain through the first 15 degrees of knee flexion during the loading response of gait. A closed chain eccentric quadriceps exercise such as a short-arc (0 to 15 degrees) leg press is a better choice than concentric isokinetic exercise. This is an example of the SAID principle guiding the activity choice (**Building Block 11-4**).

Patient-Related Instruction 11-2

Signs of Overload

The following signs and symptoms suggest that exercise or activity is too much and should be decreased or modified:

1. Increased pain that does not resolve within the next 12 hours
2. Pain that is increased over the previous session or comes on earlier in the exercise session
3. Increased swelling, warmth, or redness in the injury area
4. Decreased ability to use the part

BUILDING BLOCK 11-4

A 26-year-old recreational soccer player sustained a second-degree MCL sprain 8 weeks ago and is preparing to return to soccer. Design a late phase exercise program that would prepare this athlete to return to soccer. Assume full ROM and strength within 10% of the opposite leg.

The SAID principle also guides exercise prescription parameters. For example, in the late stage of healing, a patient returning to tennis should increase the speed and intensity of exercise, whereas the patient returning to marathon training should increase the exercise duration. When the stage of healing and optimal loading parameters allow, training should as closely as possible reflect the specific demands of the patient's functional task.

Preventing Complications

Be sure to consider the effects of the connective tissue injury on surrounding tissues. For example, immobilization imposed while a fracture is healing is unhealthy for the joint's articular cartilage, ligaments, and surrounding musculature, although it is necessary for bone repair. Muscle atrophy and weakening of the immobilized ligaments ensue during the immobilization period. Use any available interventions that might minimize these effects. For example, electrical stimulation or isometric muscle contractions can be used to retard strength losses in the muscle, tendon, and tendon insertion sites. Active muscle contractions also prevent thrombus formation after surgery. ROM exercises at joints above and below injury sites may preserve some soft-tissue relationships and prevent loss of mobility. Weight-bearing loads the articular cartilage and lessens degradation caused by immobilization.

MANAGEMENT OF IMPAIRMENTS ASSOCIATED WITH CONNECTIVE TISSUE DYSFUNCTION AND LOCALIZED INFLAMMATION

Patients with acute soft-tissue injuries such as sprains and strains are commonly treated by physical therapists. Management of these injuries is discussed together because of the many similarities, and any differences are highlighted.

Sprain: Injury to Ligament and Capsule

A sprain can be defined as an acute injury to a ligament or joint capsule without dislocation. Sprains occur when a joint is extended beyond its normal limit, and the ligament or capsule tissues are stretched or torn beyond their limit. Sprains are common at the ankle (i.e., anterior talofibular and calcaneofibular ligaments), knee (i.e., medial and lateral collateral ligaments, anterior [ACL] and posterior cruciate ligaments [PCL]), wrist, and spine. A sprain may resolve with short-term immobilization, controlled activity, and rehabilitative exercises, but other sprains may require surgery to stabilize the joint.

Sprain Classification

Sprain severity occurs along a continuum from microscopic tearing and stretching of ligament or capsule fibers to complete disruption of the ligament. Sprains are classified by severity based on clinical examination or special testing (e.g., magnetic resonance imaging, arthrometer testing).

- Grade I sprains are mild sprains in which the ligament is stretched, but there is no discontinuity of the ligament.
- Grade II sprains are a moderate sprain in which some fibers are stretched and some fibers are torn. This produces some laxity at the joint.
- Grade III, or severe sprains, are a complete or nearly complete ligament disruption with resultant laxity (**Table 11-2**).

Examination and Evaluation Findings

Examination findings following a ligament sprain include ecchymosis and edema. Functional mobility losses include the mobility of a single joint (ICF b7100), the mobility of several joints (ICF b7101), or the loss of stability of a single (ICF b7150) or multiple (ICF b7151) joints. Additionally, muscle performance or power functions are typically decreased. When sprains occur in the lower extremity, gait pattern functions are impaired, and when the upper extremity is involved, functional reach and the ability to hold and manipulate objects may be impaired. Sprains of the spine can impact many aspects of functional mobility such as self-care, home and community mobility, and work. Joints proximal and distal to the primary joint injury may have associated injuries or compensation. Determine activity limitations and identify the relationship between impairments and those activity limitations.

TABLE 11-2

Classification of Sprain

GRADE	DESCRIPTION	CHARACTERISTICS
I	Mild	Fibers are stretched without loss of continuity; no laxity on physical examination
II	Moderate	Some fibers are stretched and some are torn
		Some laxity observed on examination
III	Severe	Ligament completely or nearly completely torn; laxity results

From American Academy of Orthopaedic Surgeons. Athletic Training and Sports Medicine. Park Ridge, IL: American Academy of Orthopaedic Surgeons, 1991.

Strain: Musculotendinous Injury

A strain is an acute injury to the muscle or tendon from an abrupt or excessive muscle contraction. Strains are usually the result of a quick overload to the muscle-tendon unit in which the tension generated exceeds the tissue's capacity. Strains occur when a contracting muscle is excessively or abruptly stretched in the opposite direction. The person who reaches quickly to catch a falling object or the individual who suddenly stops or changes direction when walking or running is susceptible to a muscle strain. Overuse injuries are another type of muscle strain.

Strain injuries are difficult to classify and can be graded as mild, moderate, or severe based on clinical examination findings such as pain, edema, loss of motion, and tenderness. Muscle strains can be complete or incomplete, although complete tears are less common.

Most strain injuries occur at the myotendinous junction.[15] Structural features of the sarcomeres and connective tissues in this area suggest that load transmission occurs across the musculotendinous junction. As with many other structures in the body, transitions from one tissue type to another are areas of increased stress and risk of injury. In this case, the transition zone from contractile to noncontractile tissue creates an area of increased stress that is susceptible to injury. Factors that may contribute to muscle strain injuries include poor flexibility, inadequate warm-up exercise, insufficient strength or endurance, training errors, and poor coordination.[15]

Examination and Evaluation Findings

A history of an abrupt decelerating movement, change of direction, or quick stretch suggests a muscle strain injury. On physical examination, the musculotendinous junction or the muscle belly may be painful. Pain in the injured muscle is reproduced clinically by active or resistive contraction of the muscle and by stretching it. For example, a quadriceps strain is reproduced by stretching the knee into flexion and by resisting active knee extension. The muscle may need to be put on stretch during the muscle contraction, or may need to be loaded in a weight-bearing position to stress the lesion. Occasionally, localized swelling and warmth may be observed.

Application of Treatment Principles

Although each intervention program should be directed toward the specific impairments, activity limitations, and goals for each patient, some general guidelines can help the clinician make informed choices that will maximize recovery and return to function.

Inflammatory Phase

Treatment principles in the early phase include optimal loading and prevention of secondary complications. As the inflammatory response initiates the healing response, an environment conducive to healing must be established. The appropriate balance of rest and loading ensures loads within the optimal loading zone for the patient's age, medical condition, and injury severity. Overload may perpetuate bleeding or the inflammatory response beyond its useful purpose, and underload may result in complications such as motion loss, scar tissue adhesions, or ectopic ossification.

FIGURE 11-7 Physical therapist cueing a patient to contract the hamstring muscle with the cue "Imagine you are going to bend your knee, but don't actually lift your foot from the ground."

Modality use in this phase usually includes cryotherapy and compression with elevation to decrease bleeding and swelling. Most injuries allow passive, active-assisted, or active ROM in a pain-free range, although exercise may be contraindicated in some severe cases. Isometric muscle contraction, in the absence of moderate or severe muscle strains, can lessen atrophy and serve as a learning activity, reminding the patient how to contract involved muscles (**Fig. 11-7**). Because the muscle is the primary tissue involved in a strain, active muscle contraction capability may be limited or reduced significantly. When treating lower extremity injuries, assistive devices, immobilizers, and weight-bearing restrictions can maintain tissue loading within the optimal loading zone. Treatments that impose rest or restriction must be balanced with activity that offsets the negative effects of immobility (see **Selected Intervention 11-1** and **Building Block 11-5**).

BUILDING BLOCK 11-5

A 63-year-old woman sprained her left knee 4 days ago when she slipped on the ice. She sustained first-degree sprains of her MCL, joint capsule, and ACL. Due to underlying arthritis, her swelling and functional instability were significant. She has a 2+ effusion, is unable to fully bear weight on the left, has limited ROM, and poor quadriceps function. Provide a list of goals and interventions for the first phase.

SELECTED INTERVENTION 11-1

Isometric Ankle Eversion for the Patient After Ligament Reconstruction

See Case Study No. 1

Although this patient requires comprehensive intervention as described in the patient management model, one specific exercise is described.

ACTIVITY: Isometric ankle eversion

PURPOSE: Increased ability to produce torque in the peroneal muscles without excessively loading the acutely injured tissue

RISK FACTORS: No appreciable risk factors

STAGE OF MOTOR CONTROL: Mobility

POSTURE: Any comfortable position such as sitting or supine. The lateral border of the foot is stabilized against a stationary object.

MOVEMENT: Patient performs an isometric ankle eversion contraction against a stationary object.

SPECIAL CONSIDERATIONS: Ensure that muscle contraction is at a submaximal level during the acute phase. Maximal muscle contraction can overload recently injured tissues. Be sure eversion is not substituted with tibial external rotation, hip abduction, or external rotation.

DOSAGE

TYPE OF MUSCLE CONTRACTION: Isometric

Intensity: Submaximal

Duration: To fatigue, pain, or 20 repetitions

Frequency: Hourly or as frequently as possible during the day

Environment: Home

RATIONALE FOR EXERCISE CHOICE: This exercise was chosen to begin retraining the peroneal muscles. Isotonic exercises can overload the muscle in the acute phase, but submaximal isometric contraction maintains loading within the optimal loading zone. Gentle isometric activation "reminds" the muscle how to contract, providing a foundation for further strengthening in later phases.

EXERCISE MODIFICATION OR GRADATION: As healing progresses, isometric contractions may be performed at multiple angles. Isometric contractions should be progressed to isotonic exercise through a ROM. Closed chain exercise should be incorporated as weight bearing allows.

Getting the correct dosage is the greatest challenge. No standards exist to provide the clinician with precise frequency, intensity, and duration of exercise. This is one reason why the intensity of physical therapy services is greater in the early phase of rehabilitation. More frequent contact with the clinician can ensure that the exercise dosage is appropriate for the patient's current physical condition. Modify the rehabilitation program as changes occur.

Proliferative/Fibroplasia Phase

As healing progresses to the proliferative phase, treatment principles focus on restoration of normal tissue relationships, optimal loading, and preventing complications. Complications in this phase may result from changes in movement patterns to accommodate pain, weakness, or motion loss. These movement pattern changes can create excessive loads on uninjured tissues that can become painful. These changes also become habitual and can be difficult to correct. Examples of these habits are hiking the shoulder (i.e., scapular elevation) during forward reaching and ambulating with a flexed knee gait. Faulty movement patterns are deleterious for the long-term health of the joint and should be corrected as quickly as possible.

Restoration of normal tissue relationships can prevent these faulty movement patterns by reestablishing joint ROM and muscle length. Manual therapy, including joint mobilization techniques, stretching, and massage techniques, as well as postural education exercises, can facilitate restoration of these relationships. Connective tissue massage performed by the patient can increase scar tissue mobility (**Fig. 11-8**). This type of self-management increases the activity dosage to a level that can impact outcomes. Muscle contraction of the muscle opposing the short muscle is an active stretching technique that can restore normal tissue relationships via reciprocal inhibition (**Fig. 11-9** and **Building Block 11-6**).

FIGURE 11-8 Scar mobilization performed by the patient.

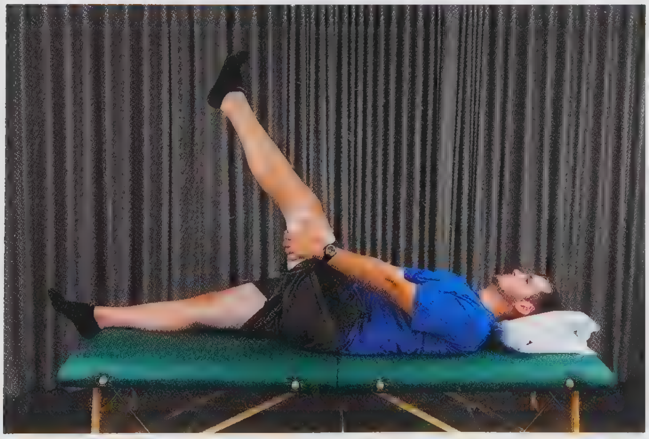

FIGURE 11-9 Active quadriceps contraction facilitating a hamstring stretch.

BUILDING BLOCK 11-6

The patient from Building Block 11-5 is now 8 weeks postinjury. She has regained full motion of her knee. Strength testing reveals strength to be with 75% of the contralateral limb. Her knee is stable to clinical ligamentous stability testing. However, she complains of a feeling of "giving way, wobbliness, and instability" in her left leg, especially with stairs, ramps, and uneven surfaces. She desires to return to trail hiking and gardening. Please progress her rehabilitation program at this stage (it is understood that you have continued to progress her program throughout the past 8 weeks).

Optimal loading concepts provide the framework for exercise parameters. Understanding the effects of muscle contraction and the location and direction of loading on the healing tissue is fundamental to optimally loading the tissue. Loading is important in the repair-regeneration phase, because loads help orient newly forming collagen fibrils along the lines of stress. Excessive loading disrupts the healing process, and underloading results in randomly organized collagen. Weight bearing, active and resistive mobility activities, massage, and functional movement patterns can provide these loads. It is the clinician's charge, along with input from the patient, to prioritize these activities to close the gap between current and desired functional performance. By the end of this phase, mobility and a strength base should be established.

Remodeling and Maturation Phase

As the patient returns to activity, the guiding principles are optimal loading and SAID. The type and magnitude of loads encountered in the patient's daily routine, including work and leisure activities, determine the specific interventions chosen (**Fig. 11-10**). The goal in the final phase is to "fine-tune" or convert the baseline strength and mobility into functional movement patterns and activities that address the patient's activity limitations and participation restrictions. The exercises generally consist of more whole-body patterns and functional activities related to the patient's lifestyle. At the same time, consider the status of healing tissue and the loads placed on it

FIGURE 11-10 Example of impact loading in a horizontal position as a transitional activity between strengthening and impact loading in a vertical position.

FIGURE 11-11 A soccer drill performed by a soccer player is an example of a graded, progressive study.

as you choose activities. For example, repeatedly throwing a fastball on a repaired elbow MCL excessively loads the repair at this point. A graded, progressive functional exercise is necessary to resume activities with such loads (**Fig. 11-11**). In the final phase, the patient should be instructed in a comprehensive home program to ensure continued maturation of the tissue according to the patient-specific loads.

Tendinopathy

Tendon failure can occur as a result of macrotrauma or microtrauma. Tendons are able to withstand high loads, but if these loads become repetitive, injury may result. Injury occurs on a microscopic or macroscopic level, with damage to the structural proteins and the blood supply. Adequate recovery and healing time must be allowed or tendinopathy will develop. As the understanding of tendon disorders has progressed, new classification schemes of tendon injury have been developed. In addition to the global categories of acute and chronic, tendon injuries have been subclassified as paratenonitis, tendinosis, tendinitis, and paratenonitis with tendinosis.[16] Each of these subcategories has specific treatment ramifications, which will vary with classification. However, all tendon injuries will be discussed together for simplicity.

Classification of Tendon Injuries

Tendon injury can be classified by etiology (macrotrauma, microtrauma), by duration (acute, chronic), or by presumed histopathology (tendinitis, paratenonitis, tendinosis). Tendinopathy is a global term for tendon disorders without presumptions about histopathology, duration, or etiology. Historically, the most common term for tendon injury was "tendinitis," implying inflammation.[17] The term "tendinosis" is used as a histologic description of degenerative tendon without inflammation. Examination of tissue with chronic tendinopathy has found little evidence of inflammation.

Tendon may be injured by acute macrotrauma, such as landing from a jump, or microtrauma, such as the trauma associated with repetitive uphill walking. Acute macrotraumatic injuries occur as a result of a sudden contraction, often decelerating in nature.[16] Loads during normal activities generally do not exceed 25% of the tendon's ultimate tensile strength.[18,19] However, loads during high-level activities, such as kicking, have been found to exceed this average level. For example, loads estimated in a weight lifter at the time of patellar tendon rupture were 17 times body weight.[20] Most macrotraumatic injuries occur at the musculotendinous junction and result in a profound inflammatory reaction.[21] This reaction initiates the phases of healing outlined previously.

Microtrauma, or repetitive loads without adequate recovery time, can also result in injury to the tendon. *Paratenonitis* is an inflammation of the outer layer of the tendon (i.e., paratenon), whether lined with synovium or not.[16,22] Histologically, inflammatory cells are found in the paratenon or peritendinous areolar tissues, and, clinically, the cardinal signs of inflammation such as pain, crepitation, swelling, and palpable tenderness occur. Treatment procedures, including anti-inflammatory measures, are indicated.

Tendinosis is an intratendinous degeneration without an inflammatory response.[17,23,24] It is generally caused by atrophy from aging, microtrauma, or vascular trauma. Histologic findings include fiber disorientation, hypocellularity, scattered vascular ingrowth, and occasional necrosis or calcification.[16,22] Because there is no inflammatory response, none of the cardinal signs of inflammation are present, and anti-inflammatory measures are ineffective. A nodule may be palpable but nontender. Tendinosis may also occur with paratenonitis, in which paratenon inflammation accompanies intratendinous degeneration. Symptoms in this case may be confusing, combining signs of inflammation with a chronic degenerative tendon. Histologically, scattered vascular ingrowth may be present, although no true intratendinous inflammation exists. Areas of neovascularity are evident in both Doppler studies and ultrasound.[17,24] Degenerative Achilles tendons show high blood vessel density compared with healthy tendons.

The term *tendinitis* is used to describe an acute inflammatory process, usually the result of overuse in a young individual. Histologically, tendinitis is classified into three subgroups, each with different findings, from purely inflammation to inflammation superimposed on preexisting degeneration to calcification and tendinosis changes in chronic conditions. The symptoms in this group are proportional to the vascular disruption or atrophy and can be inflammatory, depending on the duration (**Table 11-3**).

TABLE 11-3

Classification Terminology of Tendon Injury

NEW	OLD	DEFINITION	HISTOLOGIC FINDINGS	CLINICAL SIGNS AND SYMPTOMS
Paratenonitis	Tenosynovitis, tenovaginitis, peritendinitis	An inflammation of only the paratenon, lined by synovium or not	Inflammatory cells in paratenon or peritendinous areolar tissue	Cardinal inflammatory signs: swelling, pain, crepitus, local tenderness, warmth, dysfunction
Paratenonitis with tendinosis	Tendinitis	Paratenon inflammation associated with intratendinosis degeneration	Same as above, with loss of tendon collagen, fiber disorientation, scattered vascular ingrowth, but no prominent intratendinous inflammation	Same as above, with often palpable tendon nodule, swelling, and inflammatory signs
Tendinosis	Tendinitis	Intratendinous degeneration resulting from atrophy (aging, microtrauma, vascular compromise)	Noninflammatory intratendinous collagen degeneration with fiber disorientation, hypocellularity, scattered vascular ingrowth, occasional local necrosis, or calcification	Often palpable tendon nodule that is asymptomatic; no swelling of tendon sheath
Tendinitis	Tendon strain or tear	Symptomatic degeneration of the tendon with vascular disruption and inflammatory repair response	Three recognized subgroups; each displays variable histology, from pure inflammation to inflammation superimposed on preexisting degeneration in chronic conditions: (1) acute, (2) subacute, (3) chronic	Symptoms are inflammatory and proportional to vascular disruption, hematoma, or atrophy-related cell necrosis. Symptom duration defines each group: (1) <2 wk, (2) 4–6 wk, (3) 6 wk

From American Academy of Orthopaedic Surgeons. Athletic Training and Sports Medicine. Park Ridge, IL: American Academy of Orthopaedic Surgeons, 1991

Etiology and Risk Factors

A number of causes have been linked to the development and progression of tendinopathy. These causes include, but are not limited to:

- Age[25,26]
- Overuse and training errors[27,28]
- Insufficient recovery[27]
- Smoking[29]
- Hypercholesterolemia[30,31]
- Diabetes[32]
- Genetics[33–35]

In general, an imbalance between tendon loading and recovery leads to tendon failure on a microscopic and eventually macroscopic level. How much loading an individual's tendon can withstand varies with risk factors as noted above. For example, a patient who is obese and has type II diabetes will require closer attention to exercise dosing and recovery as compared to a patient without these comorbidities (**Evidence and Research 11-1**). Likewise, elderly individuals participating in sports should be cautious with any sudden increase in exercise dosage (**Evidence and Research 11-2**). The overarching issue is determining the balance between loading and recovery necessary to maintain tendon loading within the optimal loading zone.

EVIDENCE and RESEARCH 11-1

Ultrasound examination of the Achilles tendon in patients with type I and type II diabetes showed poorer ultrastructure, a potential risk factor for tendinopathy.[32] The tendon degeneration in this population has been linked to metabolic disorders that trigger persistent low-grade inflammation, including hypercholesterolemia.[30,31,36] Obesity contributes to tendinopathy both through mechanical mechanisms and metabolic, as evidenced by changes in both weight-bearing and non–weight-bearing tendons.[37] Tendons of patients with obesity show impaired remodeling, lipid deposition, and disorganization. Metabolic measures suggest a chronic, low-grade inflammation.

EVIDENCE and RESEARCH 11-2

Increasing degeneration of the rotator cuff tendon makes it challenging to know if the pathology seen on imaging following a shoulder injury in the elderly is new or if it has been long-standing. Research shows an overall prevalence of rotator cuff abnormalities of 9.7% in those <20 years of age compared with 62% in those >80 years (odds ratio = 15)[38] Studies of mice tendons have shown fiber realignment changes suggesting decreased ability to respond to load in older subjects.[39]

Treatment Principles and Procedures

Treatment of tendinopathies is based on the specific tendon injury, framed within the context of the tendon's role in function. Restoring the tendon to optimal length, cellularity, and ability to withstand loads is fundamental to complete rehabilitation. The optimal loading zone is the foundation for choosing loading techniques. Educate the patient about strategies that maximize symptom resolution and minimize harmful effects (**Fig. 11-12**). Using assistive devices or splints can minimize loads on overworked tendons during necessary activities.

Rehabilitation should be of appropriate intensity, frequency, and duration such that, when combined with essential activities of daily living, it keeps loading within the optimal loading zone.

Anti-inflammatory measures are helpful when inflammation is a component of the tendinopathy. If you are treating inflammation as the primary problem, the injury may be treated in the localized inflammation practice pattern. Physical agents such as ultrasound and cold packs can be used as adjunctive agents for pain control, allowing greater participation in the therapeutic exercise program.

Incorporate stretching if muscle length is inadequate for the demands placed on the musculotendinous unit. In cases of recovery from an acute tendon injury, stretching is critical for restoring the normal length of the tissue. Moreover, in the early stages, stretching is a stimulus for the proper alignment of healing collagen. In healing tissue, gentle stretching to provide a stimulus for fiber orientation without disruption of the immature collagen facilitates the remodeling process. In the early stages of recovery, stretching should be light, imparting a gentle stimulus for repair, rather than a vigorous intensity that may disrupt the healing process.

FIGURE 11-12 A wrist splint can be used to decrease loads on the wrist extensor musculature during work activities.

In the chronic tendon injury, stretching increases the tissue's resting length, allowing loading through a greater range and force dispersion over a larger surface area. Changes in resting length may affect the muscle spindle, altering its sensitivity and resultant muscle stiffness. As with resistive exercise, stretching should be prescribed according to intensity, frequency, and duration parameters. Too often, these prescriptive factors are neglected, leading to overload. For example, patients often believe that a strong stretching sensation is necessary to adequately stretch the muscle. However, a strong stretch can be just as damaging to an injured muscle-tendon unit as too much resistance. Patients should feel a "low" to "medium" stretching sensation during the stretch, without an increase in symptoms after the stretching session. While stretching is frequently recommended in the treatment of tendinopathy, little evidence exists to support its use.[40,41]

Progressive resistive exercises are a key component of the intervention program. Eccentric muscle contractions have been implicated in the development of tendinopathies.[42–45] Eccentric contractions allow the series elastic component (SEC) to contribute to force production. Tendon and other connective tissue proteins in parallel with the muscle fiber form the SEC.[9] Eccentric contractions usually precede concentric contractions in activities such as jumping, allowing the SEC to contribute to force production. The force generated in the tissue during eccentric contractions depends on the velocity of the stretch, the distance moved, and the amount of load placed on the tissue (e.g., body weight, external loads). These parameters are used in the rehabilitation of tendon injuries.

Curwin and Stanish[9] outlined a progressive resistive exercise program in an attempt to strengthen tendon tissue. Because eccentric muscle contractions allow the SEC to contribute to force production and because eccentric muscle contractions are frequently associated with the development of tendinopathies, this muscle contraction type is emphasized. Before an effective eccentric contraction can be performed, the individual must first be able to isometrically hold at the starting position. Thus, the first appropriate resistive exercise may be a submaximal isometric contraction. As the individual progresses, an eccentric program is initiated, with a progression of speed built into the program. The resistive eccentric program is performed slowly for the first 2 days, progressed to a moderate speed for 3 days, and then to a fast speed for 2 days. The resistance is then increased, and the speed progression instituted again. This program is easily performed at home, and intensity, frequency, and duration are clearly outlined to prevent overload (**Fig. 11-13**). Be sure to begin and end each session with a warm-up.

A

B

FIGURE 11-13 Eccentric wrist extensor work with a wrist weight is performed by the patient. **(A)** Uninvolved hand lifts the relaxed involved hand. **(B)** Involved wrist then lowers the weight eccentrically.

Others have advocated for a more aggressive eccentric training program.[42,44,46,47] This type of training has been studied in the Achilles and patellar tendons using high loads and decline boards; it has also been studied in lateral epicondylitis (**Evidence and Research 11-3**). This type of heavy load eccentric program has been successful in treating chronic Achilles and patellar tendinopathy, and has been more successful than programs using concentric contractions[42,45–47] (**Evidence and Research 11-4**). It is theorized that eccentric training interferes with the neovascularization apparent in chronic tendinosis, in a manner similar to that of sclerosing injections[44,46,47] (**Evidence and Research 11-5**).

As with any soft-tissue injury, rehabilitation activities must mimic the demands placed on those tissues on return to activity. The prescription parameters are framed around the functional outcome. For the individual returning to a work, leisure, or home environment that places him or her at risk for reinjury, appropriate modifications to the environment or to the individual (e.g., technique, adaptive, or supportive devices) must be made as part of the prevention and long-term care program.

EVIDENCE and RESEARCH 11-3

Patients with chronic lateral epicondylitis were divided into control (usual care) and eccentric exercise groups. The eccentric group used an isokinetic dynamometer that progressively increased the speed and eccentric resistance in a programmed manner based upon a repetition maximum criteria.[48] Results favored the eccentric group for significant pain reduction, increased strength, improved tendon thickness and structure on imaging, and a marked improved in disability status. Page[49] also found positive results with a home program utilizing a flexible bar to perform eccentric contractions. Using this bar, Tyler et al.[50] found significant improvements in pain levels, strength and functional outcome measures.

EVIDENCE and RESEARCH 11-4

Subjects with patellar tendinosis trained with either painful eccentric contractions (on a decline board) or painful concentric contractions (15 exercises, 3 sets, 2 times per day × 12 weeks) while stopping all sports for the first 6 weeks. At a mean of 32 months' follow-up, 9/10 subjects in the eccentric group were satisfied, with significant improvements in pain and functional outcome scores. In contrast, 9/9 subjects in the concentric group were dissatisfied, showing no change in pain or function.[43]

EVIDENCE and RESEARCH 11-5

Ultrasound examination has provided insight into the relationship between neovascularization and tendinopathy. Ohberg and Alfredson[44] performed dynamic ultrasound examination of 41 tendons in 30 patients with chronic mid-portion Achilles tendinosis who underwent eccentric training. At a mean of 28 months' follow-up, 36/41 had a good results. Thirty-two of these 36 tendons showed no remaining neovascularization, while 5/5 tendons with a poor result showed remaining neovascularization. Divani et al.[51] found the site of maximum neovascularization to correlate with the site of pain in patients with mid-portion Achilles tendinopathy. Yang et al.[52] found 97% of the pathologic Achilles tendons investigated to have neovascularization, 56% of which were associated with the location of tendon thickening. The pain level was positively associated with the area of thickening. In contrast, van Snellenberg et al.[53] found neovascularization in both painful and nonpainful tendons raising the question of a threshold of neovascularization at which the patient becomes symptomatic.

Articular Cartilage Injury

Articular cartilage injury can lead to both short-term and long-term activity limitations and participation restrictions. The pain associated with damage to the articular cartilage can impact a person's ability to stand, sit, walk, or perform other important functional tasks necessary for self-care or employment. Damage to the articular cartilage can occur from mechanical injury or from other nonmechanical trauma. Nonmechanical traumas include infection, inflammatory conditions, or prolonged joint immobilization and can result in loss of proteoglycans. Proteoglycan degradation or suppression of synthesis from these conditions results in articular cartilage damage that may be irreversible. Mechanical damage to the articular cartilage (i.e., chondral injury) or to the articular cartilage and underlying bone (i.e., osteochondral injury) can happen as a result of blunt trauma, frictional abrasion, or excessive weight-bearing forces.[54] For example, knee hyperextension injuries or ankle rotational injuries can result in chondral or osteochondral injuries and ligamentous injuries. Excessive weight bearing and joint compression combined with rotation produce high shear forces on the articular cartilage, resulting in chondral or osteochondral injury.

In addition to the mechanism of injury, articular cartilage damage is also classified by size and depth. While more complex grading systems exist, a simple classification describes whether it is partial or full thickness and the width of the lesion. Other important information includes the status of the joint surface and the location of the lesion. All of these factors (depth and diameter, articular surface and lesion location) have implications for prognosis and treatment.

Articular cartilage has a poor healing response. In adults, the tidemark prevents the underlying bony vascular supply from providing nutrition to the articular cartilage. The articular cartilage receives its nutrition by diffusion of synovial fluid. Therefore, chondral injuries that do not penetrate the underlying subchondral bone will lack sufficient blood supply to create a healing response. While these injuries may not heal in adults, they may not worsen in the presence of loading that stays within the patient's optimal loading zone. This requires education and guidance through an appropriate rehabilitation program.

Etiology and Risk Factors

While the cause of articular cartilage injuries in acute trauma is obvious, a poor healing response or chronic articular cartilage degeneration in some patients can be a frustrating situation. Chronic, progressive deterioration of articular cartilage can ensue following an acute injury such as an ACL sprain, ankle osteochondral injury or hip labral injury. Risk factors such as smoking, genetics, body weight, joint congruity, additional joint injury, concomitant injuries, occupation, strength, biomechanics/malalignment, sex, estrogen loss, dietary intake, and age have been implicated[55–63] (**Evidence and Research 11-6**). Of these risk factors, a history of previous injury to the same joint, particularly at the knee and hip, appears to increase the odds of developing osteoarthritis significantly (**Evidence and Research 11-7**).

EVIDENCE and RESEARCH 11-6

Patients sustaining joint injury, particularly meniscal injuries at the knee, have a high risk of developing osteoarthritis. Three hundred seventeen patients who had undergone meniscal resection 15 to 22 years earlier but had an intact ACL underwent radiographic and clinical evaluation. Symptomatic osteoarthritis (OA) was found in 27% of operated knees compared with 10% of control knees. Obesity, female sex, and preexisting early-stage OA were associated with a poorer outcome.[64] Valgus knee alignment also increases the risk for lateral compartment OA, likely through the mechanism of meniscal injury.[65] Similarly, varus aligned knees were at a higher risk of medial compartment OA.[63]

EVIDENCE and RESEARCH 11-7

Kramer et al.[66] note that the risk of developing posttraumatic OA after joint injury ranges from 20% to more than 50%, even in the presence of anatomic fracture fixation, ligament reconstruction, and restoration of normal joint biomechanics. Richmond et al.[67] found that a history of previous joint injury increased the odds ratio of developing knee OA to 3.8, and hip OA to 5.0. A study of female soccer players 12 years after their index ACL injury found radiographic changes in 82% of index knees, and 51% of those met the radiographic criteria for OA compared with 7% on the uninvolved side.[68] Anderson et al.[69] note that joint ligamentous or capsular injury results in a nearly 10-fold increase in the risk of OA.

The large number of both intrinsic and extrinsic risk factors accounts for the large variability in outcomes of articular cartilage injuries. Genetics can account for up to 50% of the risk of developing OA.[56] We inherit not only our connective tissue cellular and extracellular components, but also body morphology (i.e., varus or valgus alignment, kyphosis) predisposing some to higher OA risks. While the genetic factors, age, sex, and other intrinsic risk factors are fixed, the lifestyle factors are not. Activity level, diet, and other extrinsic factors may be the only opportunities to effect the progression of articular cartilage decline. These might include:

- Diet and nutritional modifications
- Weight loss
- Lifestyle changes (i.e., work and leisure activities)
- Appropriately dosed activity choices
- Injury prevention strategies
- Loading adjustments such as shoe/surface changes, braces/orthotics, assistive devices
- Training in posture and appropriate movement patterns
- Mobility and strengthening
- Education associated with all these factors

Treatment Principles

Minimum requirements for healthy articular cartilage are freedom of motion, equitable load distribution, and stability.[70] Beyond this, issues such as appropriate body weight, efficiency of movement to minimize joint loads, and avoiding overload[64] are important in long-term joint health. Exercise is healthy for joints; joint motion and alternating joint loading and unloading provide articular cartilage nutrition.[71] This nutrition is achieved by diffusion of synovial fluid across the joint surface. When joints are immobile or held in a single position for long periods of time (such as sleeping or riding in a car), stiffness and pain ensue due to lack of joint surface nutrition. Therefore, use a period of "preconditioning" or warm-up at the beginning of an exercise session or after periods of rest. Gentle muscle contraction exercises or ROM activities serve as good preconditioning exercises for people with articular cartilage injury (see **Display 11-1**).

Initiate treatment focused on restoration of joint osteokinematics and arthrokinematics as a primary goal. The aggressiveness of other interventions such as muscle performance exercises and progressive weight bearing is dictated by other factors and medical management of the injury. The articular cartilage has a better chance of recovery after injury or surgery when the loads across the recovering joint surface are controlled and progress as healing occurs. Optimal recovery is more likely to take place in the presence of equal load distribution (i.e., medial and lateral compartments in the knee) and joint stability. For example, a knee with significant varus or valgus alignment excessively loads the medial and lateral compartments, respectively. This loading is the rationale for tibial osteotomy procedures, which attempt to balance load distribution medially and laterally. An unstable knee (anterior or posterior cruciate deficient) also places greater loads on the articular cartilage, and rehabilitation after articular cartilage injury or surgery in an unstable knee must proceed

DISPLAY 11-1

Principles of Treating Articular Cartilage Injuries

1. Understand and apply the biomechanics of the joint of interest and its relationship to the rest of the kinetic chain.
   - Avoid shear forces across the lesion.
   - Utilize proximal and distal joint relationships to improve mechanical loading.
2. Respect the biomechanics of lubrication and nutrition.[72]
   - Adult articular cartilage gets its nutrition by diffusion, primarily through cyclic loading and unloading (i.e., weight bearing followed by unloading in a repetitive fashion) and motion.
   - Continuous static loading (i.e., continuous weight bearing) is deleterious to the articular cartilage.[73]
3. Avoid chronic and acute joint overload.[72]
   - Work or leisure activities that require prolonged standing or working in a single position can overload joints in the spine and extremities.
   - Obesity or malalignment can magnify these loads.
   - Avoid impulsive loading such as impact activities.
4. Design programs and educate patients regarding appropriate exercise and activity programs.
   - Consider mode, frequency, intensity, and duration.
   - Multimodal including muscle performance, aerobic and mobility activities.
   - Allow sufficient recovery.

cautiously. A patient with Ehlers–Danlos syndrome will have more difficulty recovering from an acute articular cartilage joint injury than a patient without this connective tissue disease.

Restoration of motion in a compromised joint allows loads to be distributed across a greater joint surface area, decreasing peak focal loads. Mobility activities enhance fluid dynamics in the joint, assisting with lubrication and nutrition of the joint. Active and passive ROM activities are important for the recovery of articular cartilage lesions.

In addition to the restoration of motion, normalization of gait and increased muscle performance decrease loads on the articular cartilage.[74] Effective eccentric muscle forces during the loading response of gait can minimize articular cartilage and subchondral bone loads at the tibiofemoral joint. Strengthening activities play an important role in the protection of articular cartilage. Muscle performance exercises must be performed at a dosage that minimizes shear forces and maintains compressive forces within the tissue tolerance. Little empirical clinical evidence exists to provide guidance in program design.[74] Guidelines are generally a compilation of basic science, animal studies, biomechanics, and expert opinion.

Consider alternative exercise modes for patients with articular cartilage injuries of the lower extremity. Clinical research has shown the effectiveness of aquatic rehabilitation for persons with knee arthritis.[75] Water-based programs have shown significant reductions in pain and improvements in strength function in patients with knee and/or hip arthritis.[76–79] Compliance rates were 84% for water therapy and 75% for land therapy. Patients frequently report that pain is lower with exercise in the water compared with exercise on land.[78] Continued participation following the conclusion of formal rehabilitation is also common following aquatic therapy, theoretically maintaining gains achieved in therapy.[80,81] The results reinforce the notion that patients can improve strength and function effectively in either a land or aquatic environment. The key is the ability to provide a comprehensive program, whether on land, in the water, or some combination of both, that the patient will enjoy and continue once formal rehabilitation is completed.

Contusion

A contusion occurs as the result of a blow and can occur in any area of the body to a variety of tissues. No break in the skin occurs, although blood vessels below the skin may be injured, causing ecchymosis in the area. If the damage is more extensive and large blood vessels in the area are disrupted, a localized area of blood may accumulate in deeper tissues, forming a hematoma. When a deep-tissue hematoma occurs, ecchymosis may or may not be seen on the skin surface. For example, quadriceps femoris contusions frequently result in hematoma formation. This hematoma is easily palpable within the muscle, but is rarely accompanied by ecchymosis. The severity of this type of injury can be deceptive, and if left untreated, may progress to myositis ossificans. Myositis ossificans is the formation of heterotopic bone within the muscle, which can lead to impairments in muscle performance, flexibility, and pain.

Treatment Principles

Simple contusions generally resolve in a timely manner without secondary complications or long-term consequences. However, this will be determined by the extent and location of the contusion. Be sure to consider the many layers of soft tissue comprising most injured areas. Contusions that occur in areas of high loads or poor blood supply may eventually result in a chronic inflammation. For example, a blow to the Achilles tendon may result in secondary Achilles tendinitis. Also, deep muscle contusions are at a high risk for long-term complications. Quadriceps and biceps brachii contusions, if left untreated, may result in myositis ossificans or ectopic bone formation within the muscle. This bone results in significant impairments such as loss of motion and muscle performance, as well as activity limitations relative to gait or arm use. These impairments and activity limitations can result in participation restrictions in those who are physically active as part of their lifestyle.

Treatment principles are therefore grounded in an understanding of the consequences of the specific contusion. ROM must be restored as quickly as possible, although in the case of a deep muscle contusion, aggressive mobility early on can increase bleeding. Thus, a balance must be struck between treating the impairments and causing further damage. In the case of a quadriceps contusion where the risk of myositis ossificans is high, this balance can be difficult. Use ice to control swelling and local inflammation as necessary. Use measures of pain, muscle length, and muscle performance to guide the aggressiveness of treatment for this condition. When these measures decline, the pace of the program is too aggressive, potentially causing further damage. Muscle performance measures must be restored, and these activities progressed to functional skills such as walking, stair climbing, and upper extremity work tasks. Submaximal isometric contractions can be safely initiated in the early phases, and these exercises progressed to more challenging muscle performance activities as healing progresses.

MANAGEMENT OF IMPAIRMENTS ASSOCIATED WITH FRACTURES

A fracture can be defined as a break in the continuity of the bone.[82] Most fractures are the result of an acute injury (i.e., macrotrauma), although stress fractures can occur as the result of microtrauma. Fractures are categorized by:

- Whether the skin is broken (i.e., open or closed)
- The amount of disruption (i.e., displaced or nondisplaced)
- The type of fracture (e.g., greenstick, comminuted)

The type and degree of force required to fracture a bone usually injures the surrounding soft tissue as well. Most fractures are treated in the practice pattern of impairments associated with fracture. However, patients undergoing surgical stabilization may be more appropriately treated in the bony and soft-tissue surgical procedures pattern. All fractures are discussed together for clarity.

Classification of Fractures

Fracture classification is first determined by whether or not the fractured bone is protruding through the skin. Fractures breaking the skin surface are considered open fractures; those that do not break the skin are classified as closed fractures. The continuity of the ends of the fracture is then considered. If the bone on all sides of the fracture remains in anatomic alignment,

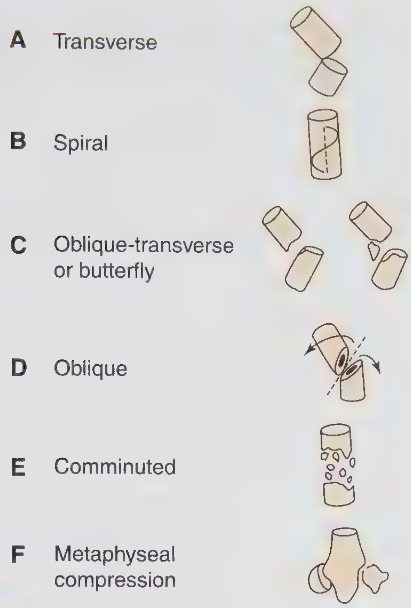

FIGURE 11-14 Types of fractures. **(A)** Transverse, **(B)** spiral, **(C)** oblique-transverse or butterfly, **(D)** oblique, **(E)** comminuted, and **(F)** metaphyseal fracture.

the fracture is considered nondisplaced. Nondisplaced fractures are more difficult to diagnose and require special studies such as radiography to verify. Fractures in which the ends of the bones are not in anatomic alignment with each other are considered displaced fractures. Finally, fractures that extend into the joint are considered intraarticular fractures and can significantly impact joint biomechanics. Failure to restore normal mechanical relationships can place the patient at risk of progressive osteoarthritis.

Fractures are described by the type of break or disruption (**Fig. 11-14**). A **greenstick** fracture is an incomplete fracture that occurs in children. It is so named because of its resemblance to a green stick or twig that partially breaks when bent. **Epiphyseal** fractures also occur in children and are fractures through the growth plate. Salter and Harris[83] subclassified epiphyseal fractures into five different types depending on the extent of fracture affecting the epiphysis and metaphysis. Children are also susceptible to **avulsion** fractures, in which a tendon or ligament is separated from its attachment by a small piece of bone. Because of the relative strength of the collagenous tissues compared with bone in this population, it is not uncommon to see young persons avulse structures such as ACLs or the proximal origin of the hamstring muscle from the bony attachments (**Building Block 11-7**).

BUILDING BLOCK 11-7

A 65-old female fell on ice and sustained a proximal humeral fracture. She has mild osteoporosis. She was immobilized in a sling for 6 weeks and presents to physical therapy for a rehabilitation program. Which associated tissues should be considered and assessed at this point? Presume sufficient healing of the fracture.

Comminuted fractures break into more than two fragments and are often the result of significant trauma, such as a fall or motor vehicle accident. **Pathologic** fractures occur in damaged or diseased bones, as in the elderly with osteoporosis. These fractures are produced with surprisingly minimal force. **Stress** fractures are overuse injuries in which the bone's ability to remodel is incapable of keeping up with the breakdown resulting from activity. Stress fractures occur in persons involved in repetitive activities such as running and jumping and in those with decreased bone density.

Application of Treatment Principles

When designing the rehabilitation program, consider associated soft tissues that have been injured and subsequently immobilized. Although the fracture may be of primary importance from the physician's perspective, rehabilitation of the associated soft tissues may be more challenging than the healing of the fracture. These soft tissues may have been injured at the time of fracture, they may be impaired because of the resultant immobilization, or both. Be sure to relay this information to the patient so realistic expectations after fracture treatment can be developed. Often patients believe that when the fracture is healed the limb should be functional. Soft tissues can take longer to recover than bone, and ensuring that the patient understands this is important for prognosis and program adherence.

Immobilized Fractures

The fracture site and joints above and below the fracture usually are immobilized for some time to allow healing. For patients with external fixation (e.g., cast, splint), physical therapy treatment focuses on rehabilitating the soft tissues that were damaged at the time of fracture and that were subsequently immobilized. The effects of immobilization on soft tissues are profound and consist of:

- Softening of the articular cartilage
- Shortening and atrophy of musculotendinous units
- Decreased mobility of the joint capsule and periarticular connective tissues
- Decreased circulation

Consider these changes when initiating rehabilitation after immobilization. Optimal loading and restoring normal tissue relationships are the goals when rehabilitating patients after fracture immobilization.

Initially, joint mobilization, stretching, and other gentle mobility activities can begin to restore ROM and normal soft-tissue relationships without overloading the tissues. Gentle strengthening in the form of isometrics or gentle isotonics stimulates increases in muscle performance. These same activities and controlled weight bearing load articular cartilage to reverse the changes resulting from immobilization. Electrical stimulation or biofeedback may be necessary in treating significant muscle atrophy. As impairments improve, initiate activities to alleviate any remaining activity limitations to facilitate the patient's return to work, leisure, and community activities.

Surgically Stabilized Fractures

Fractures of the hip and femur are examples of fractures that are frequently treated with surgical stabilization. The lengthy immobilization and significant lifestyle restrictions make conservative treatment of some fractures unrealistic. Open reduction and internal fixation (ORIF) provides immediate fixation of the fracture without the deleterious effects of immobilization.

When treating the individual who underwent surgical fixation of an acute fracture, treatment principles in the early phase focus on recovery from the traumas of the original injury and subsequent surgery. The principles are the same as those for treating soft-tissue strains, sprains, and contusions when addressing postfracture and postoperative pain. When choosing exercises, be sure to consider the effects of the magnitude and direction of loading on the fracture site. The stability of the fracture and fixation guides exercise choice, and this information should be obtained from the patient's medical record or from the physician. For example, a patient with a fixated patellar fracture may avoid weight bearing to prevent distraction loads at the fixation site, but a patient with a fixated tibia fracture may be allowed to bear weight to compress the fracture. Activities that address impairments and activity limitations while keeping loads within the optimal loading zone can then be safely chosen.

Stress Fractures

Stress fractures are a type of overuse injury in which the osteoblastic activity cannot keep pace with osteoclastic activity. This occurs when repetitive loading without adequate recovery is imposed. The metatarsals, tibia, and spine are common sites of stress fractures (**Evidence and Research 11-8**).

EVIDENCE and RESEARCH 11-8

Athletes participating in repetitive sports and military recruits are at a high risk of stress fracture. Data from a high school surveillance program found a rate of 1.54 stress fractures per 100,000 athlete-exposures, with the highest rates in girls' cross-country, girls' gymnastics and boys' cross-country.[84] In sex-comparable sports, girls had higher rates of stress fractures and overall sustained more stress fractures (63%) than did boys (37%). The lower leg and lumbar spine were the most common sites of injury. Participation in ball sports as a youth has been suggested as a way to prevent stress fractures due to the multidirectional and odd loading nature of ball sports, compared with activities such as running and swimming.[85] Stress fractures of the ankle and foot are also common in the military and have been associated with low vitamin D levels.[86,87]

The most important aspect of stress fracture care is decreasing loading to allow healing to occur. This may range from leisure activity limitation to short-term immobilization. During this phase, rehabilitation procedures include treating any impairment of mobility, muscle balance, or movement patterns that may have predisposed the individual to a stress fracture. For example, in the individual who participates in a symmetrical sport, such as running, a biomechanical evaluation of running mechanics is warranted to identify any impairments that may have resulted in asymmetric loading, leading up to the stress fracture. In addition, if decreased bone mineral density is suspected as an underlying problem, institute education or referral for proper evaluation and testing (**Building Block 11-8**).

BUILDING BLOCK 11-8

Consider the patient in Building Block 11-7. She has active shoulder flexion from 0 to 85 degrees, abduction from 0 to 75 degrees, external rotation from 0 to 15 degrees, and internal rotation from 0 to 35 degrees. Passive ROM is slightly greater. Cervical spine ROM is decreased in all directions by ~25%. Provide a sample beginning rehabilitation program.

Once increased loading at the fracture is allowed, determine the patient's optimal loading zone, or current capacity. The patient must learn which exercise or work parameters (e.g., intensity, repetitions, duration, and frequency) keep within that capacity. As tolerated, progress activities using the parameters described in Chapter 5 (Fig. 5-20). Progress parameters moving from patient's current status toward their desired performance or capacity. Choose activities that duplicate the activities to which the patient will be returning. If possible, the activity should be used as a component of the rehabilitation program. Use the functional activity, whether work, leisure, or recreational activities, as the measure of progress, and allow full return when the fracture has healed and is no longer painful to load.

MANAGEMENT OF IMPAIRMENTS ASSOCIATED WITH BONY AND SOFT-TISSUE SURGICAL PROCEDURES

Surgical procedures necessitating rehabilitation can be broadly categorized into soft-tissue procedures and bony procedures, although bony procedures intimately affect the surrounding soft tissues. Soft-tissue procedures are operations primarily directed at the soft tissues, such as tendons, ligaments, or joint capsules. In contrast, bony procedures are operations primarily directed at bone and adjacent tissues. These categories are not exclusive, because surgery often includes soft tissues and bone. However, the primary procedure may predominantly affect one or the other, and rehabilitation follows those guidelines. Not all surgical procedures can be discussed here, and as new surgical techniques are employed, the rehabilitation may change. The physical therapist should focus on the principles of treating patients with different categories of procedures, rather than on specific diagnosis-based protocols.

Frequently, a course of conservative management, including physical therapy, precedes surgery, and follow-up therapy is provided in the postoperative period. This gives the physical therapist the opportunity to participate in the patient's care in two critical perioperative periods. Many specific physical therapy outcomes can be achieved when the therapist has the opportunity for a preoperative visit. This visit allows positive interaction and development of a good rapport between the therapist and patient. Instruction in the postoperative exercise program occurs at a time when full attention can be given to the rehabilitation program, without the complications of postoperative pain and nausea. Instruct the patient in crutch training, wound care, bed mobility, precautions and contraindications to certain movements, and use of any immobilization or supportive equipment so that the patient is not overburdened with multiple instructions after surgery. Emphasize the importance of adhering to the prescribed exercises in the postoperative program. Consult with the patient about expected outcomes and return to function to reinforce realistic expectations after surgery.

Soft-Tissue Procedures

A multitude of soft-tissue procedures are routinely performed by surgeons and include transfer, reattachment or realignment of tendons, ligament reconstructions, capsular tightening, debridement and synovectomy procedures, and stabilization techniques. Regardless of the specific procedure, consider the stages of healing and the effects of immobilization and remobilization on connective tissue. In addition to the specific tissues involved in the surgery, consider adjacent tissues that may be affected indirectly by the surgery. These tissues may include supporting musculature, tissues at adjacent joints, articular cartilage, and associated joint structures (see **Display 11-2**).

Some soft-tissue procedures often require a longer recovery period than bony procedures because of the difficulty in obtaining fixation in soft tissue. Capsular reefing or tightening surgeries in which soft tissue is sutured to soft tissue or tendon transfer or repair procedures in which soft tissue is attached to bone require adequate healing time to ensure fixation. Most importantly, be sure to understand the surgical procedure and communicate with the surgeon to ensure optimal rehabilitation for the patient.

The goals of therapeutic exercise in the perioperative period are to restore motion, strength, and function and to reduce pain. The principles of optimal loading and SAID provide the framework for intervention choices. Be sure to observe for and educate the patient about potential postoperative complications such as infection or deep vein thrombosis. Prevention of these complications by early detection minimizes the risk of and protracted course of care associated with these problems. The rehabilitation program should include exercises and modality treatments to be performed at home to reinforce self-management of the condition.

Ligament Reconstructions

The most common sites of ligament reconstructions are the ulnar collateral ligament at the elbow, the lateral ankle ligaments, and the ACL, PCL, and MCL of the knee. Ligament reconstruction should not be confused with a primary ligament repair. Ligament reconstructions generally use other tissues (e.g., tendon) to create a new ligament, rather than repairing the original ligament. Communication with the surgeon regarding the specifics of the procedure provides the clinician with information critical to proper patient care.

Not all individuals with ligament injuries are candidates for reconstructive procedures. Ample evidence exists supporting the conservative management of knee MCL injuries in the presence of an intact ACL. Many individuals are able to return to their previous activity levels after ACL injury without surgical reconstruction. Decisions regarding the appropriateness of reconstructive procedures are based on the patient's activity level, clinical signs and symptoms, and the natural history of the injury.

The postoperative rehabilitation course after ligament reconstructions depends on factors such as the graft material, fixation, quality of the tissue, status of the joint surfaces, comorbidities, and associated injuries. In the knee, ACL reconstructions using the bone-patellar tendon-bone have solid, bone-to-bone fixation, whereas ACL reconstructions with other graft material may have soft-tissue fixation. Frequently, associated injuries or procedures affect the rehabilitation (e.g., meniscus repair, ulnar nerve transposition). Comorbidities such as diabetes or degenerative joint disease may alter the typical postoperative procedures by accelerating some aspects (e.g., mobility), but in other cases, it may slow down elements of the rehabilitation program (e.g., weight bearing). Every individual should be considered in light of the specific situation.

Impairments after ligament reconstructive surgeries include pain, swelling, and loss of mobility and strength. Weight bearing and all weight-bearing activities are impaired after lower extremity procedures. These impairments may result in activity limitations, including inability to perform activities of daily living such as bathing, dressing, and household chores or an inability to participate in leisure activities. Associated participation restrictions may include an inability to fulfill expected roles as worker, student, or spouse (see **Selected Intervention 11-2**).

DISPLAY 11-2

Rehabilitation Considerations Following Soft Tissue Surgical Procedures

- Respect the stages of healing
- Consider the effects of the original injury, if any, on adjacent tissues
- Address the additional impact of immobilization on all tissues in the kinetic chain (i.e., articular cartilage, ligament, and tendon insertions)
- Understand the implications of an underlying disease process (i.e., osteoarthritis, rheumatoid arthritis), if any
- Modify the treatment plan based on comorbidities (i.e., diabetes, heart disease)
- Adjust interventions based on patient response to the treatment program

Tendon Surgery

Surgery to repair or transfer tendons is commonly performed in orthopedics. Whether a tendon has been torn acutely or has undergone a degenerative process over a protracted period, surgery to repair or debride the injury can maximize the outcome. Common areas of tendon surgery include the tendons of the hand and the rotator cuff, and Achilles, the patellar and quadriceps tendons. As with ligament injuries, not all tendon ruptures need to be treated surgically. Many individuals return to a high level of function despite an unrepaired rotator cuff tear or conservative management of an Achilles tendon rupture.

The specific rehabilitation program depends to a great extent on the location and function of the musculotendinous unit, the location and extent of damage within the musculotendinous unit, the quality of the tissue, and the ability of the surgeon to effectively repair the damage. Areas of poor blood supply, inferior tissue quality, extensive damage, or comorbidities can deleteriously affect the surgical outcome. Communicate with the physician to ensure an understanding of the quality of the surgical repair to avoid overtreating or undertreating the patient.

SELECTED INTERVENTION 11-2

Quadriceps Setting for the Patient with a Knee Injury

See Case Study No. 10

Although this patient requires comprehensive intervention as described in the patient management model, one specific exercise is described.

ACTIVITY: Quadriceps setting

PURPOSE: To increase superior glide of the patella, to teach activation of the quadriceps, and to maintain or increase strength in the quadriceps muscle

RISK FACTORS: No appreciable risk factors

STAGE OF MOTOR CONTROL: Mobility

POSTURE: A variety of positions such as long sitting, supine, or standing. Initially, the exercise is performed with the knee fully extended.

MOVEMENT: Isometric contraction of the quadriceps muscle

SPECIAL CONSIDERATIONS: Ensure normal tracking of the patella. Avoid substitution with hip extensor musculature. Check quadriceps muscle contraction by attempting to perform a medial-lateral glide of the patella during the contraction. With an effective quadriceps set, the patella should not be mobile.

DOSAGE

TYPE OF MUSCLE CONTRACTION: Isometric

Intensity: Submaximal to maximal

Duration: Hold for up to 6 seconds for up to 30 repetitions

Frequency: Hourly or as frequently as possible

RATIONALE FOR EXERCISE CHOICE: Quadriceps setting is a key exercise to maintain the health of the extensor mechanism. This activity lubricates the patellofemoral joint, increases superior glide of the patella (necessary for full knee extension), and increases or maintains quadriceps muscle strength. Full knee extension with quadriceps activation is necessary for a normal gait.

EXERCISE GRADATION: Quadriceps setting is a foundation exercise that serves as a precursor to other exercises. This activity is progressed to more difficult exercises that require quadriceps muscle activation (i.e., any closed chain exercise).

Key issues after a tendon injury are the prevention of mobility impairment without overloading the tendon repair and prevention of excessive atrophy. Immobilization results in loss of normal tendon gliding within the tendon sheath and the associated soft-tissue and joint adhesions due to the postoperative restrictions placed on muscle-tendon stretch and contraction. Unlike ligament reconstruction surgery, after which strengthening exercises can be initiated early, these same exercises may overload the repaired tendon (**Table 11-4**).

Debridement

Surgical debridement is performed alone or in combination with other procedures at a number at joints. Debridement refers to the removal of tissue from an area until healthy tissue is exposed. The purpose is to remove potential sources of pain or irritation and, in some cases, to stimulate a healing response. For example, in osteoarthritic knees, debridement may remove osteophytes and loose bodies, shave or trim areas of roughened articular cartilage, and trim or remove areas of torn meniscus. When performing a ligament reconstruction, the remains of the torn ligament are debrided before the reconstruction is performed, and the torn ends of a tendon are debrided before tendon repair.

Because of the variety of situations in which this procedure is used, rehabilitation is dictated by the primary procedure. Rehabilitation after debridement that accompanies tendon or ligament repair follows the repair guidelines. Debridement performed primarily (e.g., arthritis) is guided by the underlying pathology. Understanding the extent of debridement and the status of the joint (e.g., location, extent, and depth of articular cartilage changes, meniscus tears) ensures appropriate pacing of the rehabilitation program.

Synovectomy

Synovectomy, the removal of the synovial lining of the joint, is a procedure performed primarily in the case of rheumatoid arthritis and other diseases such as pigmented villonodular synovitis. The purpose of synovectomy in the case of rheumatoid arthritis is to remove the inflamed synovium and thereby relieve pain and swelling and perhaps retard the progressive joint destruction associated with chronic inflammation.[88] This procedure is performed only after conservative measures to control the pain and swelling have failed.

Rehabilitation after synovectomy is guided by the primary pathology, such as rheumatoid arthritis. Because this procedure has been performed as a last resort to control pain and swelling, every effort should be made during rehabilitation to restore motion and strength without increasing pain or swelling. These two factors guide the pace of the rehabilitation program and provide the clinician with the parameters for optimal loading.

Decompression

Decompression procedures are used to relieve pressure in an area and are commonly performed at the shoulder to reduce pressure on the subacromial soft tissues and in the spine to reduce pressure on the spinal cord. Surgery in the wrist to relieve pressure in the carpal tunnel and fasciotomies in the leg to reduce compartment pressures may be considered forms of decompression. Excessive pressure in these areas may result from bony or soft-tissue architecture, and decompression involves the release or removal of these soft tissues and shaving or removal of bony sources of pressure.

Rehabilitation after a decompression is guided by the primary pathology and the status of the tissues decompressed, which depends on the amount and duration of compression and on the type of tissue compressed. For example, if excessive pressure on a nerve has caused neurologic changes, rehabilitation focuses on recovery of nerve function. In the spine, a decrease in neurologic symptoms in the arm (following cervical spine decompression) or the lower extremity (following lumbar decompression) is a sign that the decompression has been successful. As neurologic symptoms decrease, progressive strengthening of the core and extremity musculature should increase. If pressure has caused poor muscle function (e.g., rotator cuff), rehabilitation focuses

TABLE 11-4

Sample Rehabilitation Program Following an Achilles Tendon Repair

	PRECAUTIONS	ROM	THERAPEUTIC EXERCISE	PROGRESSION CRITERIA
Phase 1: Inflammatory phase to early proliferative phase surgery to 2 wk	Boot locked in 20–30 degrees PF Touchdown WB using axillary crutches Avoid long periods of dependent positioning	NA for ankle; well limb and proximal joint mobility	Well limb training UBE or upper body circuit	Time-based; 2 wk postoperative
Phase 2: Proliferative fibroplasia phase 2–4 wk postoperative	Continue use of boot progressing to 10 degrees PF at week 2 and 0 degrees PF at week 3	AROM exercises in all ranges Joint mobilization	Isometric exercise of all muscle groups; submaximal for plantar flexion	Time-based: 4 wk postoperative
	WBAT using crutches and boot Watch for appropriate wound healing		Hip and core strength UBE or upper body circuit	Pain-free active DF to neutral No wound complications
Phase 3: Late proliferative fibroplasia phase 4–8 wk	Wean from boot Start with ¼–½ in heel lifts in tennis shoes for short distances on level surface Gradually reduce heel lift	Continue AROM, stretching, and joint mobilization	Progressive isotonic strengthening Static balance exercises Frontal and sagittal plane stepping drills Low-velocity functional movements Hip and core strength Pool exercise	Normal gait Squat to 30 degrees knee flexion with normal mechanics Stork stand with good control for 10 s. AROM from 5 degrees DF to 40 degrees PF
Phase 4: Remodeling phase ~8 wk	Compensations Forceful impact	Continue ROM to 15 degrees DF and 50 degrees PF	Frontal and transverse plane agility drills, progressing from low to high velocity and to sagittal plane Progress hip and core exercise	Squat and lunge to 70 degrees knee flexion with good mechanics AROM to 15 degrees DF and 50 degrees PF
			Multiplane single leg stance activities Bike, cross trainer, swimming	
Phase 5: Maturation phase ~4 months to discharge	Postactivity soreness should resolve within 24 h. Avoid anything producing abnormal movement patterns	ROM as necessary	Impact control exercises progressing from 2 footed through alternate footed to single footed Movement control exercises Work- or sport-specific activities	Completion of functional progression or similar measure

DF, dorsiflexion; PF, plantarflexion; WB, weight bearing; UBE, upper body ergometer; WBAT, weight bearing as tolerated.

on recovery of muscle function. As rehabilitation progresses, avoid using activities or positions that may excessively compress the tissue just decompressed (**Table 11-5**).

Soft-Tissue Stabilization and Realignment Procedures

Soft-tissue stabilization procedures are performed in the case of joint instability resulting from capsular laxity. Capsular laxity can be the result of an acute injury such as a dislocation, or can be part of an overall pattern of hypermobility that has become symptomatic. Soft-tissue stabilization procedures are performed most frequently to correct an unstable shoulder and may be combined with other stabilization procedures (e.g., bony stabilization). A variety of surgical techniques can stabilize a joint with capsular laxity. Each technique has risks and benefits that should be evaluated on a case-by-case basis. Likewise, soft-tissue realignment procedures are performed to redirect the pull of soft tissues that may or may not be the result of instability. For example, proximal patellar realignment is used to enhance the effective pull of the vastus medialis obliquus on the patella. Regardless of the procedure, the fixation usually is soft tissue to soft tissue, without bony stability, which is an important factor in the early rehabilitation phases.

TABLE 11-5

Sample Rehabilitation Guidelines Following Rotator Cuff Repair with Subacromial Decompression

	PHASE 1: INFLAMMATORY PHASE TO EARLY PROLIFERATIVE PHASE	PHASE 2: PROLIFERATIVE FIBROPLASIA PHASE	PHASE 3: EARLY REMODELING-MATURATION PHASE	PHASE 4: REMODELING-MATURATION PHASE
Timeframe	Postoperative to 2 wk	Week 2–5 or 6	Week 6 to phase 3 goals met	Phase 3 goals to discharge
Immobilization	Sling continuously	Gradually wean out of sling; fully out of sling by week 6	NA	NA
Range of motion	Elbow, wrist, and neck AROM: up to 100 degrees elevation and 35 degrees external rotation	PROM progressing to AAROM for shoulder girdle in all cardinal planes Passive pendulum Neck and scapular mobility exercise; joint mobilization at cervical spine and scapulothoracic region as needed UBE within ROM limits and without resistance	AAROM progressed to AROM PROM to end range GH joint mobilization Cervical and thoracic mobility as needed	Mobilization as necessary for normal arthrokinematics
Neuromuscular exercise	Ball squeezes	Postural exercises Scapular retraction Core strengthening Submaximal multiple angle isometrics for shoulder rotation Manual resistance for secondary and distal musculature	Isotonic shoulder strength Scapular strength progressed to plyometrics Submaximal elastic resistance and isokinetic exercise	Total arm strength emphasizing patient's functional needs
Cardiorespiratory	Walking, stationary bike, or cross trainer with sling	Walking, stationary bike, or cross trainer with sling	May begin running if 5/5 strength in rotation	Sport- or work-specific
Progression criteria	Time-based: 14 d postoperative	Minimum 5 wk postoperative; pain controlled and mobility returning	Full AROM 5/5 strength Negative impingement signs	
Other	Ice or other modalities for pain			

AROM, active range of motion; GH, glenohumeral; AAROM, active assisted range of motion; UBE, upper body ergometer; PROM, passive range of motion.

Because of the lack of rigid fixation and length of time necessary for soft tissue to heal, the loads placed on the repair site are controlled for some time after stabilization. For example, when an anterior capsular shift is performed to stabilize a shoulder with anterior inferior glenohumeral instability, external rotation is limited for a short time after surgery to avoid stretching the anterior capsule excessively. Because the repaired tissue is noncontractile, muscle activation is usually allowed early in rehabilitation, as long as ROM precautions are considered. As rehabilitation progresses into the range that stresses the repaired tissue, be alert for signs of progressive loosening of the repair, such as complaints of slipping or instability. Depending on the specific procedure, mobility recovery should be full, without the return of instability symptoms.

Rehabilitation following stabilization procedures focuses on restoring mobility, strength, and function. The rate of progression of mobility activities may vary from one person to the next due to individual variations. Some patients progress slowly due to concern that the stabilization will "stretch out" or loosen. Differences in tissue quality, joint architecture, and surgical technique impact the progression of mobility activities (**Table 11-6**).

Meniscal and Labral Repairs

The meniscus of the knee and the labrum of the hip and shoulder are common sites of fibrocartilage repair. When repairs are performed in the shoulder, they are often at the superior aspect of the labrum where the long head of the biceps inserts into the labrum. Repair of torn menisci of the knee is commonly performed alone or in combination with other procedures such as ACL reconstruction. In the knee in particular, the repair is of a soft tissue with an inferior blood supply. Healing may be enhanced by associated procedures to increase the blood supply to the area.

Important issues during rehabilitation include understanding the loads placed on the repair when the joint is in a variety of positions. These positions should be avoided in the

TABLE 11-6

Sample Rehabilitation Program Following an Anterior Shoulder Reconstruction with Bankart Repair

	PHASE 1: PROLIFERATIVE FIBROPLASIA PHASE	PHASE 3: PROLIFERATIVE AND EARLY REMODELING PHASE	PHASE 4: REMODELING PHASE	PHASE 5: REMODELING AND MATURATION
Timeframe	Weeks 2–6 postoperative	Weeks 6–10 postoperative	Weeks 10–15 postoperative	Weeks 18+
Range of motion	Sling immobilization for 3–4 wk	Continue AAROM and AROM	Posterior glides if posterior capsule tightness present	As needed
	No external rotation with abduction for first 6 wk	Gentle joint mobilization as necessary	Stretching and joint mobilization for any motion limitations	
	PROM/AAROM for all ranges except external rotation only to neutral	Cervical spine and scapular AROM		
	Begin AROM week 5			
Therapeutic exercise	Submaximal shoulder isometrics beginning week 3	Core strengthening	Progressive multiplane resistive exercise	Total arm/core functional exercise Dumbbell, resistive band, and medicine ball exercise
	Elbow, forearm, wrist, and hand exercise	Postural exercise	Stabilization exercises using PNF, rapid alternating, or closed chain techniques	Higher velocity strengthening and control exercise Inertial exercise
	Cervical spine and scapular exercise	Rotator cuff strengthening in nonprovocative position		Plyometric exercise
	Well limb activities	Scapular strengthening and dynamic control		Progress to functional program: throwing, swimming, and racquet sports
		Partial weight-bearing exercise		
Cardiorespiratory fitness	Walking and stationary bike with sling	Walking, stationary bike, elliptical trainer	Walking, biking, elliptical trainer, and running	Sport- or work-specific
Criteria for progression	Full AROM in all ranges except ER	Full AROM	Continued strength and function progress without apprehension or impingement	Discharge to sport/work when functional progression complete
	5/5 IR/ER strength in neutral	5/5 IR/ER strength at 45-degree abduction		
	Negative apprehension and impingement signs			

AROM, active range of motion; AAROM, active assisted range of motion; IR/ER, internal rotation/external rotation; PNF, proprioceptive neuromuscular facilitation; PROM, passive range of motion.

early stages when the repair is still fragile. For example, full overhead positions may be avoided early after glenohumeral labral repairs in the superior zone. Full knee flexion in weight bearing is limited for several weeks after meniscal repair, because this position places high loads on the meniscus. Return to activities such as impact loading, jogging, deep knee flexion, and pivoting should be approached cautiously, particularly in the early postoperative phase.

Communicate with the surgeon regarding the location and extent of tissue repair. The type, location, and extent of tear provide important information about the rehabilitation protocol. At the knee, the margins of a longitudinal tear will be approximated with weight bearing, via hoop stress, whereas the margins of a radial tear will be disrupted. Tears located in the peripheral one-third, or vascular zone, have a better prognosis than those in the central one-third, or avascular zone. However, surgical techniques have improved and meniscus tears in the avascular zone are repairable with good success.[89,90]

Meniscal allografts are used in situations in which patients have undergone a complete meniscectomy, and are generally young and active (age 50 or less), have a varus alignment and mild to moderate tibiofemoral arthrosis. The goal is to perform the surgery early before extensive articular cartilage damage occurs.[91] In fact, meniscal allograft transplantation is contraindicated in patients with significant arthrosis.[92]

Rehabilitation following meniscal repair or transplantation focuses on limiting weight-bearing forces to control compressive and shear forces.[92] The rate of program progression will depend upon many individual factors, most importantly keeping joint loads within healing tissue tolerance. Appropriate progression requires attention to external factors (i.e., age, joint surface quality, body mass index, joint alignment, etc.) and internal factors (i.e., size and location of lesion, direction of tear, etc.). Maintain close communication with the surgeon to ensure progression that is consistent with surgical findings and procedures.

The rise of hip arthroscopy has expanded the understanding and treatment of hip pathology. Procedures such as debridement of loose bodies of removal of osteophytes that were previously performed as open techniques can now be done more efficiently arthroscopically. Additionally, arthroscopy has helped identify previously underrecognized problems such as labral tears and chondral injuries.[93] These injuries occur as acute traumatic episodes in athletic activities, such as landing directly on the greater trochanter. This impact can produce shearing of the articular cartilage on the acetabulum resulting in a chondral injury.[93]

Injuries to the acetabular labrum can occur acutely or as the result of aging and degeneration.[93–95] Femoral acetabular impingement can produce anterosuperior labral and chondral lesions.[95] Labral injuries have been classified into four different types and occur in different locations.[95] Symptoms are similar to those of a meniscal or shoulder labral tear, where the patient experiences pain, clicking, catching, and instability. Hip arthroscopy can help to identify and correct the injury.[96] Like surgery for a torn meniscus, arthroscopy to debride the unstable labrum, maintaining as much of the tissue as possible, will lead to the best outcomes. A sample rehabilitation program following hip arthroscopy can be found in **Table 11-7**.

TABLE 11-7

Sample Rehabilitation Program Following Hip Arthroscopy for Labral Tears

	PHASE 1: INFLAMMATORY AND EARLY PROLIFERATIVE PHASE	PHASE 2: PROLIFERATIVE FIBROPLASIA PHASE	PHASE 3: REMODELING AND MATURATION PHASE
Timeframe	Postoperative to week 2–3	Completion of phase 1 to approximately week 6	Completion of phase 2 to discharge
Weight bearing	Crutches and limited weight bearing; normalize gait	Discontinue crutches when gait is normal without pain medication	Full weight bearing
ROM	AAROM, PROM all planes Gentle hip mobilization and distraction	Continue ROM and mobilization until full or desired ROM is achieved	Maintenance, patient-specific stretching
Neuromuscular exercise	Gait activities: marching, weight shifting, and normalizing gait (may use pool)	Progressive gait activities including balance, direction changes, and functional movements (may use pool)	Gentle impact on shock absorptive surfaces, 2 ft–2 ft progressing to single foot
	Isometrics of all hip and knee musculature	Nonimpact hip and core muscle strengthening (resistive bands, swiss ball, etc.)	Progress to multiplane
	Short-arc dynamic hip exercises	Lower extremity strengthening (PNF, leg press, knee extensions, etc.)	Dynamic control exercises reproducing functional activities Running program if returning to running sport
			Sport- and work-specific drills
			Progressive hip, leg, and core strengthening
Cardiorespiratory	UBE or pool without kick	Nonimpact: stationary bike, cross trainer, swimming, and deep water running	Sport- or work-specific in neuromuscular and cardiorespiratory demands
Progression criteria	Normal gait without assistive device or pain medications on level surface	Normal gait on all surfaces Completion of functional movement patterns without compensation Single leg balance ≥15 s	Return to work or sport when functional progression and/or work conditioning program is passed
	Functional ROM without pain		
	Good leg control during slow movements		

AROM, active range of motion; AAROM, active assisted range of motion; PROM, passive range of motion; ROM, range of motion.

Bony Procedures

Rehabilitation is often necessary after bony surgical procedures to restore motion at adjacent joints, strengthen related soft tissues, and increase general endurance. Most articular cartilage surgeries are a combination of soft tissue and bony procedures. The number of available procedures suggests that there is no one optimal treatment for those with articular cartilage injuries. Many individual parameters such as age, body mass, activity demands, status of the primary and adjacent joints, as well as specifics of the lesion itself weigh heavily in surgical planning.[97,98] The specific procedure, tissue damage, and the patient's general health, balanced with the optimal loading and SAID principles, guide intervention choices. The focus of these sections will be on the knee due to the volume of research and high utilization at this joint. However, use of many of these procedures is being successfully extended to other joints.

Surgical Management

Surgical management of articular cartilage defects can be thought of as a spectrum: from palliative care to reparative management to restorative intervention. Articular cartilage defects are similar to potholes in the street. Palliative care "ignores" the pothole and just cleans up the edges surrounding the pothole. Reparative techniques fill the articular cartilage defect (pothole) with a native, suboptimal substance (such as filling a hole in a concrete road with tar). Restorative techniques fill the articular cartilage defect with the same structure, as filling a concrete pothole with concrete. Each surgical technique, its advantage and disadvantage, will be discussed.

Palliative Management: Lavage/Debridement

Surgical procedures to remove loose fragments and other mechanical or chemical irritants may provide some temporary relief to joint pain in the degenerative joint. Simple arthroscopic irrigation (lavage) along with removal of loose bodies or other tissue fragments can produce improvement in many patients. The purpose of these procedures is to reduce inflammation and mechanical irritation by washing away fragments of cartilage and calcium phosphate crystals from the joint.[99] This procedure can decrease mechanical symptoms as well as night pain in the short-term following surgery.[100] In some patients, lavage can decrease symptoms for up to 3 years. Additional debridement including smoothing of fibrillated joint surfaces, removal of osteophytes, or partial synovectomy may further reduce symptoms.[99] Patients with good joint space, a short duration of symptoms, good alignment, and a stable knee may do well with this procedure. However, neither lavage nor debridement addresses the underlying pathology, so improvements are short lived. As a result, the benefits of these procedures may be limited, and the improvements restricted to a small proportion of patients.

Reparative Management: Microfracture

Other patients may require more aggressive treatment that attempts to stimulate healing. Microfracture is a procedure performed alone or in combination with other procedures in cases of articular cartilage lesions. This procedure is performed most commonly at the knee, where articular cartilage lesions may result from degenerative joint disease or acute injury. The microfracture technique can be used for isolated defects or for bipolar or "kissing" defects, where defects on opposing joint surfaces contact one another. These lesions produce impairments such as pain, swelling, and motion loss, as well as activity limitations such as the inability to walk distances, stand for long periods, or negotiate stairs.

The surgical procedure involves a diagnostic arthroscopy and correcting any associated intraarticular pathology. The zone of calcified cartilage is debrided, taking care to avoid abrading the subchondral bone. Subsequently, a surgical awl, drill, or pick is used to make several small holes or "microfractures" in the subchondral bone. This procedure basically makes a partial thickness articular cartilage lesion a full-thickness lesion, because the awl, drill, or pick passes through the tidemark zone into the subchondral bone. This procedure creates a roughened surface to which a blood clot can adhere. This procedure stimulates a healing response and local fibrocartilage ingrowth. Unfortunately, the mechanical properties of the replacement fibrocartilage are significantly inferior to the original tissue, similar to filling a concrete pothole with tar.[99,100]

Rehabilitation after microfracture varies with the extent and location of the articular cartilage lesion. Large lesions on weight-bearing surfaces have a poorer prognosis than small lesions on non–weight-bearing surfaces. The joint with extra loads from excessive body weight, malalignment, or instability is likely to require a longer rehabilitation course, with a greater likelihood of overloading the new fibrocartilage. These individuals may have weight-bearing and exercise limitations for up to 8 weeks after surgery. Depending upon the size and location of the lesion, weight bearing can be progressed to partial weight bearing between weeks 2 and 4. The patient should be full weight bearing by week 8.

Restoration of motion and strength as quickly as possible without disrupting the healing process provides the best opportunity for healing of this fresh injury (**Fig. 11-15**). Many surgeons advocate the use of continuous passive motion with their patients for up to 6 weeks postoperatively to create a healing environment.[100] Typically, PROM is performed immediately without restrictions in most cases.

Strengthening exercises in the early phase consist of multiangle isometrics and non–weight-bearing leg-raise activities. The pool is an effective place for gait training, ROM, and functional training, and is initiated when incisions have healed. A stationary bike with light resistance can be used for mobility and strengthening as early as week 3 to 4. By week 4, with the progressive increase in weight bearing, balance and light weight-bearing activities such as wall slides, mini-squats and lunges can be initiated or advanced. Hip and core strengthening are important as well. Strengthening exercises should continue and replicate functional activities by weeks 8 through 16, with gradual return to activities over the next 2 months.[101] High-impact activities can be considered at 6 to 8 months postoperatively.

Restorative Management

Osteochondral Autograft Transplantation Several surgical techniques attempt to restore and preserve articular cartilage. More aggressive techniques are indicated in the case of full-thickness defects of the weight-bearing surface of a joint.[99,102] The osteochondral autograft transplantation (OAT)

FIGURE 11-15 Using activities in a gravity-minimized environment can progressively load the lower extremity. **(A)** Begin walking in deeper water and progress to **(B)** walking in shallow water. Walking faster also increases the weight-bearing forces. Educate patients to avoid this common mistake of ipsilateral arm and leg movement in the water.

procedure transfers articular cartilage tissue from areas of low loading to areas of high loading. In addition to the knee, OAT procedures have been used with lesions on the talus, tibia, humeral capitellum, and femoral head.[102] Indications include focal chondral or osteochondral defects of weight-bearing surfaces or joint surfaces that are frequently loaded, age <50 years, concurrent treatment of instability, malalignment and meniscal injuries, and compliance with weight-bearing restrictions.[102] This procedure is performed most often at the knee, where bone plugs are removed from trochlea and intercondylar notch and placed on the articular surface lesions. When multiple plugs are used to fill a larger defect, the procedure is often termed a "mosaicplasty." Problems with this procedure are related to limitations in the graft size, obtaining good congruity of the graft and adjacent articular cartilage, and graft fixation. Additionally, few areas of a joint surface are truly "non–weight bearing," resulting in significant risk of donor site morbidity.[102]

Rehabilitation after an OAT procedure will vary with the size and location of the lesion and fixation stability. The general rules about rehabilitating any articular cartilage lesion apply here and are modified based on individual patient factors. General guidelines allow unloaded PROM as tolerated with emphasis on restoring full motion as quickly as possible, whereas AROM varies depending on the size, location, and fixation of the lesion. Typically, there is no period of strict immobilization. Particular attention should be paid to treatment of the underlying causes of the original articular cartilage lesion. Patients are generally non–weight bearing for 2 to 4 weeks, followed by a gradual progression of weight bearing over the next 3 to 4 weeks. This varies with the size and location of the lesion. Lesions that are found on a non–weight-bearing surface may be non–weight bearing for 1 week only. Muscle performance activities include isometric contractions in pain-free ranges and the non–weight-bearing leg raises immediately. Concentric active exercises in ranges that do not engage the lesion can begin as early as 1 week with light resistance as early as the second week after surgery.[102] Strength and functional activities progress and include balance and proprioception drills by 6 to 12 weeks postoperatively.[101] Low-impact activities are allowed at 6 to 8 months, while higher impact activities such as running and aerobics are no allowed until 8 to 10 months following surgery[101] (see **Table 11-8**).

Autologous Chondrocyte Implantation

The autologous chondrocyte implantation (ACI) procedure is indicated for cases of large, full-thickness chondral lesions located on the femoral condyles or trochlear groove. Patients should be under 50 years of age and be willing to adhere to the postoperative protocol.[97] The lesion typically ranges in size from 2 to 10 cm^2 in diameter, but ACI has been successfully used in lesions up to 20 cm^2.[103] Other prerequisites include good alignment, ligamentous stability, and good ROM.[98] Any associated pathology must be corrected prior to or at the time of surgery. While ACI can be used in joints with multiple chondral lesions, ACI is contraindicated for "kissing lesions" or significant bone loss.[99]

This procedure is performed in two stages. In the first stage, two to three full-thickness samples of healthy articular cartilage are harvested from the patient, typically from the superior peripheral edges of the lateral or medial femoral condyles.[97] These samples are cultivated and held until the second stage, performed anywhere from 6 weeks to 18 months after graft harvest.[97,99] The patient should obtain full motion and sufficient strength prior to the second procedure. In the second surgical procedure, the cartilage defect is debrided, avoiding disruption of the subchondral bone. Once the lesion

TABLE 11-8

Rehabilitation Program Following OAT Procedure

	PHASE I: INFLAMMATORY PHASE TO EARLY PROLIFERATIVE PHASE	PHASE 2: PROLIFERATIVE FIBROPLASIA PHASE	PHASE 3: REMODELING PHASE	PHASE 4: MATURATION PHASE
Timeframe	Weeks 0–6	Weeks 6–12	Weeks 12–26	Weeks 26+
Weight bearing	Brace locked in full extension	Discontinue brace	Full WB	NA
	Status will vary with location and size of lesion; follow physician guidelines	Progress WB based upon physician recommendations		
	Generally NWB for up to 4 wk with progressive WB by 25%/wk	*Generally* full WB by 8–10 wk		
Range of motion	PROM as tolerated CPM for up to 8 h/d	Continue PROM AROM in ranges that do not engage lesion	Full ROM Continue stretching as needed	Continue maintenance stretching
	Immediate full extension	Continue mobilization and stretching Knee flexion to ~130 degrees by week 8–10		
	Stationary bike as tolerated			
	Joint mobilization			
	Flexion goal of 90 degrees by ~2 wk			
Therapeutic exercise	Quadriceps sets	Partial WB weight shifts	Continue progressing strength exercises	Progress strengthening
	Multiangle isometrics	Gentle leg press, wall slides, and lunges with resistive bands or weights through partial ROM	Increase resistance	Progress balance and proprioception activities
	Leg raises	Partial WB balance and proprioception drills	Leg press 0–90 degrees	Functional progression
	Pool exercises	Partial ROM resisted knee extension	Squats 0–60 degrees Step-ups	Impact activities as determined by individual needs
	Well limb exercise		Lunge walking,	Return to work or sport
			Elliptical trainer	
			Progressive walking, bicycling	
			Functional activities that are nonimpact	

NWB, non-weight-bearing; WB, weight bearing; PROM, passive range of motion; CPM, continuous passive motion; AROM, active range of motion; ROM, range of motion.

is debrided and prepared, a periosteal flap is harvested from a different site (typically the superior medial tibia) and sutured over the lesion. The suture line is sealed with fibrin glue to ensure a watertight seal at the edges of the periosteal flap.[104] The cultured chondrocytes are injected under the periosteal flap and the injected site closed with additional sutures and fibrin glue. Periosteal flap hypertrophy can be a complication in up to 20% of patients. As such, synthetic flaps are beginning to be utilized with good success.[103]

Rehabilitation after ACI is similar to that of other articular cartilage procedures. A balance must be found between protection of the healing tissue and loading of the maturing tissue. The actual progression will vary with the size and location of the defect.[97,101] In general, full unloaded PROM is allowed early on, and the patient will be non–weight bearing or touch-down weight bearing for the first 2 to 4 weeks, with progressive weight bearing over the next 2 to 4 weeks. Weight bearing is performed with axillary crutches and the knee locked in full extension. Full weight bearing without crutches is expected by 6 to 9 weeks. Full passive knee extension is expected immediately, with knee flexion to 90 degrees by week 2 and 130 degrees by week 8.[97,101] Isometrics that do not engage the lesion are initiated and progressed to short-arc isotonic exercises, again, in positions that do not engage the lesion. The pool is an ideal place to initiate and progress activities, particularly gait, weight bearing, and balance activities. Return to activity is anywhere from 6 to 12 months depending upon the lesion, patient factors, and type of activity.

Open Reduction and Internal Fixation

ORIF of a fracture is commonly performed when closed reduction is impossible or when fracture healing would be protracted if treated without fixation. The goals of ORIF are to stabilize a fracture while allowing early motion and activity, to decrease the chances of nonunion, and to decrease the deleterious effects of immobilization on the limb. Surgical fixation may use plates, screws, wires, or other forms of hardware to stabilize the bone and fragments. In most situations, the hardware is left in permanently, although it may be removed in the case of superficial discomfort or loosening after the bone is healed.

Rehabilitation after ORIF is directed at any impairments or activity limitations associated with the injury. Any force great enough to fracture a bone is likely to have produced some local soft-tissue damage, which must be treated as well. Restrictions (e.g., weight bearing, motion) are specific to the location and severity of the fracture and to the extent of associated soft-tissue injury. In general, surgical fixation stabilizes the fracture, and treatment focuses on associated soft-tissue damage and restoration of full function.

Fusion

Fusion is the operative formation of an ankylosis or arthrodesis.[105] Fusions are performed most commonly in the spine, although some joints in the extremities are fused. Spinal fusions are used to treat problems such as instability, facet pain, and disk disease. Glenohumeral joints are fused in cases of severe pain, especially in the presence of neurologic injury (e.g., axillary nerve, long thoracic nerve) that severely restricts functional use of the arm. Knee joints are fused as a last resort when severe arthritis produces pain and disability and total joint replacement is not a treatment option. Fusions about the ankle are used to treat hindfoot pain and arthritis.

The postoperative rehabilitation program must consider the mechanical changes that occur as a result of the fusion. Because mobility is limited at a joint (or series of joints in the spine), adjacent joints compensate to restore the presurgical mobility. How effectively these joints compensate or overcompensate has a profound impact on the result. If the hip and ankle are unable to adequately compensate for a fused knee, the patient has difficulty getting in and out of a car, a chair, and on and off the floor. Because the spine is a series of joints, adjacent segments can often compensate for fusion at one or more levels. However, adjacent segments may become hypermobile in response to the fusion, creating pain above or below the fusion. An important aspect of postoperative rehabilitation is focused on the adjacent joints and procedures necessary to ensure the long-term health of these joints. The muscles must be retrained to function in a new movement pattern.

Osteotomy

Osteotomy, the surgical cutting of a bone, is a procedure performed to correct bony alignment. This procedure is performed most commonly at the knee to correct excessive genu varus or valgus. Excessive varus or valgus places increased loads on the medial and lateral compartments of the knee, respectively. This may result in degeneration of the articular cartilage in that compartment. The purpose of performing an osteotomy is to decrease the load incurred by the compromised compartment and to disperse the load over a larger area. To correct for excessive varus, a high tibial osteotomy (or valgus osteotomy) is performed at the proximal tibia. To correct for excessive valgus, a distal femoral osteotomy is performed. These procedures remove a wedge of bone from the respective site, and the "fracture" is fixated with hardware.

Rehabilitation focuses on the precipitating issues that led to surgery (usually degenerative joint disease) and the preservation or restoration of motion and strength. An important consideration is the change in loading patterns on the articular cartilage. The compartment that has been excessively loaded will have decreased loading; the other compartment that has been underloaded will have increased loading. How well a compartment adapts to the increased load depends on many factors. The health of the articular cartilage in this compartment is probably the most important factor. Weight-bearing activities may have to be restricted until the joint can adapt to this change.

MANAGEMENT OF IMPAIRMENTS ASSOCIATED WITH JOINT ARTHROPLASTY

Joint replacement surgery is performed to remedy significant joint deterioration after other conservative or surgical measures have been exhausted. Joint replacement is performed in many joints, including the hip, knee, glenohumeral joint, elbow, wrist, and carpometacarpal joint in the hand. The chief goal of joint arthroplasty is pain relief. Generally, the patient cannot expect increased joint motion, strength, or function other than that resulting from a decrease in pain.

Joint replacement is categorized by component design (i.e., constrained, unconstrained, or semiconstrained), fixation (i.e., cement or cementless), and materials (i.e., cobalt-chrome alloy, titanium alloy, or high-density polyethylene). A *constrained* design allows motion in only one plane; an *unconstrained* design allows motion in any axis. A *semiconstrained* design allows full motion in one plane and some motion in other planes. Fixation is achieved with cement or with some type of biologic fixative. Biologic fixation may include a porous coat or similar surfaces that allow bony ingrowth into open areas on the surface. Recovery of components with this type of fixation is difficult in the patient in need of revision arthroplasty. Materials usually are a combination of metals and plastic.

In addition to total joint arthroplasty, joint resurfacing procedures are also available. Total surface arthroplasty (TSA) is being performed more routinely at the hip joint. While patients in the past underwent total joint arthroplasty for pain relief, more patients are requesting TSA to improve their quality of life and to remain active. TSA preserves more bone. In the hip procedure, the prosthesis is metal-on-metal, where the acetabulum is lined with a metal cup and the femoral head is capped with a metal prosthesis. Unlike a total hip arthroplasty, the femoral head is not removed in a TSA.

Rehabilitation issues are joint- and prosthesis-specific. In general, restoration of motion, strength, and function and consideration of the underlying cause of the surgery constitute the rehabilitation framework. Unlike a total hip arthroplasty, there are no limitations in hip ROM with a TSA. Consideration must also be given to the adjacent joints, which may be compromised by the same disease process and the excessive loads placed on them in the perioperative period. After recovery from the operation, the patient generally feels much better than before the surgery, with less pain in the affected joint. Education regarding the long-term health of the resurfacing procedure and the adjacent joints is a large component of the patient care program.

KEY POINTS

- The composition and structure of connective tissues provide information about each tissue's mechanical properties and function.
- The unique viscoelastic characteristics of connective tissues are the result of their fluid and solid constituent materials.
- When connective tissues are loaded, the stress (i.e., force per unit area relative to the strain) or change in the length per unit length provides information about the tissue's ability to withstand loads.
- The viscoelastic properties of relaxation, creep, and hysteresis are the physiologic basis for changes seen with stretching.
- The stages of healing along with knowledge of the specific injury provide the clinician with guidelines for intervention selection throughout the episode of care.
- Restoration of normal tissue relationships, optimal loading, the SAID principle, and prevention of secondary complications are broad rehabilitation principles that guide treatment.
- Acute soft-tissue injuries such as sprains, strains, and contusions necessitate early intervention to avoid secondary complications.
- Management of tendon injuries and prognosis varies according to the injury classification.
- Interventions used in the treatment of bony or surgical procedures should have a solid foundation in basic science and require an understanding of the anatomy and kinesiology of the area.

CRITICAL THINKING QUESTIONS

1. Consider Case Study No. 2 in Unit 7, before her total knee replacement surgery. Presume that she came to your clinic 2 years earlier in an attempt to delay surgery. At that time, her motion was decreased by 15%, and her overall strength was decreased by 20%. Describe her exercise program. Provide the rationale for restoration of her joint motion and strength in the case of osteoarthritis of the knee.
2. The patient in the first question is given a home exercise program to carry out for 2 weeks, after which she returns to the clinic for reevaluation and progression.
   a. Explain to this patient how to differentiate the discomfort associated with some exercise from pain that may be related to harming her knee.
   b. Compared with her previous visit, her knee is more swollen and warm to the touch. She has lost 5 degrees of knee extension and 10 degrees of knee flexion. Her gait is significantly impaired. What are your recommendations at this time? When should you see her again and why?
3. Why are repeated eccentric muscle contractions associated with tendinitis?
4. If eccentric muscle contractions contribute to tendinitis, why are they used to treat tendinitis?
5. Consider Case Study No. 6 in Unit 7. How would your acute-phase mobility program differ if the patient
   a. Were generally hypermobile, demonstrating elbow hyperextension, knee recurvatum, and thumb to volar forearm?
   b. Were generally hypomobile, with a history of excessive scar formation?
6. Consider Case Study No. 1 in Unit 7. Previously this patient was seen for nonoperative treatment. Unfortunately, he continued to be symptomatic and unable to return to activity. He underwent arthroscopic debridement of the hip, removing loose bodies, smoothing labral irregularities, and resecting the pathologic cartilage/bone mass. He is now 2 weeks postoperative and sent for rehabilitation. He is to start full weight bearing this week.
   a. What are the key considerations as you initiate his program? Does his previous rehabilitation impact your decision-making?
   b. What signs or symptoms might suggest that the program is moving too quickly? Too slowly?

LAB ACTIVITIES

1. A patient comes to the clinic on a Monday morning with acute Achilles tendinitis after a weekend tennis tournament.
   a. Instruct your patient in a home exercise program, including dosage, to be performed until he or she returns in 4 days.
   b. Explain to your patient about adjunctive agents and give any special instructions.
2. The patient returns 4 days later and is in a subacute phase of injury.
   a. Demonstrate five stretching techniques for the Achilles tendon.
   b. Instruct the patient in a home stretching program, including dosage.
   c. Demonstrate three ways to strengthen this muscle group, including dosage, using
      i. concentric only
      ii. isometric only
      iii. eccentric only
3. This patient has improved with the exercise program and desires to return to basketball. Demonstrate the final phase of the rehabilitation program to prepare the patient for this activity.
4. Instruct each of the following patients on five exercises to increase knee flexion mobility:
   a. A 19-year-old student 2 weeks after a grade II MCL sprain of the right knee with a 0- to 90-degree ROM
   b. A 75-year-old woman who is unable to get up and down off the floor 2 weeks after a total right knee replacement with a 0- to 60-degree ROM

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CHAPTER

12 Therapeutic Exercise for Arthritis

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PATHOLOGY

An important principle of therapeutic intervention is that treatment should consider the underlying causes of disease as well as the resulting effects on body function and structure, activity and participation (see Chapter 1). This approach necessitates an understanding of the pathology and its relation to broader functional effects in order to guide treatment design, including the choice of intervention, understanding of precautions, and formulations of rational goals.

Arthritis literally means joint inflammation, but there are approximately 100 different types of arthritis (inflammatory and noninflammatory, affecting not only joints but soft tissue as well). Osteoarthritis (OA) and rheumatoid arthritis (RA), two of the most common forms of arthritis, are discussed in this chapter. OA represents a type of nonsystemic, mostly noninflammatory, localized pathology. In contrast, RA is a systemic, inflammatory disease that usually involves multiple joints and often affects organ systems. Because these two diseases have distinctly different pathologic mechanisms, and because of the widespread systemic effects of RA, some of the exercise design considerations vary.

Since many of the same principles of degenerative and inflammatory processes are encountered in the less common forms of inflammatory arthritis, similar thought processes can be applied to developing exercise approaches for patients with these diseases. Effects of the two diseases on joints and related structures are listed in **Table 12-1**.

Osteoarthritis

Etiology

Osteoarthritis is characterized by the breakdown of articular cartilage under load with resultant changes in bone and other soft tissue periarticular structures. The view that OA is the result of passive wearing of cartilage with time is being replaced with an

TABLE 12-1

Effects of Osteoarthritis and Rheumatoid Arthritis on Joint Structure and Function

STRUCTURE	FUNCTION	EFFECTS OF OSTEOARTHRITIS	EFFECTS OF RHEUMATOID ARTHRITIS
Cartilage	Shock absorption, joint congruence	Thickening to softening to thinning to loss	Erosion of cartilage
Synovium	Secretes synovial fluid for nutrition of cartilage, lubrication, and stability	Secondary involvement occasionally	Microvascular lining cells activated by inflammatory process, pannus formation
Ligaments	Stability, reinforce capsule and limit movement, guide movement	Abnormal joint alignment stresses	Erosion weakens
Muscles	Reinforce joint capsule, reflex joint protection, move joints	Immobility shortens; pain causes guarding and reflex inhibition, leading to weakness	Joint deformity interferes with peak torque generation; immobility causes shortening; myositis weakens; pain and effusion cause guarding and reflex inhibition, leading to weakness
Bone	Structural support	Subchondral bone remodeling changes shock-absorbing properties, joint margin spurring leads to bony blockade and pain	Erosion leads to joint deformity, bony blockade, pain
Extraarticular system		Increased energy expenditure from abnormal movement patterns	Myositis, anemia, sleep disruption, fatigue, increased energy expenditure from abnormal movement patterns

increased understanding of the interaction of biomechanical and molecular events which produce osteoarthritic changes, though there is a highly positive correlation of incidence with age.[1,2]

Clinical Manifestations

Osteoarthritis typically affects weight-bearing joints and joints of the hand, is usually unilateral, and often unicompartmental; it has no direct systemic effects.

The pathologic changes in OA reflect damage to the articular cartilage and the joint's reaction to that damage. Cartilage damage diminishes the joint's ability to withstand loading forces which further stresses the articular cartilage, leading to tissue damage that can result in low-grade synovial inflammation. If chronic, inflammation can lead to fibrosis of the joint capsule and resultant range restriction. Hypertrophic bone formation at joint margins (i.e., marginal spurring) leads to joint deformity and pain (**Fig. 12-1**).

Extraarticular soft-tissue structures are affected by asymmetric joint deformity which in turn further affects joint function. A common example of this imbalance is seen in the osteoarthritic knee. Lateral compartment cartilage loss results in a valgus deformity of the knee, which stretches muscles and ligaments medially and shortens soft-tissue structures laterally. In addition to affecting alignment of the knee and weight bearing through the joint, the deformity changes the mechanical advantage of medial and lateral muscle groups and the stability of the joint as stretched ligaments become lax. Joint pain and swelling, together with splinting and guarding, can lead to muscle disuse atrophy and loss of this important component of the shock-absorbing system. Significant functional deficits can develop as these clinical changes progress. In running, the tibiofemoral joint experiences forces 2.5 to 3.0 times body weight[3] and in deep knee bends, the patellofemoral joint is exposed to forces 10 times the body weight. Impairment of the joint elements responsible for efficient shock absorbing will in turn lead to further joint breakdown during activity.

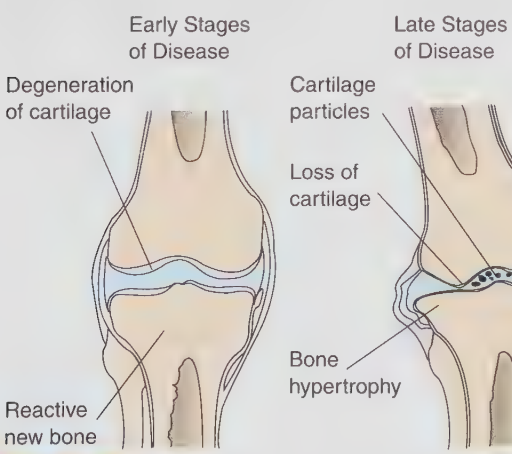


FIGURE 12-1 Osteoarthritis starts with asymmetric cartilage loss, which leads to abnormal forces on the joint. Soft-tissue imbalance, joint malalignment, and bony hypertrophy can result. Inflammation is not the major component of the osteoarthritis process. (Adapted from AHPA Arthritis Teaching Slide Collection. American College of Rheumatology, Atlanta, GA.)

Although cartilage failure may be the primary event in OA, the overall effect of the disease is rarely confined to the involved joint.[4] Patients with OA in the lower limb demonstrate impairments in adjacent and contralateral joints. In attempting to improve overall function, the exercise program should focus on impairments at the affected joint and on secondary impairments and activity limitations at associated joints caused by the primary impairments and by inactivity (see **Building Block 12-1**).

BUILDING BLOCK 12-1

A 65-year-old male is referred to therapy with complaints of left (L) knee pain. Since his recent retirement, he has spent three mornings a week at a driving range, and two times a week playing 18 holes of golf. He thinks his knee pain has gotten worse since his retirement when he was more sedentary. In addition to making it difficult for him to participate in his normal weekly golf game with friends (he is now limited to nine holes and that is getting painful enough that he is thinking of stopping altogether), he is finding it increasingly difficult to get up and down stairs, or to sit down and get up from a low chair due to pain and a perception of weakness in his L leg.

He takes no medication, reporting to you that though his doctor has told him to take an over the counter anti-inflammatory, he has chosen not to as he doesn't believe in medicine and especially doesn't want to become dependent on pain medication.

Review of systems shows a moderately hypertensive individual, who is overweight. His radiology report states that there is marked cartilage degeneration in the left medial compartment of the tibiofemoral joint which is apparent in the varus angle of his L knee compared to right (R). He recently noted that when he is on his feet a lot, his R knee can bother him as well. His doctor has suggested increased activity for both weight and hypertension control.

1. Which joints should be examined in the initial evaluation of this patient?
2. What tests should be performed in this examination?
3. Write a problem list based on the information in this case including at least two impairments of body structure or function, two for activity, and two for participation restrictions.

Rheumatoid Arthritis

Etiology

Rheumatoid arthritis is a disease of unknown etiology characterized by chronic, erosive synovitis in which an immune event triggers transformation of synovial cells causing them to proliferate. RA affects approximately 0.05% to 1% of the world population with geographic and racial variations.[5] An invasive, fibroblast-like cell mass called pannus develops and erosion of cartilage and bone follows. Synovial fluid accumulates, and the joint swells, distending the capsule, pulling on its periosteal attachment, and causing pain and potential rupture. Ligaments and muscles around the inflamed joint are also subject to weakening and potential rupture. The precise cause of RA is unknown, but appears to be an interplay between genetics and environmental factors[6] (**Evidence and Research 12-1**).

EVIDENCE and RESEARCH 12-1

Studies of twins suggest an underlying genetic susceptibility in RA that may be triggered by environmental factors, within a framework of chance.[6,7] The extraarticular manifestations of RA implicate other systems in the etiology as well as the clinical presentation. Smoking and other forms of bronchial stress have been linked to RA, as has periodontal disease, the hypothalamic-pituitary-adrenal axis, the gastrointestinal microbiota, and infectious agents such as Epstein–Barr virus.

Diagnosis

Laboratory tests for diagnosis of RA often have limited sensitivity and specificity, high levels of false-positive and false-negative results, and a lesser capacity than patient self-report questionnaire scores to provide a sensitive measure for documenting future improvement, recognizing incomplete responses, and predicting work disability and premature mortality. Laboratory tests are useful in many patients and essential in a few, but physicians and patients often attribute disproportionate importance to laboratory tests in rheumatic diseases.[8] Clinical decisions in RA are recognized to be guided primarily by a patient history and physical examination in contrast to other chronic diseases, in which clinical decisions are guided by biomarkers such as blood pressure, laboratory tests, or imaging studies.[9] However, the only quantitative data in the medical records of many patients with RA in usual care are laboratory tests. This practice reduces the capacity to monitor, recognize, and document clinical improvement or deterioration in patient status according to quantitative data. Laboratory tests may not detect serum abnormalities unless their presence is related to another disease process. The rheumatoid factor test is generally negative. If the rheumatoid factor is found in the serum of older patients, its presence may be unrelated to the arthritis because false-positive results for rheumatoid factor increase with age in the normal population[10–12] (**Evidence and Research 12-2**).

EVIDENCE and RESEARCH 12-2

Analyses of 287 patients with RA seen in three clinical care centers indicated that at presentation elevated erythrocyte sedimentation rate (ESR) was abnormal in 57% and C-reactive protein (CRP) in 58% of patients.[10] By contrast, scores on a patient questionnaire were abnormal for physical function in 70% and pain in 89% of patients.[10] Self-report scores have been found to be as responsive to change over time as any of the RA Core Data Set measures.[11,12] Core Data Set for assessment of RA includes seven measures: three from the physical examination—swollen joint count, tender joint count, and physician estimate of global status; three from the patient history information—physical function, pain, and patient estimate of global status; and one laboratory test—ESR or CRP.[13] Criteria for measurement is continuously changing based upon new outcome measures.[14] There is no statistical advantage to joint counts or laboratory data versus patient questionnaire or global estimate data on the basis of relative efficiencies. The most specific measures are not necessarily the most sensitive or efficient measures to distinguish active from placebo treatments. Furthermore, patient self-report questionnaire data are the most feasible and cost-effective measures in terms of time and resources for the medical system.[15] Therefore, a strong case could be made that scores for physical function and pain, although only indirectly related to pathophysiologic mechanisms, are at least as valuable as ESR to monitor the clinical status of patients with RA.

Clinical Manifestations

Loss of cartilage and bone integrity, soft-tissue disruption, and swelling lead to joint dysfunction as they do in OA, but often the deformities are more severe, and usually the entire joint is affected rather than just one joint compartment (**Fig. 12-2**). As the disease becomes more chronic, contralateral joints are affected. The joint changes are usually reversible if the disease remits within 1 year and no structural deformity has occurred. Early diagnosis and intervention with newer pharmaceuticals and an emphasis on education regarding joint protection strategies is important as irreversible changes usually occur between the first and the second year in more chronic forms of RA.[6]

Classification of RA and subsequent treatment choices have evolved and changed over time. Patients diagnosed with RA prior to the mid-1980s were typically treated with the least aggressive pharmacologic agents first, often starting with nonsteroidal and

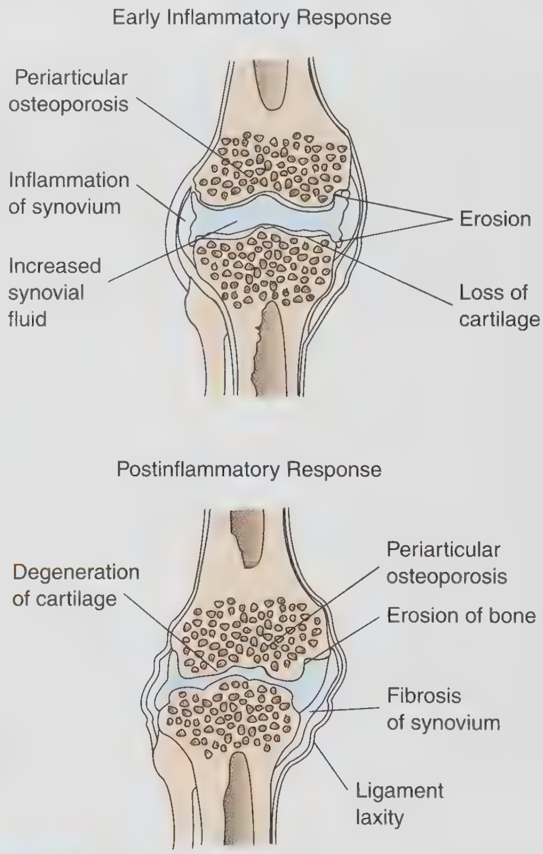


FIGURE 12-2 Early inflammatory joint response to rheumatoid arthritis includes pannus formation and erosion of cartilage and bone. Postinflammatory irreversible joint changes include destruction of cartilage, bone, and soft tissues and fibrosis of the joint capsule. Damage affects joint alignment, stability, and ROM. (Adapted from AHPA Arthritis Teaching Slide Collection. American College of Rheumatology, Atlanta, GA.)

then steroidal medications followed eventually by cytotoxic drugs like colloidal gold. As newer cytotoxic and biologic drugs aimed at interfering with immune system events leading to joint damage became available, this approach changed and patients diagnosed in the 1990s and later were typically treated with steroidal and cytotoxic drugs immediately. Therefore, patients with disease onset prior to the 1980s may have more extreme joint deformities as once joint deformities are present, they are not reversible. The newer approach is aimed at minimizing joint deformity in the patient with RA upon the onset of the disease.

Additionally, the 1987 criteria for diagnosis of RA focused on identifying patients with clearly established RA, and therefore missed patients in the early stages of disease, when disease-modifying treatments would be most effective.[16,17] The American College of Rheumatology (ACR) and the European League Against Rheumatism (EULAR) worked together to develop a new classification system, which was released in 2010. A comparison of the classifications can be found in **Table 12-2**.[5,16,18] **Display 12-1** summarizes the classification of RA progression. Unlike OA, RA has systemic effects such as fatigue, malaise, anemia, and sleep disorders (i.e., pain and abnormal sleep cycles). Nearly 40% of patients develop extraarticular manifestations while 15% develop severe extraarticular problems at some point.[19,20] Organ systems, including lungs and the cardiovascular system, may also be affected. Medications used to treat RA may contribute to myositis, gastrointestinal distress, and sleep disruption. These systemic effects should be considered in designing exercise programs for the patient with RA. Some of the extraarticular manifestations of RA can be found in **Table 12-3**.

The course of RA is variable and characterized by exacerbations (i.e., flares) and remissions. During a flare, joints are hot and swollen, morning stiffness is present and often lasts longer than 60 minutes, and systemic effects may be more obvious. This is considered an *acute phase* of the disease. As the pain, swelling, systemic effects, and morning stiffness decrease, the disease state is considered to be *subacute*. Between exacerbations, the disease state is considered *chronic*.

The clinician needs to consider the phase of RA when designing an exercise program. After prolonged inflammation, synovial membranes fibrose, decreasing the vasculature such that joints may not appear hot and swollen. These are referred to as burned-out joints. Although it may appear that the disease has gone into remission (i.e., the subacute or chronic phase) and has ceased to damage the joint, the joint destruction and systemic effects continue, and the disease state remains active.

Because symptoms wax and wane, the type and intensity of appropriate exercise also varies. *Be sure to consider the phase of RA when designing an exercise program, and teach patients how to modify the program to match the phase of their illness* (see **Building Block 12-2**).

TABLE 12-2

Comparison of the 1987 Revised Classification of Rheumatoid Arthritis with the 2010 ACR/EULAR Classification

1987 CLASSIFICATION[a]	2010 CLASSIFICATION[b]
Morning stiffness in and around joints lasting at least 1 hr before maximal improvement for at least 6 wk	Number and sites of joints involved (score 0–5)
Soft-tissue swelling of three or more joints for at least 6 wk observed by a physician	Serologic abnormality (score 0–3)
Swelling of the PIP, MCP, or wrist joints for at least 6 wk	Elevated acute-phase response (score range 0–1)
Symmetric swelling for at least 6 wk	Symptom duration (2 levels; range 0–1)
Rheumatoid nodules	
+ Rheumatoid factor	
Radiographic erosions and/or periarticular osteopenia in hand and/or wrist joints	

[a] Classified as definite RA with a score of at least 6 and: confirmed presence of synovitis in at least one joint and absence of an alternative diagnosis that would better explain the synovitis. From Aletaha D, Neogi T, Silman AJ, et al. 2010 Rheumatoid arthritis classification criteria: an American College of Rheumatology/European League Against Rheumatism collaborative initiative. Arthritis Rheum 2010;62(9):2569–2581.

[b] Classified as RA when when four or more criteria are met. From Arnett FC, Edworthy SM, Bloch DA, et al. The American Rheumatism Association 1987 revised criteria for the classification of rheumatoid arthritis. Arthritis Rheum 1988;31(3):315–324.

PIP, proximal interphalangeal joint; MCP, metacarpal-phalangeal joint.

DISPLAY 12-1

Classification of Progression of RA

Stage I, Early

*1. No destructive changes on roentgenographic examination
2. Roentgenologic evidence of osteoporosis may be present

Stage II, Moderate

*1. Roentgenologic evidence of osteoporosis, with or without slight subchondral bone destruction; slight cartilage destruction may be present
*2. No joint deformities, although limitation of joint mobility may be present
3. Adjacent muscle atrophy
4. Extraarticular soft-tissue lesions, such as nodules and tenosynovitis, may be present

Stage III, Severe

*1. Roentgenologic evidence of cartilage and bone destruction in addition to osteoporosis
*2. Joint deformity, such as subluxation, ulnar deviation, or hyperextension, without fibrous or bony ankyloses
3. Extensive muscle atrophy
4. Extraarticular soft-tissue lesions, such as nodules and tenosynovitis, may be present

Stage IV, Terminal

*1. Fibrous or bony ankyloses
2. Criteria of stage III

**The criteria prefaced by an asterisk are those that must be present to permit classification of a patient in any particular stage or grade.*

From Schumaker HR Jr, ed. Primer on the Rheumatic Diseases. 10th Ed. Atlanta: Arthritis Foundation, 1993:188–190.

TABLE 12-3

Extraarticular Manifestations of Rheumatoid Arthritis

- Vasculitis/athergenesis, stroke
- Neuropathy
- Pleuritis
- Pericarditis/myocardial infarction
- Secondary Sjogren's syndrome
- Eye disease
- Osteoporosis/osteopenia
- Sarcopenia
- Fatigue, cognitive dysfunction
- Feity's syndrome

From Gibofsky A. Overview of epidemiology, pathophysiology, and diagnosis of rheumatoid arthritis. Am J Managed care 2012;18(13, Suppl):S295–S302; Turesson C, McClelland RL, Christianson T, et al. Clustering of extraarticular manifestations in patients with rheumatoid arthritis. J Rheumatol 2008;35(1):179–180; Picerno V, Ferro F, Adinolfi A, et al. One year in review: the pathogenesis of rheumatoid arthritis. Clin Exp Rheumatol 2015;33(4):551–558.

BUILDING BLOCK 12-2

1. List at least three characteristics of RA that distinguish it from osteoarthritis.
2. List three special considerations in designing an exercise program necessitated by the clinical manifestations of RA.

In addition to the local pathologic changes caused by both RA and OA, the resulting joint pain and effusion in both diseases trigger protective and reflex spasm and immobility. Immobility leads to further muscle atrophy and loss of normal protective reflex responses.[3,21] Immobility combined with non-weight bearing contributes to cartilage breakdown, aggravating the condition. Diminished joint complex integrity can also lead to movement patterns that are energy inefficient, limiting activity in an already fatigued patient. For these reasons and because of the effects of low-dose steroids on muscle[22] and the destructive effect of myositis in RA, muscles often atrophy significantly. Type II fiber deficits occur in patients with RA and OA,[23,24] and isometric strength deficits have been reported for these patients compared with controls.[21,25–27] These impairments underlie the development of functional deficits as patients find it more difficult, painful, and less efficient to move. The combination of fatigue, pain, decreased activity and systemic effects can lead to early mortality in patients with RA.[28] Exercise correctly prescribed can address impairments and functional deficits.[29–31]

Various classifications have been useful in guiding exercise prescription and in teaching patients to monitor and appropriately modify their home programs and activities of daily living (ADLs). In the classification of functional status proposed by the ACR, patients are divided into four groups based on their ability to perform self-care, vocational activities, and avocational activities (**Display 12-2**). Most exercise program studies that looked at exercise effects considered patients in functional class I, II, and occasionally, III.

Another classification scheme that may guide the therapist in exercise program design examines the radiologic and clinical evidence of disease progression (see Display 12-1 and **Building Block 12-3**).

DISPLAY 12-2

Classification of Functional Status of Patients with RA*

Class I: Completely able to perform usual ADLs (self-care, vocational, and avocational)*
Class II: Able to perform usual self-care and vocational activities, but limited in avocational activities
Class III: Able to perform usual self-care activities, but limited in vocational and avocational activities
Class IV: Limited in ability to perform usual self-care, vocational, and avocational activities

**Usual self-care activities include dressing, feeding, bathing, grooming, and toileting. Avocational (recreation, leisure) and vocational (work, school, homemaking) activities are patient desired and age- and sex-specific.*

From Hochberg MC, Chang RW, Dwosh I, et al. The American College of Rheumatology 1991 revised criteria for the classification of global functional status in rheumatoid arthritis. Arthritis Rheum 1992;35:498–502.

BUILDING BLOCK 12-3

RA-1

A 54-year-old woman with a 30-year history of RA is referred to therapy with complaints of pain, weakness, fatigue, and an increasingly difficult time doing her half time job as a computer programming instructor, her house work, and cooking due to these factors. She lives with her husband in a one-story house with five stairs with railing to enter the house. Her adult children live out of state; her husband does most of the heavy work around the house and is not currently working due to a job layoff, so they depend on her job for health insurance.

Her RA was originally treated with nonsteroidal anti-inflammatories, followed by steroidal treatment then colloidal gold, and finally with methotrexate. She has joint deformities in the feet, hands, knees, and elbows. She has had multiple tendon transplants and fusions in her feet, tendon transplants in her hand, and has both elbow and knee ligament laxity. She reports that with the onset of the gold treatment and then methotrexate, the progression of joint deformities stopped. She continues to take methotrexate.

Her main complaint at this visit is bilateral shoulder pain, difficulty driving due to shoulder pain when holding and turning the wheel, and neck and shoulder pain when she turns her head. She is having increasing shoulder pain at the end of a work day.

Review of systems is unremarkable except for slight hypotension, and increased respiratory and heart rate (HR) from resting rates of 12 and 72 respectively to 20 and 90 after walking 200 ft. Gait is inefficient with hip hiking and trunk rotation initiating swing phase and lumbar hyperextension with rollover to toe-off phase of gait.

RA-2

The patient is a 32-year-old, right (R) hand dominant female competitive tennis player. She was diagnosed 3 years ago with RA following episodes of pain and swelling in bilateral (B) hands and feet. She was started initially on prednisone and methotrexate. Prednisone was then withdrawn as methotrexate took effect. She presents today with complaints of R elbow pain while playing tennis and as well

(continued)

BUILDING BLOCK 12-3 (*continued*)

as pain when using her arm at home for cooking and gardening. No other joint pain is reported except occasional brief twinges of left (L) elbow pain. She has not played tennis in 6 months and has stopped all gym exercise due to fear of aggravating her symptoms.

She has been taking methotrexate since the RA was diagnosed and had a cortisone injection to the area of the common extensor tendon origin 3 weeks ago. This gave her about 50% relief of pain at rest, but with any use, symptoms flare again. She takes no other medication and has no other significant medical history.

R medial and lateral epicondylar provocation testing is positive. R elbow and wrist range of motion (ROM) is normal though she complains of tightness with both wrist flexion and extension and palpation is positive for pain in both flexor and extensor muscle groups. Mild joint laxity is present with varus and valgus testing R > L elbow. The R elbow joint is warmer than the L per palpation.

Her goal is to return to doubles tennis and to household tasks including cooking and gardening, pain free.

1. For the patients listed in cases RA-1 and RA-2, write out instructions to give them to recognize when they may be entering a stage of acute inflammation (either autoimmune- or activity-triggered) and what their actions should be.
2. To which functional class does the patient in case RA-1 belong? The patient in case RA-2?

EXERCISE RECOMMENDATIONS FOR PREVENTION AND WELLNESS IN OA AND RA

There is no direct way to prevent RA. On the other hand, the literature suggests that certain factors including obesity, trauma, hypermobility, and inflammation correlate with the development of OA.[28] An exercise regimen aimed at maintaining appropriate body weight, sustaining good postural alignment, developing good muscular strength and length, and correctly using joints in ADLs may be logical and desirable for joint protection. Because OA has a genetic basis in some persons and, in some cases, is correlated with trauma, infection, and inflammation, exercise is not a guarantee against developing OA. A well-designed therapeutic exercise program can remediate the impairments and activity limitations associated with arthritis and reduce the impact of risk factors for disease progression. Despite this, many individuals with RA are inactive according to recommended standards.[28] Intervention includes assessing and treating impairments and resulting functional losses in an attempt to avoid disablement, within the framework of associated comorbidities and barriers to participation.

THERAPEUTIC EXERCISE INTERVENTION FOR COMMON IMPAIRMENTS

Exercise programs to address common impairments and activity limitations affecting a person's ability to function in society are necessary. A recent review of randomized controlled studies on the effect of water exercise on hip and knee OA showed positive short-term effects on function, quality of life, and pain[29] (**Evidence and Research 12-3**). Ongoing exercise is of particular importance in patients with RA who are twice as likely to suffer from cardiovascular disease.[32] Importantly, these patients must also learn to pace their activities due to the cyclical nature of RA flares.

EVIDENCE and RESEARCH 12-3

A large study of 220 participants determined the effect of aerobic exercise on symptoms, function, aerobic fitness, and disease outcomes in patients with RA at 1, 6, and 12 weeks. Positive effects were found on walk time and grip strength; overall fatigue, pain, and depression symptoms were positively influenced. There was no finding of increased disease activity with exercise.[30] A study[31] of the effect of short-term intensive training in posthospitalization patients with RA or following joint replacement in patients with OA showed long-term (52 week) gains in ROM and self-reported function. Training was physiotherapist led and consisted of mobility, strength, aerobic and functional activities. A Cochrane review of dynamic exercise programs focusing on muscle strength and/or aerobic capacity found positive short- and long-term effects of this exercise with no deleterious effects noted.[33]

In OA, the goal of treatment is to decrease pain and any inflammation which is present, to restore normal joint mobility, to improve muscle function, and to reestablish normal movement patterns throughout the kinetic chain. Any adaptive changes in joints proximal, distal, or contralateral to the affected joint and its surrounding structures must also be addressed. Performing basic functional tasks (e.g., sit to stand to sit, balance, timed walking, performing household, vocational, and recreational activities) and optimizing cardiovascular fitness are the tasks of an exercise program designed for a patient with OA (**Fig. 12-3**).

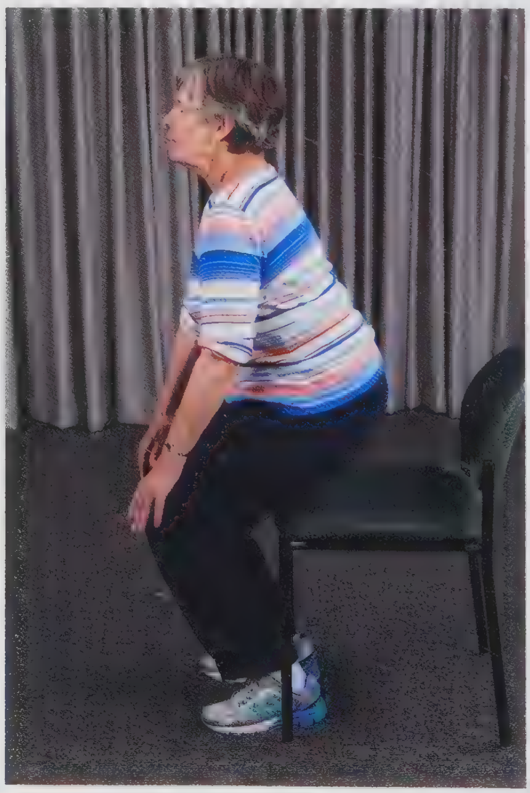


FIGURE 12-3 Sit to stand from chair.

FIGURE 12-4 Manual dexterity assessments.

For patients with RA, exercise program considerations are largely those outlined for OA, but because of the variability of its course and the possible systemic involvement of the disease, careful monitoring by the physical therapist and the patient is necessary. Patients must be taught to recognize symptom development and the stage of the illness and how to modify activity appropriately.

The patient with arthritis typically presents with pain, mobility impairment, imbalances in muscle length, and faulty movement patterns, all of which contribute to impaired muscle performance, and cardiovascular endurance impairment. The clinician must evaluate these factors bilaterally throughout the entire extremity kinetic chain and the trunk. It is equally important to look at functional movement patterns, including gait, stair negotiation, sit to stand to sit, and manipulation of tools and the environment when hands are involved (**Fig. 12-4**).

The exercise program must carry the effects of therapy beyond treatment of a localized joint problem to issues of function in an attempt to reverse the disablement process. In planning an exercise regimen, impairments at the primary joint and secondary impairments and activity limitations must be addressed. Limitations may occur along a continuum of function, ranging from deficits in high-level athletic performance to an inability to perform self-care activities.

The aims of treatment are to decrease impairment while improving function. Functional improvement includes ADL and instrumental ADL performance and improved muscle and cardiovascular conditioning. Incorporate functional activities into the exercise routine to ensure that functional skills are mastered and carried into daily life. Protect affected joints during exercise and during functional activities (see **Building Block 12-4**).

BUILDING BLOCK 12-4

1. Write a problem list including at least two impairments to body function or structure; two activity limitations, and two participation restrictions for cases RA-1 and RA-2.
2. Write one goal for the patient in each case addressing activity and participation deficits.

Pain and Fatigue

Pain and fatigue are significant impairments found in patients with arthritis, particularly those with RA. Fatigue in patients with RA is multidimensional, including physical, emotional, environmental, and personal factors.[34] In addition to its relation with pain, fatigue in RA is also associated with anxiety, depression, reduced self-efficacy, disturbed sleep and impaired social functioning.[35] Although physical therapists generally address physical factors, understanding associated factors is critical for successful program design (**Evidence and Research 12-4**).

EVIDENCE and RESEARCH 12-4

In a review of the relationship between RA and fatigue, Nicklaus et al.[34] found that causes of fatigue can be related to: illness-related aspects (i.e., pain, disease activity markers, comorbidities, symptoms, disease duration), physical functioning (i.e., sleep disturbance, disability measures), cognitive and emotional issues (i.e., depression), social and environmental factors (i.e., interpersonal events, social support), demographics (i.e., sex) and baseline fatigue levels. Models of this relationship have been suggested but none validated.

Be sure to minimize pain during therapeutic exercise because pain may lead to other impairments. Joint pain and swelling together with splinting or guarding can inhibit periarticular muscle function, lead to disuse atrophy, suppress the normal protective reflex response, and cause further cartilage breakdown.[3,21,36,37] These changes can lead to inefficient movement patterns, thereby decreasing cardiovascular endurance and further limiting activity. The changes may also disrupt the soft-tissue balance around the joint, affecting its stability, alignment, and active motion. When a joint is abnormally aligned, muscles can no longer generate peak force, contributing to strength deficits.

Studies have examined the effects of exercise on arthritis[38,39]; the use of exercise to restore muscle balance and joint range for cardiovascular conditioning and to improve functional status was associated with no increase in pain in some studies and with a decrease in pain in others.[26] Patients often present with some degree of pain in the affected joints, which may prevent exercise to the full extent possible or signal the presence of an inflammatory process. In either case, revising or modifying the exercise program can maximize patient participation, which could potentially control the inflammatory processes.[33] Any exercise-induced pain necessitates modification of the exercise.

Exercise Modification in Response to Pain and Fatigue

Systemic deconditioning, muscle weakness, joint irritability, and cardiorespiratory disease are common in patients with inflammatory arthritis and necessitate ongoing evaluation of the patient's response to treatment to ensure appropriate and timely modification of the exercise prescription. Irreversible joint changes (i.e., cartilage loss, bony deformity, or ligament

laxity) together with systemic symptoms (i.e., fatigue, reduced cardiovascular capacity) require modification of exercise to avoid worsening joint irritation or undue fatigue.
Importantly:

- Modify or avoid any exercise that increases joint pain.[40,41]
- Teach the patient to differentiate between muscle reaction to exercise and joint pain.
- Undue fatigue after exercise in deconditioned patients indicates a need to further modify the exercise prescription. Keep in mind that fatigue can be either systemic or exercise-induced, or both.
- Instructions to the patient with a rheumatic disease should include sleep and rest guidelines.[42]

Compliance with exercise programs increases when exertion and pain are within acceptable limits for the patient.[27,38] The patient's reaction to exercise should be carefully monitored, and self-monitoring skills should be taught as an essential element of the therapy program (see **Building Block 12-5**).

BUILDING BLOCK 12-5

1. Each of the patients in cases OA, RA-1, and RA-2 have been prescribed an exercise routine at their first visit. List at least two questions important to ask all of them at the beginning of their second visit regarding the routines.
2. The following scenarios exist during the second visit. List your response to them:
   a. In case OA, the patient noted increased pain with the exercise routine prescribed at the last visit.
   b. In case RA-1, the patient reported no increase in shoulder pain, but an overall increase in fatigue in general and especially when she had a few late nights staying up to do her physical therapy exercises, after completion of the rest of her household chores.
   c. In case RA-2, the patient admits she didn't do her exercises.

Impaired Mobility and ROM

Osteoarthritis and RA often contribute to mobility impairment. ROM can be diminished by several factors:

- Stiffness and shortening of muscles or tendons from spasm, guarding, or habitual postures
- Capsular stiffness or contracture
- Loss of joint congruity because of bony deformity

These conditions lead to muscle imbalances that can initially limit joint mobility and lead to joint contractures and muscle weakness affecting the entire limb; this can spiral into affecting the whole body. Be aware of the muscle groups most typically affected by OA and RA in specific joints. Muscle shortening leads to weakness and joint malalignment. For example, in hip OA, hip flexor shortening and hip flexor and extensor weakness are common (**Table 12-4**; **Fig. 12-5**). A thorough musculoskeletal evaluation should indicate which of these factors are present. Consider which of these ROM impairments are amenable to physical therapy intervention and can lead to functional improvement. These are the only mobility impairments that should be addressed in goal setting.

When goal setting, consider that cartilage maintenance depends in part on joint movement.[36] Design passive, active, and active-assisted ROM exercises to ensure that affected joints move through the full range available to them. When possible, choose exercises that will increase the working ROM so that loads can be distributed over a larger articular cartilage surface area thereby decreasing focal loads.

Passive ROM is rarely necessary, except in cases of acute joint exacerbation or of severe muscle weakness and inflammation in RA. These patients may need some combination of rest and light activity. Perform one or two repetitions of gentle passive movement through full available range each day to avoid contracture and to ensure maintaining full ROM. Too many repetitive passive ROM movements may increase joint inflammation.[40] For patients in all classes of RA or who have OA, perform active ROM exercises daily for affected joints.[43]

When weakness prevents the patient from attaining full ROM, assistance from another person or another limb may be required to achieve full available range. Typically, patients start with one to five repetitions and progress to performing 10 repetitions daily.

When **muscle shortening** is the cause of range limitations, passive stretch controlled by the patient or clinician may be provided as long as the joint is stable. Considerations outlined in Chapter 7 regarding stabilization of proximal and distal attachment sites to avoid stressing joints above and below the target muscle are especially important in this population. In patients with RA for whom the integrity of muscle, tendon, or ligament is in question (especially in smaller joints), *gentle* active ROM exercises are preferable. As a safety measure, it is important that the patient be safely positioned while performing active ROM exercises to ensure they do not fall, lose control of a limb, or apply more force than is intended.

Ligament laxity can occur in the cervical spine of patients with RA, and special considerations, especially for stretching exercises, apply. A more detailed description of these precautions is given in the section "Precautions During Strengthening Exercises When Ligament or Capsular Laxity Exists."

Patients who have RA with prolonged morning stiffness or OA with brief morning stiffness (<0.5 hour) may benefit from instruction in a ROM and stretching routine targeting the stiff areas. This exercise can be done before retiring at night, in the morning after a warm shower, or during both periods.

Instruct the patient in self-mobilization techniques as part of a home exercise program in cases of OA in which capsular restriction limits movement but no acute joint irritation or bony block exists[44] (see **Self-Management 12-1**). Capsular stiffness in patients with RA often results from joint distension, and further distractive forces on this inflamed and often weakened tissue should be avoided. When stability is good, passive application of grade 1 oscillations by a skilled therapist to relax periarticular spasm and gate pain prior to performing passive or active ROM activities may be beneficial (see Chapter 7).

TABLE 12-4

Common Patterns of Joint Restriction in Osteoarthritis and Rheumatoid Arthritis

JOINT	RESTRICTION	STRETCH	STRENGTHEN
Hip (OA/RA)	■ All planes, especially internal rotation and extension	■ Flexors ■ Extensors ■ Internal and external rotators ■ Tensor fascia lata	■ Abductors ■ Extensors
Knee (OA/RA)	■ Extension	■ Hamstrings (quadriceps)	■ Quadriceps
Ankle and foot (RA)	■ Ankle dorsiflexion ■ MTP flexion ■ PIP extension	■ Ankle dorsiflexors and plantarflexors ■ Tarsal invertors and evertors ■ Toe flexors and extensors	■ Toe extensors and flexors ■ Tibialis posterior ■ Abductors
Shoulder (RA)	■ Abduction ■ Flexion ■ External and internal rotators	■ Careful in deranged joints ■ PROM, AAROM, AROM	■ External rotation ■ Biceps ■ Triceps
Elbow (RA)	■ Extension lost early	■ Careful in deranged joints ■ PROM, AAROM, AROM	■ Biceps ■ Triceps
Hand and wrist (RA)	■ MCP extension ■ Wrist extension ■ First web space	■ Careful in deranged joints ■ ROM wrist daily ■ Stretch wrist flexors and extensors, forearm pronators and supinators, hand intrinsics	■ Finger extensors ■ Wrist extensors

AAROM, active assisted range of motion; AROM, active range of motion; MCP, metacarpophalangeal joint; MTP, metatarsophalangeal joint; OA, osteoarthritis; PIP, proximal interphalangeal joint; PROM, passive range of motion; RA, rheumatoid arthritis; ROM, range of motion.

Data from Hicks JE. Exercise in patients with inflammatory arthritis and connective tissue disease. Rheum Dis Clin North Am 1990;16:845–870; Moskowitz RW, Goldberg VM. Osteoarthritis: clinical features and treatment. In: Schumaker HR Jr, ed. Primer on the Rheumatic Diseases. 10th Ed. Atlanta: Arthritis Foundation, 1993:188–190.

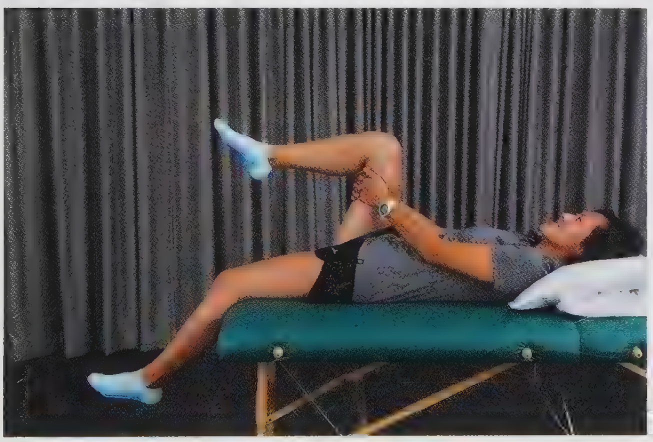


FIGURE 12-5 Hip flexor stretching with protection of lumbar spine, contralateral and distal limb.

Impaired Muscle Performance

The same forces which lead to ROM losses affect, and can in turn be affected by, muscle imbalances which occur around the involved joint or joints.

Strengthening of weakened muscles is an important part of regaining muscle balance around the joint. Strengthening can be done isometrically, isotonically, or isokinetically (see Chapter 5). Each form of exercise has its place in rehabilitation of patients with arthritic joints, depending on the state of the joint. Isokinetic equipment is most readily available in a clinical setting and is not likely to be practical for independent exercise programs; it is not discussed here (see **Building Block 12-6**).

SELF-MANAGEMENT 12-1
Self-Mobilization of the Shoulder Joint

Purpose: To stretch the tight capsule and muscles around the shoulder, which are limiting movement

Position: Sit on a straight-back chair as shown, with a folded towel padding your arm.

Movement Technique: Let your arm hang down.

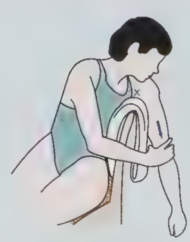
Grasp it just above the elbow with your opposite hand.

Repeat a gentle, rhythmic series of downward tugs, trying to keep your shoulder muscles relaxed.

Dosage:

Repetitions: ______________________

Frequency: ______________________



BUILDING BLOCK 12-6

1. The patient in the case OA has demonstrated loss of both active and passive ROM of L knee extension with end range pain. What objective tests should be used to determine the source of this restriction?
2. An exercise routine to address soft-tissue restrictions around the knee has been prescribed. What protective guidelines should be provided to the patient?
3. The patient in case RA-1 complains of morning pain and stiffness "all over." What recommendations should be provided to them?
4. The patient in case RA-1 is bed bound with an acute flare of symptoms. There is concern about maintaining her shoulder ROM. What instruction should be given to a family member caring for her? How would advice differ if her finger joints were involved?
5. Both patients in cases OA and RA-1 are found to have capsular tightness affecting joint ROM. How should the recommendations to them differ from case RA-2?

Isometric Exercise

Isometric exercise is most appropriate when acute flares in OA and RA occur, but use caution to avoid increased intraarticular inflammation.

Isometric Exercise in RA Patients with acute exacerbations of RA:

- Are supporting and limiting use of the involved joint(s)
- Are positioned to prevent deformity
- May have one or two daily applications of passive ROM applied to large joints
- May have one or two daily applications of active ROM applied to small joints

In this stage, preventing muscle atrophy is important. Muscle strength declines significantly in patients on bedrest[45] (**Evidence and Research 12-5**). Because it appears that isometric contractions are associated with the least joint shear and intraarticular pressure increases,[46] this form of exercise is often prescribed in the acute and subacute phases of the disease. A single isometric contraction at two-thirds of maximal effort, which is held for 6 seconds, increases strength in a non-impaired individual; three maximal contractions, with 20-second rest periods, performed three times each week increase strength in patients with RA.[40,47] However, maximal isometric contraction raises blood pressure and may increase joint pain; therefore, consider performing isometric contractions at a submaximal level.

EVIDENCE and RESEARCH 12-5

Ten days of bed rest resulted in a significant reduction in knee extension one repetition maximum strength, knee extension performance at 60 degrees per second, and isometric knee extension strength.[48] Drummond et al.[49] found 7 days of bed rest to decrease leg lean mass by 4% and to increase the body's ability to mount an exaggerated inflammatory response. Functionally, patients demonstrated decreased stair climbing ability, maximum aerobic capacity, floor transfer test, 5-minute walk time, and chair stand.[48]

As a means of increasing muscle strength without raising blood pressure significantly, Gerber and Hicks[50] described a program of brief isometric exercise (BRIME) of one to six isometric contractions, held for 3 to 6 seconds, with 20-second rests between contractions (see **Self-Management 12-2**).

Isometric contractions performed at one joint angle only strengthen the muscle at that specific angle.[51] For this reason, repetitions at various angles may be desirable (see Chapter 5). During an acute exacerbation of arthritis, it may be necessary to limit contraction to one joint angle to avoid stressing the joint.

Isometric Exercise in Osteoarthritis In the acutely painful osteoarthritic joint, especially if there is significant inflammation and swelling, intraarticular pressure and shear forces should be limited while preventing muscle atrophy. Isometric contractions are often the exercise of choice in this stage. The same considerations apply as for the patient with RA. Brief intense isometric exercises are appropriate when controlling blood pressure is an issue (see **Selected Intervention 12-1**).

For the patient with an acute arthritic joint, the home program should start with 5 to 10 repetitions of 6-second contractions with the patient revising that number based upon the response. The

SELF-MANAGEMENT 12-2
BRIME–Isometric Quadriceps Contraction

Purpose: To maintain or slightly increase strength of quadriceps muscles during acute knee joint inflammation when the joint is otherwise held at rest while avoiding an increase in blood pressure

Position: Sit with the back supported or in a supine position; bend one knee and straighten the other.

Movement Technique: Tighten the quadriceps of the straight leg at an intensity that does not increase pain.

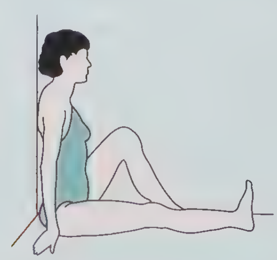
Hold 3 to 6 seconds.

Rest 15 seconds.

Dosage:

Repetitions: ______________________

Frequency: ______________________



SELECTED INTERVENTION 12-1

Hand-to-Knee Pushes

See Case Study No. 11

Although this patient requires comprehensive intervention as described in other chapters, only one exercise will be described. This exercise would be used in the early to intermediate phases of this patient's rehabilitation.

ACTIVITY: Standing hand-to-knee pushes

PURPOSE: To increase the muscle performance of the hip abductor (stance limb) and abdominal muscles

STAGE OF MOTOR CONTROL: Stability

MODE: Aquatic environment

POSTURE: Standing on one leg with your back against a wall, maintaining a proper lumbar alignment by pelvic tilting. Bend the opposite knee and flex the hip to approximately 90 degrees.

MOVEMENT: With the hand opposite your flexed hip, press isometrically against your knee. Maintain good spinal posture throughout the exercise. Hold for a count of three. Return to the start position.

DOSAGE: Perform five to seven repetitions with each knee, two to three sets to form fatigue.

EXPLANATION OF PURPOSE OF EXERCISE: Hip abductors on the stance limb are trained to maintain transverse plane pelvic position, while the abdominals work to maintain pelvic tilt against the isometric exercise. This exercise is performed in the upright position to enhance carryover to daily activities, but is performed in a gravity-lessened environment to reduce weight bearing on the single-stance limb.

number of repetitions may vary throughout the day and with the patient's activity level. The patient can gradually increase sets and repetitions as tolerated if symptoms are not exacerbated. As acute pain, swelling, and inflammation resolve, the patient will progress to an isotonic routine.

Dynamic Training

Dynamic muscle strengthening occurs when muscles contract as they shorten (i.e., concentric contractions) or lengthen (i.e., eccentric contractions), resulting in movement of the joint they cross. The advantages of dynamic exercise include increased movement of the joint, resulting in maintenance of capsular, ligament, and muscular flexibility. Joint stress and intraarticular pressure are higher with dynamic exercise as compared to isometric exercise.[34] Dynamic training is therefore appropriate for patients with chronic, subacute RA of classes I and II and for most patients with OA.

In prescribing an exercise regimen for patients with OA, both the use of low resistance and high repetition (to fatigue) and the use of high resistance low repetition exercise can be successful as long as the arc of motion does not irritate the joint[52–54] (**Evidence and Research 12-6**).

EVIDENCE and RESEARCH 12-6

Jan et al.[55] studied the effects of high- and low-resistance strength training in 102 elderly patients with knee OA. Significant improvements in all strength and function measures were found in both groups compared with controls, with the high-resistance group demonstrating a greater effect size. Thirty-three patients divided into intervention and control groups (high speed, low speed, or control) showed similar increases in leg press strength in the intervention groups.[55] King et al.[56] found improvements in a small single group sample of 14 patients with advanced knee OA and varus malalignment who underwent a 12-week high-intensity isokinetic program. A Cochrane systematic review of high- versus low-intensity exercise in people with hip or knee OA concluded that there was insufficient evidence to recommend one intensity of exercise over another for this population due to the poor quality of the existing research.[57]

The use of free weights, machines, resistance tubing, water and body weight can be appropriate ways to apply resistance, but their limitations and advantages must be considered in relation to the individual needs of the patient. For example, patients are less likely to lose control of resistance tubing than a free weight, but tubing resistance continues to increase as it is stretched, diverging from the muscle's normal torque curve. Used correctly, machines offer the advantage of stabilizing the body and exercised joint but may not offer a low enough resistance to allow a very deconditioned patient to use them. The aquatic environment provides resistance while minimizing the effects of gravity, but designing challenging eccentric contractions can be difficult for some muscle groups. Body weight exercises, which can range from mini squats to single-leg squat reaches, offer movement patterns which are the basis of function. Body weight exercise may also be introduced through functional activities such as walking, stair climbing, sit to stand, bending, and squatting (**Fig. 12-6**). Inclusion of these activities in the strengthening routine provides the clinician with an opportunity to confront safety issues involving balance and body mechanics while addressing daily activities. Bracing, assistive devices, and exercise intensity can then be considered in this context as well. The choice of resistance modality depends on the patient's presentation and the goal of treatment.

In general, start with lower weight to allow assessment of the joint's response to the resistance program. Increase the program appropriately, while individualizing the program to meet the needs of the patient. Modify the exercise dosage based upon the patient's response to the program (see Chapter 5 and **Building Block 12-7**).

BUILDING BLOCK 12-7

In the following scenarios, describe the most appropriate exercise choice to address the listed problem. Include type of muscle contraction, number of repetitions, appropriate forms of resistance (if any), stretches and any precautions your patient should take.

1. The patient in case RA-1 is now bed bound with an acute flare of joint pain and swelling and systemic effects including fatigue and apparent myositis. Prescribe an exercise routine

(continued)

BUILDING BLOCK 12-7 (continued)

which is safe for her to do to preserve current quadriceps strength (remember her knees are hypermobile into extension due to ligament laxity).

2. The patient in case OA is having problems walking up and down stairs with a step over step gait due to pain and perceived weakness.
3. The patient in case RA-2 is having difficulty pulling open heavy doors, putting on her emergency brake, and using a pen to write for more than 8 to 10 minutes due to hand weakness and elbow pain.
4. List considerations which would guide the choice of exercises.

FIGURE 12-6 Partial squat at sink.

Impaired Aerobic Capacity

Both OA and RA can negatively impact cardiorespiratory performance either through pain and disuse mechanisms or through primary disease processes. Patients affected with either disease have decreased cardiorespiratory endurance, walking time, and total work capacity compared with controls.[26,27,39,40] These patients may also have difficulty with weight control due to exercise limitations. Addressing the cardiovascular endurance impairment of patients with arthritis has several benefits, including improved cardiorespiratory status and endurance,[53] improved sense of well-being,[38,58] weight control, and improved walking distance[43] (see Chapter 6). Cardiovascular training should be a major part of therapy programs for patients with OA and RA.

Mode

Cardiovascular programs for patients with OA or RA of the weight-bearing joints need to be designed to minimize joints stress and impact, to encourage calcium uptake into bone, to encourage large muscle group engagement, and to account for any balance impairments. Several options are available, but adherence to a program is likely to be better when patients are able to pursue activities they find pleasurable.[59] Accessibility and cost factors may also be important for some people. Patient input into this aspect of the program design is important. For those needing weight loss or control, research suggests that effective weight loss can occur through both land-based and water-based exercise, with some research suggesting that overall body composition and metabolic profiles are better following aquatic-based exercise compared with land-based exercise.[52,54,60,61]

Water is a good medium for exercise and has demonstrated positive effects on pain, muscle strength, flexibility, depression, and anxiety.[38,62,63] Water provides a means of unloading joints; when immersed in a depth from the waist to the neck, body weight is far less than on land (see Chapter 16). Water provides a medium that can both resist and facilitate movement:

- It allows performance of movement patterns that may not be possible on land because of balance or strength deficits.
- It can relax muscles.
- It can modify pain perception through sensory stimulation.

Aquatic therapy can facilitate social interaction in class settings or during family recreation. This aspect may be an added benefit for a population that may be socially limited due to decreased participation in physical activities.

Cardiovascular work can come from walking in the shallow end of a pool, skiing, cycling or running in deeper water, water exercise classes, or swimming (**Evidence and Research 12-7**). Swimming is best done by skilled persons with good form so that abnormal movement patterns of the back, neck, and shoulders are prevented. Use of a snorkel and swim mask for prone swimming can be beneficial for patients with cervical spine disorders. Supine flutter kicking or elementary backstroke can help maintain a more neutral alignment when swimming and is readily performed by those who are not skilled swimmers.

EVIDENCE and RESEARCH 12-7

Numerous studies on underwater running, walking, and cycling have been performed, although most have been done on individuals without pathology. Hall et al.[64] examined the cardiorespiratory effects of underwater treadmill walking (immersed to the xiphoid) compared with land treadmill walking in 15 women with Class 1 or Class 2 RA. Results showed that HR and rate of perceived exertion (RPE) increased with increased speed and that the RPE was higher in the water at all speeds. At a given oxygen consumption level, the HR was approximately 9 beats per minute and the RPE 1 to 2 points higher than on land. Underwater treadmill walking at 4.5 km per hour was sufficient to achieve similar energy demands to land treadmill walking. Be aware that this HR response at this immersion level is very different from the typical HR response to deep water running (see Chapter 16).

Stationary or recreational bicycling can improve strength and cardiovascular conditioning in patients with OA or RA. Consider initiating bicycling on a stationary bike to limit balance and environmental factors and to control the initial exercise dosage. A variety of exercise bikes are available, all with different designs and features. Having patients exercise on different bikes can help them determine the features that best suit them. It also provides an opportunity for the physical therapist to discuss bike fit to ensure the least joint stress and the best posture and support for the patient. When appropriate, progress to recreational cycling if this is within the patient's goals. A walking program can improve cardiovascular endurance. Several studies have shown additional benefits of a walking program for patients with arthritis including reduction in pain, increase in flexibility and strength, and improvement of function.[38,65–68] Assessment for balance, safety, and current levels of function combined with advice regarding supportive footwear, acceptable walking surfaces, and progression of activities are necessary. Most neighborhoods have high school tracks that make an ideal exercise arena because of shock-absorbing level surfaces, easily calibrated distances, freedom from traffic hazards, and easy accessibility to a car to return home when the person becomes fatigued. Many shopping malls make their hallways available before hours for mall walking. This is ideal in inclement weather or as a social opportunity, and it provides frequent opportunities for resting if necessary. This form of exercise, however, is not without risk, because falls are always possible, and an assistive device or walking poles might be considered where balance is a problem.

Devices such as treadmills, elliptical machines, or recumbent trainers offer options for low-impact, potentially limited weight-bearing activity. This equipment requires more agility, balance, and coordination than outdoor or mall walking. Whichever form of exercise is chosen, cross-training can prevent boredom, stimulate different muscle groups, and alternate joint stress from session to session. Consider using a variety of devices within the same exercise session.

Exercise Dosage

To modify exertion during training sessions, patients should be taught to monitor their HRs or reliably apply the Borg perceived exertion rating technique[69] (see Chapter 6). Patients must also know their training parameters. Those who are deconditioned will be working at a higher percentage of their aerobic capacity than a more conditioned individual with the same disease process, or a younger, more fit individual. Be sure to monitor exercise HR and RPE and monitor for fatigue. Exercising at a HR below the recommended values can limit aerobic capacity and symptoms improvements[30] (Evidence and Research 12-8). Therefore, it is best to closely monitor exercise programs to ensure sufficient intensity while protecting patients from overexercising (**Evidence and Research 12-8**).

EVIDENCE and RESEARCH 12-8

A group of 220 patients with RA were randomized into control, class exercise, and home exercise. The exercise groups performed low-impact aerobic exercise three times per week for 12 weeks either in a class format or at home with a videotape. Participants were given their target HR and told to gradually increase their HR as tolerated. After 12 weeks, both exercise groups showed significant improvements in walk time and grip strength with no increase in measures of disease activity. Aerobic fitness improved the most in the class exercise group but the difference was not statistically significant. Those in the exercise class performed at a higher intensity (as measured by exercising HR) than the home-based group, although they performed the same number of exercise sessions. The home group had less symptom improvement compared with the class group.[30]

Whatever form of cardiovascular exercise is chosen, it should be fun and satisfying for the patient. This is an important link in maintaining or regaining function, because the more closely training fits with patient goals, the more effective it is.

Special Considerations in Exercise Prescription and Modification

The impairments common to patients with arthritis can pose specific challenges in designing a safe, effective exercise routine. The possibility of joint inflammation, laxity, and deformity in RA and OA and of systemic effects in RA necessitate precautions during exercise. Pain in both conditions can interfere with function and therapeutic exercise, and must be addressed through exercise and activity modification, therapeutic interventions, and education.

All positive findings from the initial evaluation should be considered when identifying the specific impairments to be addressed with therapeutic exercise. These findings guide decisions about the prescription variables and necessary precautions. Program design considerations include:

- Protecting joints during strengthening when ligament or capsular laxity exists
  - Example: avoid valgus load across an arthritic knee joint when medial-lateral instability exists
- Restoring muscle balance when splinting, postural habit, or pain inhibition has selectively weakened muscle groups around one or more joints
  - Example: strengthening scapular stabilizing muscles around the thoracic spine to improve posture in patients with cervical arthritis
- Normalizing specific joint movement patterns
  - Example: scapular stabilization and normal shoulder posture during arm elevation, avoiding shoulder elevation
- Restoring functional activities
  - Example: sit to stand or stair negotiation
- Treating pain and inflammation during and after exercise
  - Example: ice, soft-tissue mobilization, Grade I and II joint mobilizations
- Considering systemic variables such as fatigue levels, irritability of joints, and cardiovascular fitness, especially in the patient with RA
  - Example: breaking exercise program into several smaller exercise sessions

Joint Instability

Joint instability caused by ligament laxity, muscle atrophy, or bony joint deformity can affect arthritic joints (see Figs. 12-1 and 12-2) and must be assessed during evaluation. Muscle strengthening around these joints can increase stability, but it is undesirable to load these joints in a way that aggravates the instability. For example, in medial or lateral collateral ligament laxity of the knee, dynamic abductor or adductor strengthening without increased joint stress may be performed by placing the resistance proximal to the knee joint rather than at the ankle (**Fig. 12-7**). Other protective approaches may include bracing of the knee during exercise or the use of a closed chain pattern if proximal muscles are adequate to stabilize the knee in good alignment and the loading forces are tolerated by the joint.

In the small joints of the hand and foot, ligament laxity caused by the erosive effects of RA or asymmetric joint deformity from cartilage destruction and marginal spurring resulting from OA need to be considered as carefully in exercise prescription as they are in instructions for joint protection during ADLs.

Restoring function in hand, foot, and knee joints can be difficult in this context due to the relatively long lever forces of muscles crossing these joints where ligament laxity often is present. Intervention with exercise aimed at function in these joints will often have to be done in conjunction with ring splints, bracing, foot orthotics and special shoes, medication, therapeutic modalities, and the use of adaptive equipment. Functional use of pens, kitchen utensils, levers, and buttons (including keyboards) in hand rehabilitation, for example, provide opportunities for a combination of strengthening and safe functional training (**Fig 12-8**). Ligament integrity during ROM activities is a crucial safety issue for the upper cervical spine. RA can affect the ligaments of the upper cervical spine and middle spine segments (i.e., C5 and C6 areas) and can cause erosion of the dens.[70] Any patient presenting with upper cervical spine instability or long tract signs should be referred to the physician for consideration of immobilization. Patients with a history of RA who do not have objective signs of cervical instability should be warned that any cervical spine ROM exercise that results in cardinal signs, including perioral numbness, drop attacks, bilateral or quadrilateral paresthesias, or nystagmus, should be discontinued and they should consult their physicians.[40]

FIGURE 12-7 Standing abduction with band above knee.

FIGURE 12-8 It is important to incorporate functional activities (e.g., writing, crocheting, piano) into the treatment plan. Here, the patient with arthritic fingers practices functional skills.

Joint Protection

Joint protection can be approached through mechanisms that unload the joint, attenuate shock, and maximize neutral joint alignment. In addition to use of splints and braces, the following approaches may be implemented to decrease joint forces:

- Unweighting joints through the use of assistive devices (e.g., following hip replacement, use of a cane on the contralateral side reduced joint reaction forces on the ipsilateral side, but increased loads on the contralateral side[71–73]
- Attenuating shock forces in weight-bearing joints, although the effectiveness of adding shock absorptive insoles has been questioned[74,75]
- Using a water medium or unloading equipment, such as the Alter-G, in a clinic setting[71]

Weight reduction is an important goal of exercise for patients with pathologic joints and often a major goal of exercise programs. Obesity is a major risk factor for the development of OA; every pound of weight lost results in a fourfold reduction in knee loads per step.[76,77] Strengthening and recovery of joint reflex mechanisms offers increased joint protection, and normalizing joint alignment to as nearly neutral as possible distributes forces more symmetrically through the joints.[78]

Choosing exercise equipment that does not stress joints (e.g., cuff weights for upper extremity strengthening rather than free weights when there is wrist or finger joint instability), that can be of low enough resistance to ensure control of the joint by the patient (i.e., some machines do not start at a low enough weight setting for deconditioned individuals), and that encourages movement in physiologic patterns (e.g., shoulder abductor strengthening should be done in shoulder external rotation and in caption) contributes to patient safety during exercise. By understanding the factors necessary for good joint health, the therapist is able to design an exercise program that protects the unhealthy joint from forces it is unable to resist while helping the patient achieve muscle balance around the affected joint in an effort to improve joint physiology (see **Building Block 12-8**).

BUILDING BLOCK 12-8

1. The patient in case OA was referred in part to establish a cardiovascular routine for help with weight control and hypertension. Design one possible routine which will also help him reach his goal of returning to play golf with friends. Set target HR and explain how he should be taught to monitor this. List precautions to teach him.
2. The patient in case RA-1 shows signs of cardiovascular deconditioning (increased heart and respiratory rate with a 200-ft walk). Design a possible aerobic conditioning routine for her, including a way for her to assess her level of exertion. List precautions and protective devices to suggest for her.

Coordination of Multiple Medical Interventions for Energy Conservation

A patient with more advanced or complicated arthritis may have a multidisciplinary health care team consisting of a rheumatologist, orthopedic surgeon, psychologist, vocational counselor, orthotist, nurse, podiatrist, nutritionist, occupational therapist, and physical therapist. Demands made on the patient's time, energy, and financial resources by individual team members must be considered. Duplication of services should be avoided, whereas teamwork to provide positive functional outcomes should be practiced.

PATIENT EDUCATION

Chronically affected patients should be educated about their conditions during treatment and given self-help literature and information about community resources such as the Arthritis Foundation. Some treatments may be appropriately applied by family members or caregivers, and their involvement in treatment sessions to learn these techniques and to ask questions can be an efficient use of treatment time.

Working with patients with arthritis can be an exciting challenge to the physical therapist. This is an opportunity to apply the principles of exercise prescription in a situation demanding knowledge of joint and muscle pathology, the ability to do careful and complete assessment, the ingenuity to modify treatments to fit the determined requirements, and the ability to motivate patient cooperation. The benefit to the patient of this successful process can be an improvement in the quality of her life.

KEY POINTS

- Exercise can mitigate impairments that lead to functional deficits in patients with RA and OA and has a positive effect on numerous quality of life variables.
- The stability and mobility of a normal diarthrodial joint depend on the integrity of its anatomic parts. The disease processes of OA and RA attack these anatomic parts and affect joint integrity and function.
- The pathology of one diarthrodial joint in a kinetic chain can adversely affect joints proximal and distal in that same chain as well as in the contralateral joints. Exercise prescription should consider these joints when assessment indicates the need.
- Pain is a common impairment in patients with OA or RA. Management of pain with therapeutic modalities, safe alignment, bracing, and pacing is a necessary component of exercise prescription.
- Joint movement is necessary for maintaining joint health. Passive, active assisted, and active ROM exercises are appropriate, and the choice depends on the severity of involvement of the joint as well as the phase of inflammation of the joint.
- Isometric exercise is useful in maintaining strength of the muscles around an affected joint. It can be done without aggravating an inflamed joint and without raising blood pressure in patients when this is a consideration by using BRIMEs.
- Dynamic training offers the advantage of strengthening periarticular musculature through available joint range and increasing cartilage nutrition. Certain precautions must be followed, especially in strengthening muscles around unstable joints.
- Cardiovascular conditioning is frequently necessary for patients with OA or RA. It has a positive effect on the quality of life. Following specified guidelines, it is possible to prescribe exercise that does not aggravate existing joint pathology.
- Because of inflammation and joint instability, exercise prescription must include special precautions such as joint bracing, nonjarring movements, conjunctive therapeutic modality use, and pacing.
- Patients' adherence to an exercise program often depends on their belief in the program and on sharing common goals with the therapist. For this reason, the therapist must be aware of patients' beliefs and goals when designing an effective treatment program.

CRITICAL THINKING QUESTIONS

1. Consider Case Study No. 3 in Unit 7.
   a. Assuming that this patient has moderate osteoarthritis in her lumbar spine and knees and mild arthritis in her hips, create three different exercises to address the limited lower extremity endurance. Which muscle groups will you focus on and why?
   b. This patient returned to physical therapy a week later reporting that a friend told her that to get her legs stronger she should go up and down her 15-step staircase 10 times per day. Her knees are now swollen and more painful than when you saw her the first time. What are your recommendations at this time and why? Will your previously prescribed exercise program change?

c. Describe how you might design a walking program to improve her activity limitations in conjunction with her program to address her various impairments. How might you progress it and what are the key signs that the program is aggravating her arthritis?

2. Consider Case Study No. 7 in Unit 7.
   a. Given the findings in this patient's active and passive range of motion, list all the mobility impairments you would focus on. Understanding that this is subjective, prioritize and group the mobility impairments into those of most, moderate, and least important to restore normal movement patterns.
   b. Create two different exercise options to address the mobility impairments in your most and moderate groupings. Given her passive range of motion findings, how would you counsel this patient regarding the intensity of and pain levels during these exercises? Why?
   c. What muscle groups would you start with in her strengthening program? Would you begin strengthening immediately? Why or why not? If so, describe three exercises you might begin with.

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CHAPTER 13

Therapeutic Exercise in Obstetrics

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From the moment of conception, pregnancy profoundly alters a woman's physiology. Body system changes happen throughout the entire pregnancy and postpartum months. These changes are necessary to provide for the diverse needs of fetal growth and development, meet the metabolic demands of pregnancy, and protect her normal physiologic functioning.[1–4] By considering these changes, the physical therapist can carefully implement a therapeutic exercise program that is safe for the mother and fetus. Reasons for prescribing therapeutic exercise include:

- Primary conditions unrelated to pregnancy
- Disorders related to the physiologic changes of pregnancy, such as back pain, faulty posture, or leg cramps
- Physical and psychological benefits
- Pelvic floor dysfunction
- Preventive measures (**Display 13-1**)

During pregnancy, physical therapists have the opportunity to introduce important lifestyle changes that can be beneficial to both mother and fetus. Therapeutic exercise during this phase in life can play an important role in immediate intervention and in prevention of dysfunction and disease in the future. Today, the American College of Obstetricians and Gynecologists (ACOG) recommends that all pregnant women who are free from medical or obstetric complications engage in 30 minutes or more of moderate intensity physical activity on most days of the week.[5]

DISPLAY 13-1

General Benefits of Exercise During Pregnancy

Metabolic Benefits

- Preserve or increase maternal metabolic and cardiopulmonary capacities
- Manage gestational diabetes
- Prevent excessive weight gain

Musculoskeletal Benefits

- Promotes good posture and body mechanics
- Prevents connective injury due to laxity
- Prevent/manage low back pain, diastasis recti, and urinary incontinence
- Improve muscle tone

Manage Pregnancy/Postpartum Complications

- Decrease risk of venous stasis, deep vein thrombosis (DVT), varicose veins, edema, and leg cramps
- Decrease risk of bone loss due to higher estrogen levels
- Psychological benefits: improved mood, body image, and reduction in postpartum depression

Labor and Delivery Benefits

- Facilitates labor: endurance, possible decrease in pain perceptions, and improve relaxation
- Promote faster recovery
- Reduce postdate deliveries

Data from references 6, 7, 44, 70, 126, 160, and 195.

PHYSIOLOGIC CHANGES RELATED TO PREGNANCY

Physiologic changes occur in the maternal endocrine, cardiovascular, respiratory, and musculoskeletal systems.

Endocrine System

The endocrine system regulates hormonal changes that affect soft tissue and smooth muscle. Relaxin, estrogen, and progesterone cause fluid retention, growth of uterine and breast tissue, greater extensibility and pliability of ligaments and joints and a reduction in smooth muscle tone. Hormonal changes and structural adaptations alter gastrointestinal function.[3] Nausea, vomiting, changes in appetite, constipation, heartburn, and abdominal pain may interfere with a pregnant woman's ability and motivation to perform an exercise program (**Evidence and Research 13-1**).

EVIDENCE and RESEARCH 13-1

Studies have shown that the basal metabolic rate increases during a normal pregnancy by as much as 15% to 30% by term (i.e., birth occurring between 38 and 42 weeks of gestation).[1–4,6] The pregnant woman requires approximately 300 kcal more per day to meet this increased metabolic need.[1,2,4] Metabolic need increases (up to 500 kcal per day) in pregnant women who regularly exercise and also for postpartum lactation needs (i.e., secretion of milk by the breasts).[1,2,7,8] The thermoregulatory abilities of the body are affected by endocrine changes. For example, pregnant women may notice feeling warmer during activities of daily living (ADL); in addition, increased sweat production from elevated metabolism may be observed. Thermoregulatory adaptations appear early in pregnancy and may protect fetal development and limit thermal stress in women who exercise during pregnancy.[9]

Gestational Diabetes Mellitus

Gestational diabetes mellitus (GDM) is defined as glucose intolerance of variable degrees with onset or first recognition during pregnancy.[10] The prevalence of GDM is increasing globally. In the United States, up to 14% of pregnancies are complicated by GDM.[11] Established risk factors for developing GDM are those with a high body mass index (BMI), history of diabetes in a first-degree relative, previous macrosomic infant (birthweight of more than 8 lb, 13 oz), history of GDM in previous pregnancies, and advanced maternal age.[12] Modifiable risk factors include obesity, physical inactivity, dietary fat, smoking, and certain medications.[13] All pregnant women should be screened for GDM, because it can occur even when no risk factors or symptoms are present. Management consists of nutritional modification, careful monitoring of glucose levels, and possible insulin therapy.[7,13]

Cardiovascular conditioning exercise facilitates glucose use and reduces the amount of insulin needed to keep blood glucose levels normal, and it may play an important role in the management of GDM.[7,13–23] One study documented that women with GDM who trained with arm ergometry lowered their levels of glycemia better than with dietary changes alone.[19,20] Physical training may help avoid or delay insulin therapy.[24]

In 2004, the American Diabetes Association recommended that pregnant women without medical or obstetrical contraindications should be encouraged to exercise moderately as a part of preventing GDM.[25] A review by Russo et al. suggests a 28% lower risk of GDM among an exercise group compared to the control group, showing just how important exercise can be for managing this condition.[26] A physical therapist's exercise prescription should be individualized and include duration and intensity recommendations for women with GDM. Hypoglycemia means that levels of glucose in the bloodstream are too low to meet the body's energy needs. In pregnancy, hypoglycemia may develop in women whose bodies cannot adjust to the increased glucose requirements of the fetus, with or without exercise.[27] Some pregnant women feel better when they eat frequent, small, high-protein meals with an emphasis on complex carbohydrates (i.e., whole grains, fruits, and vegetables) rather than simple sugars (i.e., sweets).[27] Women who have GDM should consult a nutritionist regarding dietary recommendations before and after exercise (**Evidence and Research 13-2**).

EVIDENCE and RESEARCH 13-2

A recent meta-analysis suggests that physical activity in pregnancy provides a slight protective effect against the development of GDM.[28]

Even if there is no improvement in maternal glucose control, exercising three to four times each week for 30 minutes does improve cardiorespiratory fitness in pregnant women with GDM.[15,29] Since overt diabetes mellitus develops in 50% or more of women with GDM, they are at greater risk of cardiovascular complications.[7,30]

Pregnancy provides an excellent opportunity to educate these patients, instruct them in an exercise program, and stress the importance of continuing exercise after delivery[31,32] (see **Building Block 13-1**).

BUILDING BLOCK 13-1

Consider a 29-year-old pregnant woman at 32 weeks' gestation. She has just been diagnosed with GDM. What exercise advice might you give this patient to help her control her high blood sugar? What might you tell this patient about the effects of exercise during her pregnancy on her future health?

Cardiovascular System

Maternal hemodynamic changes include a blood volume increase of 30% to 50% that peaks in the middle of the third trimester.[3,7,33] The increase in maternal blood volume varies with the size of the fetus and with multiple fetuses (e.g., twins, triplets).[7] In normal pregnancy, one-sixth of the total maternal blood volume is within the uterine vascular system.[3] An increase in kidney blood flow improves removal of metabolic waste associated with fetal growth resulting in increased urine production and frequency. Increased skin blood flow helps with heat dissipation but makes the pregnant woman appear flushed.

Anemia

Hemoglobin levels fall progressively because of a greater increase in plasma than of red blood cells.[1,2,4,6,7] A deficiency in red blood cells, hemoglobin, or both is called anemia, and during pregnancy, this deficit is called physiologic dilutional anemia (i.e., 15% below nonpregnant levels).[7] Several types of anemia can develop during pregnancy including iron-deficiency anemia, folate-deficiency anemia, and vitamin B_{12} deficiency. Iron-deficiency anemia occurs when there is not enough iron to produce sufficient amounts of hemoglobin. This is the most common form of pregnancy-induced anemia. In pregnancy, iron stores are heavily called on to increase blood volume and to produce and provide hemoglobin for the placenta and fetus.[34–36] Symptoms of mild iron deficiency may be experienced early in pregnancy and include fatigue, light-headedness, and decreased exercise tolerance. Women are prescribed supplemental iron to prevent anemia during pregnancy and during breast-feeding. An inconvenient side effect of iron supplementation is constipation. Oftentimes, aerobic activity can help manage constipation brought on by intake of iron supplements.[37]

Folate and vitamin B_{12} are required for production of new cells including healthy red blood cells. When there is not enough folate and vitamin B_{12} in the diet, blood cell production is impaired, reducing oxygen transport to tissues throughout the body. Adequate folate levels are achieved through supplementation; vitamin B_{12} is found in meat, poultry, milk, and eggs.

Hemoglobin concentration determines the oxygen-carrying capacity of the blood. The amount of oxygen transferred across the placenta is influenced by maternal and fetal hemoglobin concentrations.[7] Changes in cardiac output, stroke volume, and heart rate contribute to an increase in oxygen distribution.[7] When a pregnant woman exercises, many of the variables that determine the transfer of oxygen across the placenta are affected. Physiologic adaptations to pregnancy and to exercise appear beneficial to both mother and fetus.[9,38–42]

Factors contributing to oxygen distribution include an increase in cardiac output by 30% to 50% and an increase in resting pulse by 8 beats per minute (bpm) in the early weeks of pregnancy to a plateau of about 20 bpm at 32 weeks.[1–3,7] During normal pregnancy, cardiac output is influenced by increased maternal weight, basal metabolic rate, blood volume and by decreased arterial blood pressure and vascular resistance.

Hormonal changes influence the decrease in total systemic vascular resistance by 25% and in total peripheral vascular resistance by 30%. This helps to balance the change in cardiac output and produces an arterial blood pressure decrease of 5 to 10 mm Hg for the duration of the pregnancy.[1,2,4,6] Peripheral vasodilation keeps the blood pressure within normal limits despite the increase in blood volume during pregnancy[3] (see **Building Block 13-2**).

BUILDING BLOCK 13-2

Describe changes in the cardiovascular system which are fetoprotective in the exercising woman.

Hypertension

Gestational hypertension affects 10% of pregnancies and can lead to preeclampsia or eclampsia (see **Display 13-2**). Women who are hypertensive during pregnancy are at greater risk of future cardiovascular or cerebrovascular events.[43] Pregnancy may lead to sedentary behavior and excessive weight gain, placing these women at increased risk for chronic diseases. It has been suggested that exercise may help prevent preeclampsia.[29,44] Unfortunately, these studies are considered insufficient due to a lack of randomization.[45]

A recently published animal study demonstrates that exercising during the early stages of pregnancy may protect the mother from developing high blood pressure. The theory is that expression of proteins may play a role in blood vessel health.[46]

Supine Hypotensive Syndrome

Body position also influences hemodynamic changes. As pregnancy progresses, supine hypotensive syndrome (SHS) (sometimes called inferior vena cava syndrome) may develop in females when lying on their back.[47] The increased weight and size of the uterus (usually after the fourth month of pregnancy) may occlude the aorta and inferior vena cava. The obstruction of venous return and subsequent hemodynamic adjustments from aortic compression results in decreased cardiac output.[1–4] Research suggests that a variety of factors are involved in determining the possible severity and significance of SHS.[47] Signs and symptoms of SHS are presented in **Table 13-1**. The ACOG recommends that pregnant women avoid supine lying after the first trimester.[5] Pregnant woman are encouraged to lie on their side as pregnancy progresses. A physical therapist with a thorough understanding of SHS and the rationale behind position changes can take a flexible approach to treatment and exercise in the supine position and reduce the risk of SHS (**Evidence and Research 13-3**).

DISPLAY 13-2

Cardiovascular System Changes that Contribute to Oxygen Distribution During Pregnancy

- Blood volume changes—increases 30% to 50%, peaks in the middle of the third trimester.
- Folate, vitamin B_{12}, and iron supply can affect blood cell and hemoglobin production, and low supply can contribute to anemia.
- Cardiac output can increase by 30% to 50% and resting pulse increases 8 to 20 bpm, and is influenced by:
  - Increased maternal weight
  - Increased basal metabolic rate
  - Increased blood volume
  - Decreased arterial blood pressure 5 to 10 mm Hg
  - Decreased vascular resistance

EVIDENCE and RESEARCH 13-3

As many as 60% of women may experience symptoms at some time during pregnancy, but the incidence of true SHS is about 8%, with risk peaking at 38 weeks' gestation.[47] Kotila and Lee[48] estimated the incidence of severe cases of SHS to be <1% of the 2,000 women they studied. Some studies report that, even with diminished circulation to the fetus, uteroplacental perfusion remains sufficient.[48] Other studies have determined that uterine blood flow changes are significantly less during supine exercise compared to supine rest.[49]

The earliest sign of impending SHS is an increase in maternal heart rate and a decrease in pulse pressure. Spontaneous recovery usually occurs with a change in maternal position, even if very slight.[3,4,47] Maximum venous return and cardiac output are obtained in the left lateral recumbent position, but the right lateral recumbent position also reduces symptoms.[1,2,4,47]

SHS is specific to the supine position, although anatomic anomalies (e.g., bicornuate uterus, which has two horns or horn-shaped branches) may predispose a small number of women to symptoms in sidelying positions. Prolonged and motionless standing also can occlude the inferior vena cava and the pelvic veins during pregnancy, decreasing cardiac output, increasing venous pressure, and contributing to edema and varicosities in the lower extremities.[3]

TABLE 13-1

Supine Hypotensive Syndrome

SIGNS	SYMPTOMS	SIGNS IN SEVERE CASES
Pallor or cyanosis	Faintness	Unconsciousness
Muscle twitching	Dizziness	Incontinence
Shortness of breath	Restlessness	Impalpable pulses
Hyperpnea	Nausea and vomiting	A lifeless appearance
Yawning	Chest and abdominal discomfort or pain	Convulsions
Diaphoresis	Visual disturbances	Cheyne–Stokes respiration (cycles or shallower and deeper breathing)
Cold, clammy skin	Numbness or paresthesias in the limbs	
A wild expression	Headache	
Syncope	Cold legs	
	Weakness	
	Tinnitus	
	Fatigue	
	Desire to flex hips and knees	
	Anguish	

Data from references 33 and 35.

Awareness of hemodynamic changes and SHS becomes important to the physical therapist when performing manual therapy techniques or prescribing exercises that require supine positioning or prolonged standing. Accommodating to a more upright or sidelying position (especially in the third trimester) or frequent position changes may be appropriate when working with patients at risk for SHS. Suggestions for position changes include placing a small wedge or pillow under the right hip in supine, raising the head and shoulders 20 to 30 degrees, semi-sitting, prone (on a special support or with use of pillows or wedge to decrease abdominal compression and ensure patient comfort), or quadruped (i.e., all-fours position). Changing positions from lying to upright should be done cautiously to decrease symptoms of orthostatic hypotension. In addition, SHS can be induced by increased abdominal pressure, which should be considered when positioning a patient in prone or when prescribing a maternal external support that may put pressure on the abdomen.[42] The physical therapist should encourage the pregnant patient or client to shift positions frequently during exercise, work, and treatment to avoid stasis and hypotension. Because supine positioning during labor has been associated with lower fetal oxygen saturation, position changes apply to the laboring woman as well[50] (see **Building Block 13-3**).

BUILDING BLOCK 13-3

SHS is a concern as pregnancy progresses. Describe the signs and symptoms of SHS and discuss exercise adaptations for your pregnant patients/clients.

Respiratory System

The respiratory system also adapts to the many changes in pregnancy. By 15 weeks' gestation, significant changes in lung volumes and capacities are present.[51] Hormonal changes produce increased mucus in the respiratory tract with associated increases in sinus and coldlike symptoms.[1,4] The diaphragm displaces upward by about 4 cm, but diaphragmatic excursion increases.[1,2,4,7] An increased pulmonary ventilation rate (i.e., the total exchange of air in the lungs measured in liters per minute) during pregnancy is achieved by the woman breathing more deeply, increasing tidal volume (i.e., the amount of gases exchanged with each breath).[1–3,7] The respiratory rate increases only slightly (approximately two breaths per minute), but there is an associated increase in respiratory minute volume, which is the amount of air inspired in 1 minute.[1–4,6]

Lung compliance increases and airway resistance decreases from the relaxing effect of progesterone on smooth muscles.[7] This has been referred to as hyperventilation of pregnancy. Although arterial blood gases reflect an increase in oxygen and a decrease in carbon monoxide, causing mild respiratory alkalosis, this is not true hyperventilation. This mild maternal alkalosis promotes placental gas exchange and prevents fetal acidosis.[7] It may be perceived as dyspnea at rest and during exercise or as a decrease in the tolerance for exercise and exertion. In early pregnancy, it is unrelated to the encroachment of the uterus on the diaphragm. Later, as the lower costal girth is increased, greater breathing movement takes place at the middle costal and apical regions compared with the abdomen.[5]

Oxygen consumption increases by 10% to 20% during pregnancy. This, combined with a reduction in functional residual capacity, results in a lower oxygen reserve.[7,48] With increasing body weight, more oxygen is required to exercise, and a woman reaches her maximal exercise capacity at a lower level of work.[49] Maximal exercise capacity of pregnant women may decline by approximately 20% to 25% in the second and third trimesters of pregnancy. Previously, there was some concern that muscles active during exercise would draw oxygen and blood flow away from the uterus. However, this notion has been thoroughly disproven in recent studies. Some evidence suggests that pregnancy and advanced gestation are not associated with reduced aerobic work capacity or increased respiratory distress at any given work rate or ventilation during non–weight-bearing or weight-supported exercise[7,47,50] (**Evidence and Research 13-4**).

EVIDENCE and RESEARCH 13-4

It is widely accepted that aerobic exercise improves the physical fitness levels of healthy, pregnant women.[51] Recent evidence also supports exercise for previously sedentary pregnant women without adversely affecting fetoplacental blood flow or fetal growth.[52–54]

With increasing body weight, more oxygen is required to exercise, and a woman reaches her maximal exercise capacity at a lower level of work.[55] Maximal exercise capacity of pregnant women may decline by approximately 20% to 25% in the second and third trimesters of pregnancy. Some evidence suggests, however, that pregnancy and advanced gestation are not associated with reduced aerobic work capacity or increased respiratory distress at any given work rate or ventilation during non–weight-bearing or weight-supported exercise.[7,56,57]

Musculoskeletal System

The physical therapist is perhaps best suited to address the multiple musculoskeletal changes that occur during pregnancy. Many of these changes may make the childbearing woman more vulnerable to injury and pain.[58] Most women will experience some degree of musculoskeletal discomfort during pregnancy. Approximately 25% will have disabling symptoms.[59] Although the physiologic and morphologic changes in pregnancy are normal, musculoskeletal symptoms should not be considered normal despite the fact that they are common.

Optimal weight gain by the mother during pregnancy is important to pregnancy outcome, but a wide range in weight gain is compatible with good clinical outcomes.[1–4] The pattern of weight gain may also have important implications. Birth weight of the infant parallels maternal weight gain. There are potential hazards for the mother and the infant when weight gain is restricted, and exercise should not be used to decrease weight. Both low birth weight (<2,500 g; <5 lb 5 oz) and high birth weight (>4,000 to 4,500 g; 8 lb 13 oz to 9 lb 15 oz) are associated with poor fetal outcomes.[60] An average maternal weight gain of 12.5 kg (27.5 lb) is usually recommended during pregnancy, but the desirable range is related to prepregnancy weight status and BMI (see **Display 13-3** and **Evidence and Research 13-5**).

DISPLAY 13-3
Weight Gain Recommendation During Pregnancy*

Prepregnancy Status	BMI	Recommended Weight Gain
Underweight	Less than 18.5	27.5–40 lb (12.5–18 kg)
Normal weight	18.5–24.9	25–35 lb (11.5–16 kg)
Overweight	25–29.9	15–25 lb (7–11.5 kg)
Obese	30 and greater	11–20 lb (5–10 kg)

**http://www.acog.org/Patients/FAQs/Obesity-and-Pregnancy. Accessed June 12, 2015.*

EVIDENCE and RESEARCH 13-5

Recent studies have shown that lower gestational weight gain limits, especially among obese women, are associated with a decreased risk of adverse maternal and fetal outcomes.[61] Excessive weight gain during pregnancy and GDM are not only associated with obesity and diabetes later in life for the mothers, but also with higher birth weight and obesity in their children.[7,62]

The enlargement of the uterus and its contents, increases in blood volume and extracellular fluid, and an increase in breast tissue contribute to weight gain during pregnancy.[1,2] The nonpregnant uterus is approximately 6.5 cm long, 4 cm wide, and 2.5 cm deep and weighs 50 to 70 g.[1–3,55] By term, the uterus drastically increases to 32 cm long, 24 cm wide, and 22 cm deep and weighs about 1,100 g.[1–4] By the end of 12 weeks, the uterus becomes too large to remain wholly within the pelvis and becomes an abdominal organ.[1–3] It enlarges more rapidly in length than in width. This gradual increase in size and weight causes an upward and forward shift in the woman's center of gravity, which may result in an increased lumbar lordosis and compensatory thoracic kyphosis. Enlarging breasts, gaining up to 500 mg each, add to this tendency. This can result in a change in the resting position of the scapulae, with the scapulae protracted and tilted anteriorly. Over time, this will result in lengthened scapular retractors and shortened scapular protractors. In addition, this will cause the head to shift forward and posterior neck muscle activity must increase to support the head. Posterior suboccipital muscles may also increase activity, extending the head on the neck to maintain eyes horizontal (i.e., optical righting reflex). The subcostal angle of the thorax increases from approximately 68 degrees in early pregnancy to approximately 103 degrees in late pregnancy to accommodate the fetus.[1–4,7] After delivery, this rib angle change may not fully revert to the prepregnancy state. Chest circumference typically increases by 5 to 7 cm during pregnancy. In the last trimester, the trunk may rotate to the right (dextrorotation) as the growing uterus rotates to the right on its long axis. This most likely occurs because of the position of the rectosigmoid (lower portion of the sigmoid colon and upper portion of the rectum) on the left side of the pelvis.[1,2,7]

Changes in hormones contribute to joint laxity and subsequent hypermobility (see **Building Block 13-4**). This joint laxity can contribute to increased foot pronation during pregnancy. Poor foot alignment affects the mechanics of the lower kinetic chain. Unlike other joints in the body that return to their normal prepregnancy position, the foot may not.[3] The postpartum woman may notice a permanent increase in shoe size. Since laxity and weight gain change foot biomechanics, the physical therapist should make recommendations regarding proper footwear and possibly orthotics for support during pregnancy. In addition, the therapist must educate the patient/client that, postpartum, the feet may change and the orthotics, shoes, and exercises that were effective during the pregnancy may no longer be appropriate (see Chapter 21).

BUILDING BLOCK 13-4

Consider how hypermobility can specifically impact cardiovascular activities such as walking or jogging during pregnancy. Discuss how you would educate a pregnant patient/client about changes to her current exercise program. Provide recommendations for protection against joint pain as a result of hypermobility.

Hormonal changes facilitating ligamentous laxity, softening of cartilage, and proliferation of synovium also influence postural changes. Postural changes in response to pregnancy can be further exaggerated by work, ADLs, recreation, and exercise. Mechanical changes during pregnancy may aggravate preexisting conditions. Musculoskeletal complaints associated with pregnancy and postpartum may not get serious consideration and the consequence may be underreferring to physical therapy in this population.

THERAPEUTIC EXERCISE INTERVENTION IN PREGNANCY

The following sections address common impairments seen in women during pregnancy and the postpartum period. Sample musculoskeletal evaluations that incorporate adaptations for manual muscle testing and limit the number of body position changes for the pregnant client can be found in *Obstetric and Gynecologic Care in Physical Therapy*[63,64] and *Clinics in Physical Therapy: Obstetric and Gynecologic Physical Therapy*.[55]

Uncomplicated Antepartum Pregnancy

Focusing on the balance of muscle length and strength in key postural muscles in pregnant and postpartum women is extremely important. Length-associated changes arising from the typical kyphosis-lordosis posture can be prevented by addressing the posterior neck muscles, the middle and lower trapezius muscles, the transversus abdominis (TA), external and internal obliques (EO and IO, respectively), hip extensors, and the pelvic floor. Adaptive shortening is common in the anterior shoulder muscles, lumbar paraspinals, and hip flexors. Appropriate active and passive stretches should be prescribed for these areas. Lumbar, sacroiliac, and pubic symphysis problems may be greatly relieved by lumbopelvic stabilization exercises and by the use of external supports during pregnancy.[65–67]

Muscle Performance

Abdominal Strength Goals for performing abdominal exercises during pregnancy include improvement in muscle balance and posture, support of the growing uterus, stabilization of the trunk and pelvis, and maintenance of function for more rapid recovery after delivery. Abdominal muscle strengthening exercises during pregnancy may reduce the development of a diastasis recti abdominis (DRA).[68] Most pregnant women can perform abdominal exercises in supine with frequent position changes. Exercises such as supine hip and knee flexion with hip abduction and lateral rotation (see Self-Management 17-3) and progressive leg slides (see Self-Management 17-1) are appropriate as long as the neutral spine position is maintained. In the case of an anterior pelvic tilt and lumbar lordosis, the client can be taught to use the abdominal muscles (particularly the EO) to tilt the pelvis in a posterior direction. This activity can be performed in a variety of positions (e.g., sitting, standing) and can be used to actively stretch the low back extensors while strengthening the abdominal muscles.

Some precautions should be followed when training abdominal muscles during pregnancy. Bilateral straight-leg raising and leg-lowering exercises should be avoided during pregnancy because of the vulnerability of the vertebral joints, excessive pull on an overstretched abdomen and risk of Valsalva maneuver. When a woman has SHS, the supine position should be avoided, and the use of sidelying, sitting, standing, and quadruped positions can be creatively used to train the patient in abdominal facilitation and neutral spine. The quadruped position is excellent for performing concentric and eccentric contractions of the abdominal muscles (see **Self-Management 13-1**).

SELF-MANAGEMENT 13-1
Quadruped Abdominal Exercise

Purpose: To train the patient in abdominal facilitation when a supine position is uncomfortable or contraindicated (e.g., SHS)

Position: On hands and knees

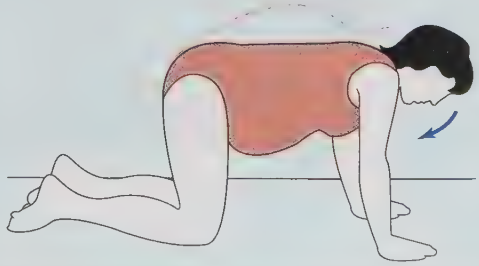
Movement Technique:

1. Concentric contraction
   a. Inhale, allowing the abdomen to expand.
   b. While exhaling slowly, pull the tummy in while maintaining neutral spine. (To stretch back extensors, push the lower back up and tuck the chin down.)
2. Eccentric contraction.
   a. Slowly relax your tummy, and return to the starting position.

Dosage:

Repetitions: ____________________

Frequency: ____________________



Pelvic Floor Strength The pelvic floor muscles may undergo length-associated changes from the long-standing pressure of the growing uterus. Hormonally softened tissue further complicates the increased load on the pelvic floor. A vaginal birth or a lengthy and unproductive second stage of labor (i.e., pushing phase) before cesarean section poses problems for a vulnerable pelvic floor. There is the potential for direct trauma to the muscles with an episiotomy (an incision in the pelvic floor made during childbirth to enlarge the vaginal opening and allow faster delivery), tears, or lacerations. In addition, pudendal or obturator nerve stretch injuries may occur during delivery.

The importance of pelvic floor muscle strength cannot be overemphasized (see Chapter 18). It plays a vital role in supporting the internal organs (such as the rectum, vagina, and uterus) by preventing downward displacement (i.e., prolapse or pelvic relaxation). Pregnancy and postpartum pelvic floor dysfunction may manifest as pelvic organ prolapse, urinary or fecal incontinence, pelvic pain from muscle spasm, painful episiotomy, tears, or joint malalignment (sacrococcygeal involvement). A strong, coordinated pelvic floor may result in improved control and relaxation during the second stage of delivery[69] and in postpartum recovery. Attention to the pelvic floor muscles should occur early in the pregnancy and should continue throughout the duration of the pregnancy and postpartum phase[55,70] (see Chapter 18). A basic program involves lying in a hook-lying position (gravity neutral). Contract the pelvic floor muscles for 10 seconds, followed by bringing soles of feet together and knees apart with relaxation of pelvic floor for 10 seconds (see **Fig. 13-1**). Repeat the cycle 20 to 25 times.

Though internal pelvic examination by a physical therapist should wait until clearance from the obstetrician at the 6-week postpartum follow-up visit, the patient may begin pelvic floor coordination exercises immediately after birth. Pelvic floor contractions immediately after delivery are essential in restoring muscle tone, reducing edema, facilitating circulation, and relieving pain, especially if an episiotomy has been performed or if the perineum was torn. The perineum comprises the pelvic floor and associated structures occupying the pelvic outlet; the area is bound anteriorly by the pubic symphysis, laterally by the ischial tuberosities, and posteriorly by the coccyx. The patient should be instructed to contract or "brace" the pelvic floor muscles with coughing, sneezing, or laughing; avoid Valsalva maneuvers when lifting the infant; and initially support the sutured perineum manually during defecation. To avoid developing overactive pelvic floor muscles, the physical therapist should instruct patients in pelvic floor coordination exercises as instructed in Figure 13-1.

Pelvic floor strengthening should continue in the postpartum phase and beyond to restore muscle tone and to enhance normal bowel, bladder, and sexual functions. A systematic review reported that pelvic floor muscle exercises were effective in reducing or resolving urinary incontinence postpartum.[71] The supportive function of the pelvic floor is additionally challenged by lifting and carrying the infant and various pieces of childcare equipment (e.g., stroller, infant seat, and diaper bag) (see Chapter 18).

Joint Integrity and Muscle Length

Joint Hypermobility During pregnancy, there is a systemic increase in joint mobility. However, studies investigating the relationship between increased joint mobility and serum relaxin levels are conflicting.[72] To date, there are no studies that document a higher incidence of exercise-induced peripheral joint injuries during pregnancy.[40,72]

Abdominal Muscle Length

Diastasis Recti Modifications to exercise for abdominal muscles are necessary for a woman with DRA.[70,73,74] In standing, the abdominal wall supports the uterus and maintains its longitudinal axis in relation to the axis of the pelvis.[2] The muscles of the abdomen that must lengthen to accommodate the enlarging uterus and growing fetus in pregnancy are the EO and IO, TA, and rectus abdominis. The linea alba is formed by the crossing fibers of the aponeuroses of these muscles, making a tendinous seam from the sternum to the pubic symphysis. Hormonal changes and the increasing mechanical stress placed on these structures during pregnancy may result in a painless separation of the linea alba.[55] The rectus muscles separate in the midline, creating a DRA. The rectus muscles can be split up to 2 cm apart above the umbilicus, but remain in contact with each other below the umbilicus. A separation greater than this is considered to be a DRA.[55,70,73,74] The prevalence of DRA has been estimated to be as high as 100% during pregnancy and reduces to 40% 6 months postpartum without any specific intervention.[75]

If the DRA is severe, the anterior uterine wall may be covered by only skin, fascia, and peritoneum. If extreme, the gravid uterus drops below the level of the pelvic inlet when the

A B

FIGURE 13-1 Pelvic floor coordination exercises. **(A)** Resting in a semi-reclined position, contract pelvic floor muscles for up to 10 seconds. **(B)** Externally rotate the hips and relax the pelvic floor muscles for 10 seconds.

woman stands. The pelvic inlet is bound posteriorly by the body of the first sacral vertebra, laterally by the linea terminalis, and anteriorly by the horizontal rami of the pubic bones and pubic symphysis.[2] Descent of the fetal head below this point is called engagement and occurs normally during the last few weeks of pregnancy or during labor. Upright exercise should be restricted if engagement occurs at any other time during the pregnancy, which is a risk factor with extreme DRA.[2]

The presence of a DRA potentially reduces the ability of the abdominal wall muscles to contribute to their role in trunk and pelvic girdle alignment, motion, and stability; support of pelvic viscera; and by way of increasing intra-abdominal pressure, forced expiration, defecation, urination, vomiting, and the second stage of labor (i.e., pushing).[55] As an adjunct to therapeutic exercise, an external support in the form of an abdominal binder, lumbopelvic support, or sacroiliac belt can assist the patient in achieving improved body mechanics and postural alignment for the patient with DRA. When a diastasis is present, the external support helps to reestablish and maintain normal alignment of the abdominal wall to prevent further stretch weakness. These supports are worn during upright exercises and ADLs (see **Building Block 13-5**).

BUILDING BLOCK 13-5

Consider a postpartum patient who has decided to return to a high impact boot camp style workout classes to get back in shape. She reports that they do a lot of planks, sit-ups and burpees in the class. She has a palpable three-finger width diastasis at the umbilicus. What modifications would you recommend she make when attending the class?

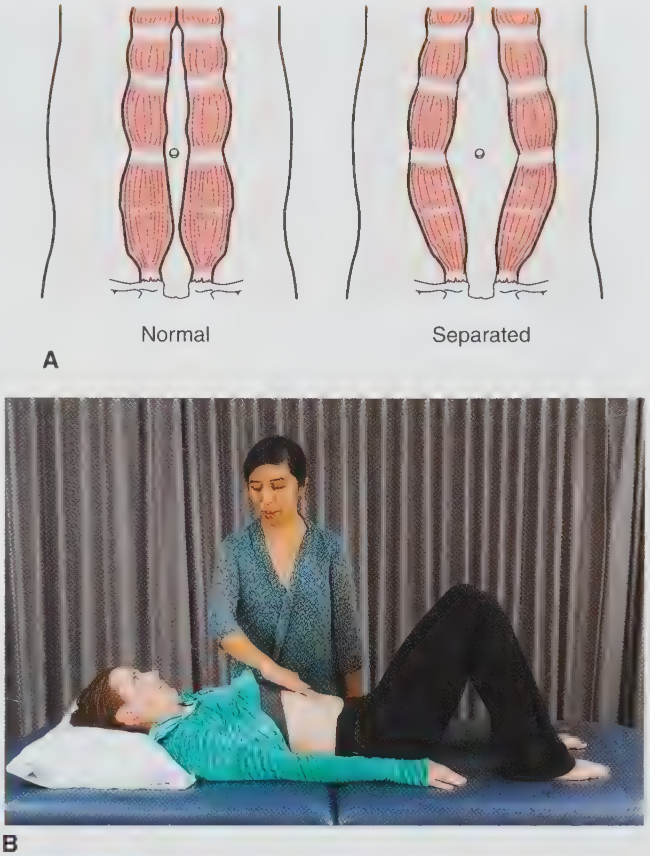


FIGURE 13-2 **(A)** Comparison of a normal abdomen with a DRA. **(B)** The therapist checks for a central bulge in the abdomen and measures the amount of separation between the rectus muscles.

Although weight management and exercise can minimize the effects of DRA during pregnancy, correction of a DRA should be done postpartum. During pregnancy, if a DRA is limiting function or causing symptoms such as low back pain, the patient can work with a therapist to manage symptoms. Management would likely include learning to recruit abdominal and pelvic muscles to stabilize the spine during movement. In addition, wearing an external support may assist with stabilization.

Even if a DRA was not present during pregnancy, a separation could have developed during the second stage of labor. A DRA does not always resolve spontaneously after delivery and may persist well into the postpartum phase. Immediate postpartum prevalence of DRA is about 35%.[76] Studies suggest that women who exercised during pregnancy are less likely to develop DRA.[76] DRA should be evaluated and reduced before aggressive abdominal strengthening begins. To evaluate the abdominal wall for a DRA, have the postpartum woman lie in the supine hook lying position. With the chin tucked and arms extended to the knees, have the patient actively raise her head and shoulders until the scapulae clear the surface. The therapist checks for a central bulge in the abdomen and, with fingers placed cephalocaudally, measures the amount of separation between the rectus muscles 2 inches above, 2 inches below, and at the level of the umbilicus.[55,74] Each finger represents approximately 1 cm (**Fig. 13-2**).

Postpartum, the physical therapist can instruct in diastasis correction exercises to maintain alignment and help to prevent further separation. The patient is positioned hook lying with arms crisscrossed over the abdomen. As the patient manually approximates the recti muscles toward midline, she performs a posterior pelvic tilt, and slowly exhales while lifting her head. The scapulae should clear the surface.[70] Exhalation prevents an increase in intra-abdominal pressure, engaging the TA first with a neutral spine.[55] The additional support of a large sheet folded lengthwise under the patient's back may be helpful to reduce strain on the upper body and neck (see **Self-Management 13-2**). The two ends of the sheet are brought up and crisscrossed over the abdomen to simulate support of the abdominal wall. The patient can grip each end of the crossed sheet to support the recti muscles toward the midline If DRA is detected in a postpartum patient, they are encouraged to avoid unsupported curl ups, trunk rotation exercises, and sitting straight up from a supine position, as these activities may encourage further separation.

Postpartum exercise is vital for the restoration of normal muscle function. Pelvic floor and abdominal contractions may be started within the first 24 hours after delivery to restore tone. It is important to remind the patient that these muscles may not provide adequate support initially for the trunk and low back, which are more vulnerable to injury.[77] In some cases, the temporary use of an abdominal binder is advisable. Because of their synergistic relationship, persistent DRA beyond the childbearing years may play a role in the development of pelvic floor dysfunction.[78]

SELF-MANAGEMENT 13-2
Correction of DRA

Purpose: To correct a DRA and improve the length–tension relationship of abdominals (rectus abdominis)

Position: Backlying with knees bent and feet flat. Cross hands over the midline of the abdomen.

Movement Technique:

1. Fold a sheet or towel lengthwise under your low back. Cross the sheet over the midline, holding the opposite ends in each hand.
2. Inhale. As you exhale draw umbilicus toward spine (engaging transversus abdominus).
3. Tuck your chin, pull outward on the ends of the sheet, bringing your abdominal muscles closer together. Slowly raise your head off the surface while pulling the belly muscle toward the midline.
4. Slowly lower the head and relax, then release your grip on the sheet.

Dosage:

Repetitions: ____________________

Frequency: ____________________

Pelvic Floor Muscle Length

During pregnancy, patients sometimes have difficulty relaxing the pelvic floor muscles and experience overactivity in the muscle groups, resulting in muscle impairment. If pelvic floor tension myalgia exists, with or without coccygodynia, emphasize pelvic floor relaxation as a part of a multifaceted plan of care.[79] After ruling out the possibility of referred pain from L5–S1, the patient can be instructed in a self-management technique to relax the pelvic floor muscles. For example, the patient can sit semi-reclined with support at the low back. The therapist should assist the patient in helping to identify the pelvic floor muscles via verbal/tactile cues. (Though internal pelvic exams are not conducted during pregnancy, a pelvic-floor trained therapist may conduct external pelvic exam.) Have the patient contract the pelvic floor muscles for a few seconds, then externally rotate the hips and place the soles of the feet together (see **Fig. 13-3**) and relax the pelvic floor muscles for 10 seconds. For the patient with pelvic pain, contraction of the muscle is used to improve proprioception and to restore full mobility by identifying overactive pelvic floor muscles, followed by practicing voluntary relaxation. This relaxes the pelvic floor and should be practiced several times each day. The use of a donut cushion or sitting with layers of towels under the thighs may be useful in keeping pressure off the coccyx.[55,80]

If pelvic floor muscle tension has caused sacrococcygeal malalignment, direct mobilization of this articulation may be performed to reduce pain.[81] This technique also is appropriate for a subluxed coccyx after childbirth.[63]

Posture

For the pregnant woman, postural awareness is vital due to the shift in the center of gravity, weight gain, and hormone-related increased joint mobility. Lumbar lordosis may result from pregnancy, or pregnancy may exaggerate a preexisting lordosis. Ideal postural alignment, as defined by Kendall et al.,[82] involves a minimal amount of stress and strain and is conducive to maximal efficiency of the body (refer to Chapter 9 for the definition of ideal alignment of the spine and pelvis). During pregnancy, the center of gravity shifts anteriorly, which may result in anterior rotation of the ilium. This accentuates and increases the normal anterior curve of the lumbar region, creating a lordosis (Fig. 13-3) (see **Patient-Related Instruction 13-1**). Muscle weakness resulting from length-associated changes in the abdominal muscles and the hip extensor muscles results in poor control of the pelvis (in this case, an anteriorly tilted pelvis). However, adaptations to biomechanical changes during pregnancy vary among women, and even between pregnancies in the same woman. Anterior pelvic tilt and lumbar lordosis have not been consistently observed and

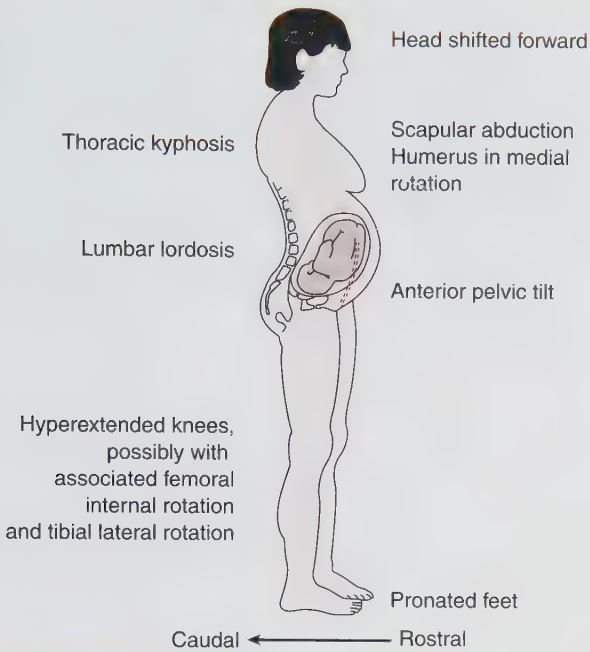


FIGURE 13-3 Incorrect posture during pregnancy.

are not necessarily associated with reports of pain.[83,84] Frequent inner core activation (see Patient-Related Instruction 17-1) in various positions enhances muscular control and strength and the postural awareness required throughout the day to relieve pain and fatigue in the low back.

A lordosis at the thoracolumbar junction may cause mechanical stress on the muscles and ligaments, producing foraminal narrowing. The result may be radicular irritation manifesting as pain along the course of the iliohypogastric and ilioinguinal nerves anteriorly and posteriorly—a common referral source of pain for prepartum and postpartum women.[55] Radicular symptoms may also be experienced in the upper extremities, chest, and neck because of a compensatory thoracic kyphosis, shoulder protraction, and increased cervical lordosis. Changes in the transverse diameter of the chest may mechanically aggravate preexisting costovertebral or thoracic joint dysfunction.

Thoracic kyphosis may develop during pregnancy and persist postpartum, related to childcare tasks, such as nursing/feeding, holding the baby, and lifting a car seat. Performing wall slides with the back to the wall (see Display 25-14, Fig. 1) facilitates strengthening of the scapular upward rotators and the thoracic erector spinae and stretches the pectoral muscles. This exercise can reduce thoracic kyphosis and lift the rib cage off the uterus by promoting balance in length and strength of the anterior and posterior upper quarter muscles. Performing this exercise frequently throughout the day can reduce postural pain and discomfort. Another useful exercise to improve posture during pregnancy is a wall abdominal contraction with a posterior pelvic tilt (**Fig. 13-4**). This exercise helps to maintain tone in the abdominal region and normal hip flexor length, both of which support the lumbar curve and pelvic position. Frequent changes in position and proper posture and body mechanics during daily activities at home and at work apply to both pregnant and nonpregnant women.

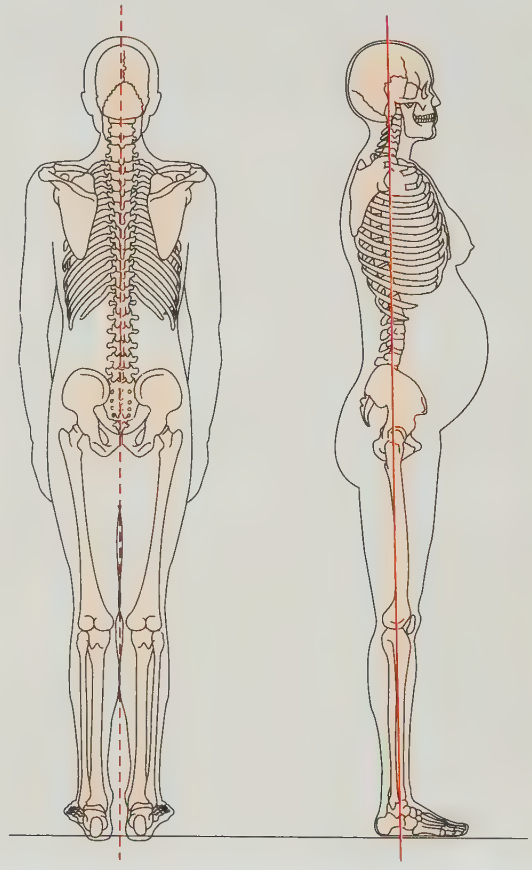
Postural dysfunction may persist into the postpartum period, especially when caring for the new infant. The patient must

Patient-Related Instruction 13-1

Postural Correction

To correct posture during pregnancy, follow the steps below. Perform these steps simultaneously as often as you can—at least six times per day. Try them during different daily activities such as brushing your teeth, washing the dishes, or standing in line. Maintain them while performing exercises in the standing position.

1. Elongate the neck by drawing the chin back and keeping eyes level.
2. Lift your breastbone, ribs, and head without arching your lower back, as though you are trying to be taller. Squeeze your shoulder blades together slightly, while keeping shoulders relaxed away from your ears. Breathe normally; do not hold your breath.
3. Tighten your deep lower abdominals for low back support. The pelvis should be in a neutral position.
4. Soften your knees (unlocked) and keep your knees facing forward.
5. Pull "up and in" with the pelvic floor muscles.
6. Shift your weight slightly so half of your weight is on your heels and half is on the balls of your feet. Slightly lift the arches of your feet without rolling out on the sides of your feet.



accommodate to multiple body changes that occur rapidly. Weight loss and a change in the center of gravity produce postural readjustments. Ligaments and connective tissue may remain under hormonal influence for up to 12 weeks postpartum and

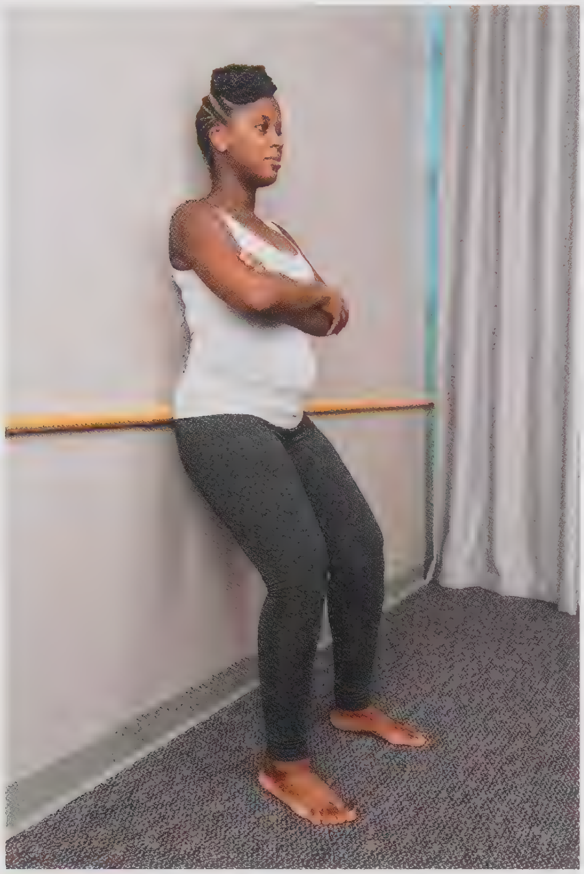


FIGURE 13-4 Wall abdominal contractions with a posterior pelvic tilt. Stand with feet 6 to 12 inches in front of the wall, keeping feet about hip width apart. Rest back against the wall. Pull belly button in towards spine and bend hips and knees, sliding flattened low back against the wall. Maintain abdominal contraction while straightening hips and knees in flattened or neutral position. Stop when low back moves into extension.

may continue with breastfeeding.[7] Feeding or nursing, repetitive bending and lifting, and carrying a car seat all challenge the recruitment and endurance of postural muscles. Proper body mechanics and joint protection should be stressed to decrease abnormal forces on joints that are at increased risk of injury because of hormonally induced laxity. Exercises should focus on scapular stability, anterior chest wall flexibility, and core and hip strengthening to support daily demands on the new mother (see Chapters 9, 17, 25 for specific exercises).

If the mother is breast-feeding, the neck and upper back muscles are affected by the increased weight of the lactating breasts and by the positions assumed by the mother during nursing. Exercises that improve postural awareness and the length–tension properties of the anterior and posterior neck muscles (see Chapter 23) and scapular muscles, such as the lower and middle trapezius, are appropriate (see Chapter 25). Certain exercises may be uncomfortable for a nursing mother to perform because of breast tenderness (e.g., prone positioning). Attention should be paid to sitting posture and positioning of the baby during breast-feeding. External supports for the baby and the patient's spine may be helpful to maintain spinal alignment and decrease muscle compensation.

Gait

During pregnancy, assess gait for adaptations or muscle imbalances. Evaluate the patient for hip abduction weakness, which may present as a Trendelenburg gait. In addition, assess knee position to determine alignment, observing for any knee valgus, varus, or recurvatum. Finally, assess the patient for excessive foot pronation. If present, determine if the patient would benefit from appropriate strengthening exercises and/or orthotics. Interestingly, three-dimensional motion analysis suggests there are minimal changes to gait mechanics in the pregnant patient.[85]

Aerobic Capacity

When a woman has maintained good physical condition during pregnancy, her postpartum fitness is improved. After labor and delivery, exercise can usually be resumed before the 6-week checkup.[55] Return to exercise should be gradual and based on her comfort level. Postpartum exercise guidelines are listed in **Display 13-4**.

Pain

Approximately 50% to 90% of women experience back pain during pregnancy.[4,7,84,86,87] Many women with chronic back pain link the onset to pregnancy.[83,88,89] Back pain may occur

DISPLAY 13-4

Postpartum Aerobic Exercise Guidelines

1. Gradually return to exercise with a goal of regular exercise (at least three times per week). The process of reversal to the prepregnant state is thought to take 6 to 8 weeks (although the anatomic effects of relaxin may persist as long as 12 weeks; longer if breastfeeding).
2. Correct anemia before engaging in moderately strenuous activities. Stop exercising if vaginal bleeding increases or bright red blood appears.
3. Avoid moderately strenuous activities if excessive vaginal bleeding occurs or soreness of an episiotomy persists.
4. Avoid ballistic movements, extreme stretching, and heavy weight lifting for 12 weeks or longer if joint laxity persists.
5. Use the same precautions (such as exercise caution with high impact activities) as in pregnancy to prevent musculoskeletal injury, for approximately 12 weeks.
6. Provide good support to the breasts during exercise, especially if nursing. Nursing mothers should feed the infant before exercising to avoid discomfort.
7. Target heart rates and limits should be established in consultation with a physician and may be based on the fitness level during and before pregnancy.

Postpartum Strengthening Exercise Guidelines

Avoid exercises that raise the hips and pelvis above the chest, such as bridging, knee-chest positions, and inverted postures, until postpartum bleeding has stopped completely. These positions put the body at risk for a rare but fatal air embolism through the vagina.

Data from references 7, 56, 70, 157, and 195.

at any time throughout the pregnancy but most commonly occurs between the fourth and the seventh months.[36] Back pain causes include:

- Biomechanical strain from increases and imbalances in joint loading resulting from increased body mass and dimension
- Postural changes, such as lumbar lordosis creating increased stress on the facet joints, posterior ligaments, and intervertebral disks
- Postural changes that aggravate a preexisting condition, such as spondylolisthesis, degenerative facet joint disease, lateral stenosis, and muscle imbalances
- Ligamentous laxity affecting the sacroiliac joints (SIJs), pubic symphysis, and sacrococcygeal joint
- Muscle fatigue from overload on key muscles including back extensors, abdominals, and pelvic floor

The relationship between postural changes during pregnancy and back pain is unclear.[84] Back pain is not entirely explained by biomechanical changes that can be measured by postural assessment. The source of pain is likely to be multifactorial, but there are common patterns of presentation. These are lumbar pain (LP), pelvic girdle pain (PGP), and nocturnal pain.[83,88,90–92] Inconsistencies in terminology and diagnostic criteria have made comparisons of prevalence, interventions, and outcomes difficult.[91]

Evaluation and exercise prescription for pregnancy-related back pain must be individualized. Higher levels of prepregnancy fitness and physical activity appear to decrease the risk for pregnancy-related LP and PGP.[83,88,90,93] Patients may need to be advised to adjust their exercise habits as the pregnancy progresses. Back pain and other pregnancy-related discomforts may be minimized by reducing the duration and intensity levels of exercises.[7,94]

Lumbar Pain LP is described as pain in the lumbar spine with or without radiculopathy. It is aggravated by prolonged standing or sitting or repetitive lifting. LP responds to treatment focused on posture, body mechanics for ADLs, and exercise similar to the nonpregnant population (see Chapter 18).

Pelvic Girdle Pain Recently published European guidelines on PGP propose that the diagnosis of PGP be reached after exclusion of lumbar, gynecologic, and urologic causes.[91] They define PGP as pain that is experienced between the posterior iliac crest and the gluteal fold, particularly in the vicinity of the SIJs. In some areas, SIJ is the preferred term over PGP; in this context, the two terms may be used interchangeably. The pain may radiate into the posterior thigh. Pain can occur in conjunction with the pubic symphysis or exclusively in the pubic symphysis. Several tests have been described to identify PGP.[83,88,95–97] Ronchetti et al.[98] reported on diagnostic tests with acceptable intra- and interrater reliability, sensitivity, and specificity for the PGP population. These include the posterior pelvic pain provocation test (or thigh thrust test), active straight leg raise test, hip abduction and adduction resistance test, the Patrick (Fabere) test, and palpation of the long dorsal sacroiliac ligament test. They concluded that each test provoked a particular aspect of PGP dysfunction. For diagnostic confirmation and assessment of PGP severity, a combination of tests is necessary[98] (see **Building Block 13-6**).

BUILDING BLOCK 13-6

A 31-year-old pregnant female presents with complaints of low back pain. What tests might be used to assess this patient's impairment and distinguish her complaints from PGP?

The prevalence of PGP during pregnancy is approximately 20%; patients at risk of developing PGP report a history of low back pain and previous pelvic trauma.[91] Other risk factors include a previous pregnancy, multiparity, a physically demanding job, and poor ergonomics.

The SIJ area has been described as the most common location of pregnancy-related back pain and is aggravated by extremes of hip and spinal movement and asymmetrical loading of the pelvis.[83,84,88,99] Patients with PGP commonly report difficulties with walking (waddle gait), standing, particularly single leg stance activities (dressing, stair-climbing), activities that require a straddle (in/out of bath or car), rolling in bed, and sexual activities.

Pain in the pelvic joints may occur very early in pregnancy, possibly because of circulating hormones. Although the lumbar spine and the hips may refer pain into the pelvic region, a variety of alterations in SIJ and pubic symphysis configuration and movement may produce impairments resulting in activity limitations. Although many women experience PGP with transitional movements, there is evidence that the degree of joint and ligamentous laxity is not related to the amount of pain experienced in PGP.[91] Some women may be able to tolerate changes in the pelvic joints better than others, and may be able to compensate for decreased joint stability through muscle function.[91] Contraction of the TA significantly decreases the excessive mobility of the SIJ.[100] As such, instruction in TA firing in a pregnant patient with PGP may be of great benefit. **Self-Management 13-3** describes a simple muscle energy technique combined with recruitment of TA to manage pain with transition movements. A pregnant patient with pelvic instability and SIJ laxity may benefit from performing a pelvic shot-gun technique (hip isometric adduction, followed by isometric abduction) and submaximal TA muscle contraction to prevent/reduce pain with transition movements (see Self-Management 13-3). Muscle imbalances in the major muscles influencing lumbopelvic joint stability must be addressed (see Chapter 18 and **Evidence and Research 13-6**)

EVIDENCE and RESEARCH 13-6

Gutke and colleagues[92] reported an association between PGP and muscle dysfunction suggesting instability as a likely cause of PGP during pregnancy manual therapy techniques may be used to reduce asymmetry and abnormal motion. Randomized controlled trials have shown stabilizing exercises (those that incorporate specifically the transverse abdominis, multifidi, pelvic floor muscles, and hip muscles) to be effective interventions to manage PGP during pregnancy[101] and postpartum.[102,103]

Stretching techniques must be performed gently and cautiously because of possible joint hypermobility or true articular instability. The therapist must perform a thorough examination to determine if stretching is truly indicated. If stretching is indicated, the pregnant patient should be encouraged to perform slow, gentle stretching and avoid ballistic stretching.[65–67]

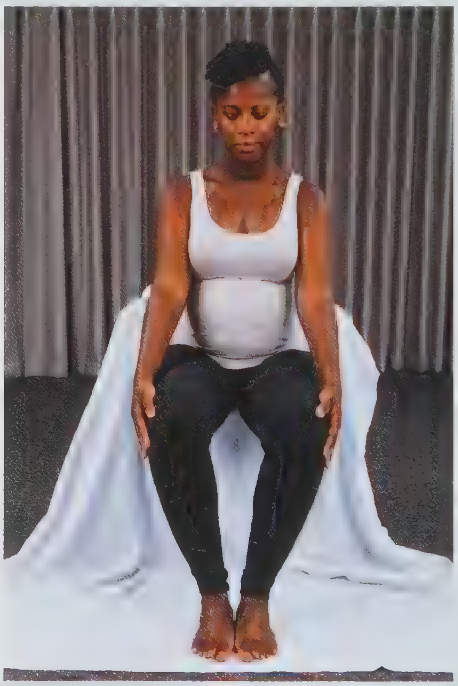
SELF-MANAGEMENT 13-3
Pelvic Alignment Before Transition Movements

Purpose: To realign pelvis and reduce pelvic girdle and/or pubic symphysis pain with transition movements

Position: Seated, with two fists between the knees.

Movement Technique:

1. Perform an isometric contraction of the hips, squeezing fists with 5 lb of force. Hold contraction for 5 seconds. Relax.
2. Place open hands to the outside of the knees and perform an isometric contraction of the hips toward the hands, with 5 lb of force. Hold isometric contraction for 5 seconds. Relax.
3. Slightly contract the lower abdominal muscles or lift the belly using your abdominal muscles.
4. Maintain normal breathing and this abdominal contraction as you move from one position to another. Then relax.

The pubic symphysis is the only bony junction that can be referred to as the "vulnerable midline."[70] This area includes the abdominal and pelvic floor muscles that are connected in midline by a tendinous seam. There is marked widening of the pubic symphysis by 28 to 32 weeks of gestation, from approximately 4 to 7 mm.[1] Widening begins early in pregnancy and facilitates vaginal delivery; unfortunately, it can lead to pelvic discomfort and gait unsteadiness in late pregnancy. Wide leg motions (such as hip circumduction) or reciprocal movement of the lower extremities such as stair-climbing or turning in bed may cause pain in a lax pubic symphysis. If such pain occurs, leg exercises may need to be eliminated until the joint is stabilized. According to the European PGP guidelines, pubic symphysis dysfunction is best identified by palpation of the pubic symphysis and by the modified Trendelenburg test.[91] The ACPWH recently released a collaborative document titled Pregnancy-Related Pelvic Girdle Pain that updates their previous pubic symphysis dysfunction recommendations.[104] This guide for pregnant and postpartum women includes general advice and information on physical therapy and exercise. Recommendations include avoidance of wide or reciprocal movements of the lower extremities, elimination of exercises or ADLs that provoke pain, and reduction in prolonged postures (sitting or standing). In addition, vigorous stretching of the hip adductor muscles should also be avoided because this exercise may result in pubic symphysis separation[105] (see **Building Block 13-7**).

BUILDING BLOCK 13-7

A pregnant patient has difficulty with walking, turning in bed, and getting in and out of her car. What exercises might minimize her discomfort?

Women with persistent PGP postpartum often have serious pain during pregnancy.[91] If muscle tension in the pelvic floor is increased as a result of pain from an infected or poorly healed episiotomy or tear, initiate downtraining of the pelvic floor muscles. Modalities in the form of superficial heat, ultrasound, ice, transcutaneous electrical nerve stimulation (TENS), and perineal massage may help to reduce discomfort.[86]

Nocturnal Back Pain Nocturnal back pain is described as "cramplike" and is thought to be linked to increased blood volume and pressure on the inferior vena cava.[106] Decreasing venous flow could result in hypoxia of neural tissues. Position changes during sleep are recommended.[107] The pregnant patient is encouraged to sleep on her side and avoid sleeping in supine. Using supportive pillows may help make different positions more comfortable.

Other Sources of Pain The round ligaments are two rounded cords that run from the superior angle of the uterus on either side to the labia majora. During pregnancy, these ligaments must stretch with the growing uterus and may intermittently pull on local nerve fibers and other soft tissue structures, resulting in sharp pain in the groin or lower abdomen. This is especially true with sudden position changes. Gentle side stretching in tailor or regular sitting positions with arms overhead may relieve this discomfort (**Fig. 13-5**). This stretch may also help relieve heartburn and the feeling of shortness of breath as it lifts the rib cage upward and away from the pelvis.

Transient osteoporosis (TO) during pregnancy is self-limiting and spontaneously resolves postpartum.[108,109] Despite the rarity of fractures, pregnant women with TO may develop pain in the back, groin, hip, or lower extremities.[110] Careful attention should be paid to medical and family history because preexisting osteopenia and genetics play a role in the degree of bone loss.[111–113] Exercise history is vital in the differential diagnosis because a woman with compromised skeletal integrity, such as an amenorrheic athlete, may be at a higher risk of osteoporosis and fracture during pregnancy and lactation.[114] Immobilization and inactivity are risk factors for TO and should be considered when treating a woman on bed rest for a high-risk pregnancy. Early recognition of TO and intervention with protective weight bearing are important in keeping the condition self-limiting and without long-term sequelae.[59]

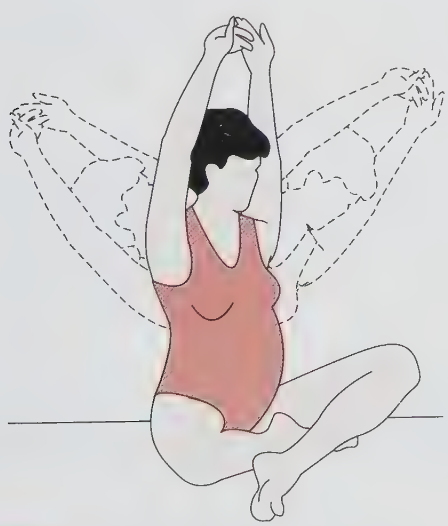


FIGURE 13-5 Gentle side stretching in tailor sitting.

Resumption of prepregnancy bone mineral density (BMD) varies between 2 and 12 months postpartum and is compromised by lactation.[115,116] Profound detrimental effects on maternal BMD during lactation are due to the cumulative effects of prolonged estrogen deficiency and calcium loss. Studies have proven that lactation-induced bone loss is less in exercising women. More research is needed to address types of exercises (high impact and site specific) and exercise duration postpartum.[114] Lactation-induced osteopenia is reversible with cessation of breast-feeding.

Stress–Cognitive Element Influences

Postpartum depression (postpartum blues) is one of the most common complications of childbearing.[117] The prevalence rate is 13% and may occur because of physiologic readjustments and endocrine upheaval. This transient depression may initially interfere with exercise performance, but physical exercise is also emerging as an effective intervention strategy.[117] Support and involvement of the spouse and family members can make a difference in the new mother's desire to exercise after delivery.[118] Because group postpartum exercise classes encourage mothers to exchange experiences and work through problems together, this may be a beneficial outlet for women with postpartum depression. Many classes incorporate exercises that include the infant and the mother.

High-Risk Antepartum

When the outcome of pregnancy is adversely affected by maternal or fetal factors, the pregnancy is identified as high risk.[119,120] Bed rest is used in nearly 20% of all pregnancies to treat a wide variety of conditions. Bed rest may be prescribed when a pregnancy becomes complicated at conception, when preexisting maternal disease such as heart disease is present, or as the pregnancy advances. It is estimated that approximately one of four complicated pregnancies leads to the birth of a premature baby.[121]

Lifespan Considerations

More women are choosing to delay childbearing until their fourth or fifth decade. Their decision may be influenced by a career, new marriage, financial security, and infertility problems.[122] Women who delay childbearing may expect good pregnancy outcome but higher incidence of obstetric complications.[123–128] These include preeclampsia, placenta previa, placental abruption, breech presentation, preterm delivery (before 32 weeks), and low birth weight. There is increased risk of operative delivery, including use of forceps, vacuum extraction, and cesarean section. Although pregnant women with diabetes and hypertension are at increased risk of adverse perinatal outcome irrespective of age, these complications increase almost linearly with age.[129]

The detrimental effects of inactivity in the form of bed rest vary according to the duration of bed rest, the patient's prior state of health and conditioning, and activity performed during bed rest. Much has been written about the negative effects of bed rest, many of which occur within the first 3 days. These effects include decreased work capacity, orthostatic hypotension, increased urine calcium (possibly leading to bone loss), decreased gastrointestinal motility (leading to constipation), and increased risk of DVT. Because maternal activity appears to modulate bone mineral acquisition during intrauterine life, bed rest may be detrimental to fetal as well as maternal bone health.[130] The theoretical basis for bed rest during a high-risk pregnancy is to promote uterine and placental blood flow and to reduce gravitational forces that may stimulate cervical effacement (i.e., obliteration of the cervix in labor) and dilation.[131-134] The left lateral recumbent (which maximizes blood flow to the mother and the fetus) or Trendelenburg position may be recommended. Bathroom privileges may be restricted. Typically, these patients report musculoskeletal, cardiovascular, and psychosocial complaints.

Even modest activity can reduce the detrimental effects of bed rest.[119,120] Therapeutic exercises for this patient population focus on several features:

- Improvement in circulation
- Promotion of relaxation
- Avoidance of increased intra-abdominal pressure by minimizing abdominal contractions during exercise, basic ADLs, bed mobility, transfers, and self-care
- Avoidance of Valsalva maneuvers
- Prevention of decreased muscle tone and deconditioning effects
- Prevention of musculoskeletal discomfort

Activity guidelines for the high-risk antepartum patient are outlined in **Display 13-5**.[6] Contraindications to any form of exercise include increased bleeding, contractions, blood pressure, or leakage of amniotic fluid; exacerbation of the condition (depends on the diagnosis); unstable conditions; and extreme cases when the patient should not move more than needed for basic care.

Muscle Performance

General strengthening and range of motion exercises help prevent or reduce decreased muscle tone and the negative effects of bed rest. Encourage frequent position changes in bed to avoid SHS and prevent musculoskeletal discomfort. Static positioning, joint stiffness, and decreased circulation can contribute to discomfort. Fluid retention and direct compression from immobility may lead to peripheral nerve impairments (discussed later in this chapter).

These strengthening and range of motion exercises can be performed in supine:

- Neck rotation and side bending
- Gentle isometric neck extension into a pillow
- Shoulder presses down and back into a pillow
- Unilateral heel slides, hip internal rotation and external rotation, hip abduction and adduction, and terminal knee extension off a pillow
- Graded pelvic floor contractions if performed correctly (with minimal abdominal muscle activation or breath holding)

These strengthening and range of motion exercises can be performed in the sidelying position:

- Unilateral shoulder circles (downward and backward), arm circles, hand and wrist active ROM, knee extension with hip flexed, partial knee to chest, and hip external rotation
- Unilateral resistive band (or light weights) for upper extremities only: biceps curl, triceps press, shoulder press, diagonal lift, shoulder extension, and horizontal abduction and adduction (avoid proprioceptive neuromuscular facilitation pattern D2 upper extremity extension with or without resistive band because it facilitates the abdominal muscles)
- Graded pelvic floor contractions

The support of a spouse, family members, and friends can greatly reduce the anxiety and stress the high-risk antepartum patient may experience. The patient on bed rest will experience significant activity limitations and participation restriction, as it will limit her roles as mother (if she has other children), spouse, and provider (unless she can work from her bed). The physiologic effects of stress can also take its toll, and the patient and caregivers must understand the rationale for bed rest and the importance of therapeutic exercise to enhance fetal and maternal outcomes. Most patients are home for their duration of bed rest, although some women are hospitalized. A home visit to teach the patient and family proper exercise performance may be appropriate (see **Self-Management 13-4**, **Patient-Related Instruction 13-2**, and **Evidence and Research 13-7**).

DISPLAY 13-5
Activity Guidelines for the High-Risk Antepartum Patient

1. Obtain approval from the health care provider before any exercise.
2. Avoid lifting legs against gravity (including kicking off covers). Lower extremity movement may increase symptoms (e.g., increased bleeding, contractions, blood pressure, leakage of amniotic fluid). If symptoms increase, lower extremity exercises should be deferred. Active assisted or passive range of motion exercises for the lower extremities may be appropriate.
3. Do not perform resisted lower extremity exercise.
4. Do unilateral exercises, except for ankles and wrists, to avoid activities that require stabilization by abdominal muscles.
5. Progress the number of exercises and repetitions gradually.
6. Do not overdo. Exercises may become more difficult as pregnancy progresses and fatigue increases or when medicated with tocolytics (medications used to stop or control preterm labor). You may need to modify exercises if tocolytics increase fatigue or give the patient the "jitters." Timing exercise further from dosage time is helpful.
7. Avoidance of abdominal contractions during exercise is necessary to help eliminate expulsion forces and uterine irritability, especially with preterm labor.
8. Avoid Valsalva maneuvers or bearing down. This increases the intra-abdominal pressure and pressure on the uterus. A Valsalva maneuver must be avoided during bed mobility, transfers, exercises, or bowel movements to avoid irritating the uterus. The therapist should instruct the patient to exhale on any effort.
9. Comfort measures include body mechanics and positioning in bed to support the spine and abdomen in proper alignment. In sidelying, pillows between the legs, under the abdomen, and behind the back and shoulders may be helpful. Encourage frequent position changes.
10. If symptoms increase with bed rest exercises, stop and report to the physician.

SELF-MANAGEMENT 13-4
Sidelying Exercises for the Patient on Bed Rest

Purpose: To maintain mobility of the lower extremities while on bed rest restrictions

Position: Sidelying. Place a pillow under your head and between your knees.

Movement Technique:

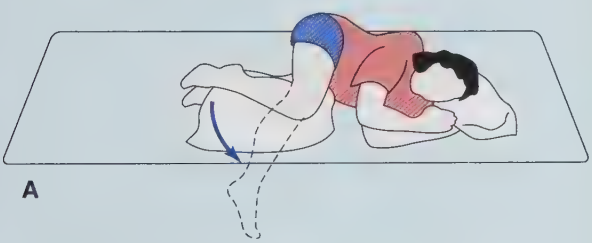
1. Knee flexion/extension with the hip flexed. Begin with the hip partially flexed. Bend and straighten the knee as shown in **Figure A**.
2. Knee flexion/extension with the hip extended. Begin with the hip in a straight position. Bend and straighten the knee as shown in **Figure B**.
3. Knee-to-chest exercise. Slowly draw the knee up to the chest and then slide it back as shown in **Figure C**.

Precaution: Stop exercising if contractions or pain is experienced.

Dosage:

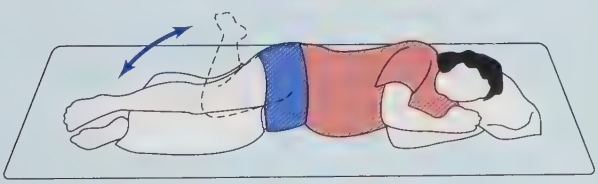
Repetitions: ______________________________

Frequency: ______________________________

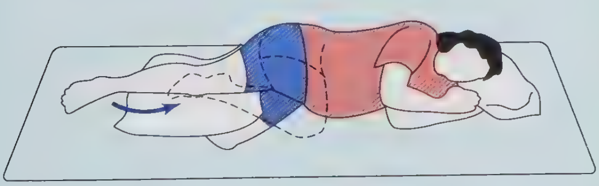


A

Knee flexion/extension with the hip flexed.



B Knee flexion/extension with the hip extended.



C Knee to chest.

Patient-Related Instruction 13-2

Bed Mobility

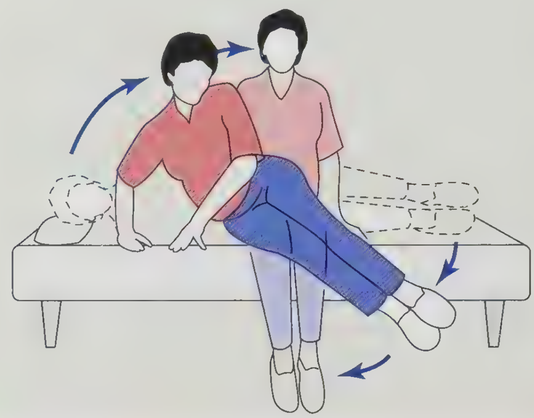
For moving from side to side:

1. Keep your head on the pillow.
2. Roll like a log, keeping your trunk and limbs in a line.

For moving from lying to sitting using the "bed rest push-up" (shown below):

1. Roll to one side.
2. Keeping your back straight, use your arms to push up to sitting while you swing your legs over the edge of the bed.
3. Reverse this to lie back down.

Be sure to breathe and keep your stomach muscles relaxed. This helps to avoid Valsalva maneuvers. Never jackknife to sit.



EVIDENCE and RESEARCH 13-7

One study reported noncompliance of 33.8% for bed rest in the high-risk antepartum women they studied.[135] Reasons for noncompliance included not feeling ill, childcare responsibilities, household demands, lack of support, having to work, and discomfort while on bed rest. Pregnancy outcomes were similar for women who did and did not adhere to bed rest recommendations. Further research is needed to address the validity of the practice of bed rest as treatment for high-risk pregnancies.[135–139]

Because many high-risk pregnancies end in cesarean section deliveries, it may be an appropriate time to prepare the patient for cesarean recovery and rehabilitation. A discussion of the cesarean section is provided later in this chapter.

Those women who have endured bed rest during their pregnancy may find that postpartum recovery is delayed. They may experience greater muscle soreness, slower muscle tone recovery, and may be more prone to musculoskeletal dysfunction.

Mobility

Circulation Exercises Supine or sidelying circulation exercises should be done every waking hour. If allowed, these exercises may be performed while sitting at the edge of the bed. This reduces the likelihood of lower extremity DVT. Ankle pumps and circles improve circulation by facilitating a pumping action in the muscles of the lower extremities. Gentle lower extremity isometrics may also help. However, the therapist must be extremely careful that the patient avoids increasing intra-abdominal pressure or blood pressure. Examples of lower extremity isometrics include quadriceps, gluteal, and adductor muscle exercises.

Pain (Stress)

Relaxation Exercises There are several ways of instructing relaxation exercises.[63,70,86] Two methods of relaxation both require conscious recognition and release of muscle tension. The Mitchell method involves contraction of the antagonist to release stress-induced tension in the agonist.[140] The Jacobson method, also known as progressive relaxation, involves alternately contracting and relaxing muscle groups progressively throughout the body[141] (**Evidence and Research 13-8**).

EVIDENCE and RESEARCH 13-8

Women with back pain during pregnancy are at high risk of back pain postpartum.[142–145] Studies suggest that attention be paid to muscles that influence spinal and pelvic stability including TA, pelvic floor, lumbar multifidus, hip rotators, and gluteus maximus[146–149] (see Chapters 17, 18, and 19). Although pregnancy itself may be a factor in the development of lumbar disc disease, second-stage labor may markedly increase intradiscal pressure.[49] A disc protrusion may develop, or a preexisting protrusion may be exacerbated. This is treated with postural education, body mechanics, exercise, manual therapies, and modalities as in the general population, keeping in mind that hormonal changes persist for several weeks after delivery. The prevalence for low back pain or PGP after delivery is 5% to 37%.[98]

Visualization techniques or meditation may be helpful as a way to withdraw from the stress-producing situation temporarily. Diaphragmatic breathing and body awareness during exercises or ADLs also improve relaxation.[70]

Biofeedback and stretching are more active forms of relaxation. The patient is required to be mentally attentive to purposefully reduce a state of tension and recognize a state of relaxation (see **Building Block 13-8**).

BUILDING BLOCK 13-8

You understand the detrimental effect of inactivity when bed rest is recommended for a high-risk antepartum patient. Describe what you might say to a patient on bed rest about the importance of performing bed mobility exercises.

Cesarean Recovery

A cesarean section (i.e., C-section) is the surgical delivery of the baby through the wall of the abdomen and the uterus after a horizontal (most preferred in the United States) or vertical incision has been made. The horizontal, or transverse, incision extends from side to side, just above the pubic hairline. This incision is preferred because there is less blood loss, it heals with a stronger scar, and it is less likely to result in complications in a subsequent vaginal delivery.[1–4,150] Vertical incisions are sometimes needed because of certain positions of the baby or placenta.

The rate for cesarean births in the United States is approximately 10% to 25%.[150] About 25% to 30% of these are performed because the pregnant woman has had a previous cesarean section.[151] Women may be encouraged to try a vaginal birth after cesarean (VBAC) delivery. Although controversial, reasons to consider VBAC are less risk, shorter recovery time, and more involvement in the birth process.[151,152]

The cesarean procedure may be planned for reasons such as placenta previa (placement of the placenta below the fetus and over part or all of the cervix), breech presentation (presentation of the buttocks or feet of the fetus in the birth canal), and maternal illness or emergently for reasons such as fetal distress (a condition of fetal difficulty in utero detected by electronic fetal monitoring and fetal scalp sampling), prolapse of the umbilical cord, or failure to progress in labor. In childbirth classes, all women should be prepared for the possibility of a cesarean section birth. Some health care facilities have group classes before delivery for patients undergoing a planned cesarean section. This class provides an excellent opportunity to educate and instruct patients in recovery after the procedure. They experience many of the same physical discomforts associated with major abdominal surgery but have the additional responsibility of caring for the newborn.

Exercises may begin within 24 hours after surgery but should be graded and based on the patient's comfort level.[70,153] Breathing exercises are important to keep lungs clear of mucus. Coughing may be painful, and "huffing" (by pulling the abdominals up and in) is recommended while splinting the incision. Pelvic rocking or bridging with a gentle twist from side to side may assist in alleviating discomfort from decreased intestinal motility. Lower extremity exercises help prevent DVT and orthostatic hypotension before early ambulation. Despite the absence of a vaginal delivery, the pelvic floor has undergone dramatic changes during the pregnancy, or from a lengthy and unproductive trial of pushing. Pelvic floor exercises should be continued or initiated immediately. Gentle activity of the abdominal muscles stimulates healing of the incision and facilitates the return of muscle tone. The patient can progress with abdominal exercises as tone increases and tissues tolerate added stress.

Scar mobilization after sutures are removed (usually 3 to 6 days), or as comfort allows, assists proper healing and reduces adhesion formation. It is important to monitor the patient's upright posture, because pain and discomfort at the incision may prompt a protective flexed posture. TENS may be helpful in alleviating incisional pain.

The breast-feeding mother requires adequate caloric intake, fluids, and plenty of rest to produce milk for lactation. Exercise is an efficient way for the postpartum woman to return to prepregnancy weight.[154] Exercise does not adversely affect breast milk as long as she has adequate energy reserves (metabolic need increases by 500 kcal per day with lactation).[154]

THERAPEUTIC EXERCISE INTERVENTION FOR COMMON IMPAIRMENTS

Nerve Compression Syndromes

Soft tissue edema is reported by 80% of pregnant women, usually in the last few weeks of pregnancy.[59] Nerve compression syndromes may arise during pregnancy because of fluid retention, edema, soft tissue laxity, and exaggerated postural changes. Special attention should be paid to blood pressure in these patients because these syndromes may be the first sign of increasing fluid resulting from preeclampsia (a condition of hypertension, edema, and proteinuria).

Intercostal Neuralgia

Intercostal neuralgia is the term used to describe unilateral, intermittent pain in the rib cage or chest from flaring of the rib cage. Exercises to relieve this discomfort include spinal elongation with arms overhead in supine, sitting, or standing positions and trunk side bending away from the pain.

Thoracic Outlet Syndrome

If muscle support is inadequate, spinal curves may become more pronounced as the center of gravity changes and the woman gains weight, especially in the breasts. The forward head and shoulder posture may lead to thoracic outlet syndrome (TOS), with compromise of the brachial plexus and subclavian vessels. A variant of TOS, called acroparesthesia, occurs when the neurovascular bundle becomes stretched over the first rib, which may be elevated in pregnancy. The woman may complain of pain, numbness, and tingling in the hand and forearm.[155]

Strengthening of the upper back and scapular muscles and lengthening of the pectoral muscles may assist in relieving symptoms (see Chapters 24 and 25). Support for the upper back and breasts in the form of a good brassiere and manufactured supports may be appropriate to decrease the load.[82] This is especially important after delivery for the nursing mother. In addition, mobilization of the first rib, postural correction, and neuromobilization of the median and ulnar nerves through sliding techniques may be of benefit.

Carpal Tunnel Syndrome

Carpal tunnel syndrome of pregnancy usually disappears after delivery but may persist or even develop in the postpartum phase in the lactating mother. Impairments related to carpal tunnel syndrome are addressed similarly as in the nonpregnant client (see Chapter 26). Patients are encouraged to decrease hand and wrist flexion activities, use resting splints at night and perform exercises to keep fingers mobile and improve movement of fluids. Unlike patients with carpal tunnel syndrome due to cumulative trauma, pregnant and breast-feeding clients typically have bilateral symptoms.

Lateral Femoral Cutaneous Nerve Entrapment

Lateral femoral cutaneous nerve entrapment (meralgia paresthetica) occurs in pregnancy when the nerve is compressed as it emerges from the pelvis at the inguinal ligament adjacent to the anterior superior iliac spine or where branches enter the tensor fascia lata. Adequate length in the tensor fascia lata, iliopsoas, and rectus femoris muscles is necessary to help prevent this condition. Exercises to balance the hip muscles may be appropriate (see Chapter 19). To test the patient for entrapment of the lateral femoral cutaneous nerve, the patient lies prone. Pillows and other supports are recommended to position the patient comfortably. The therapist stands on the side of the table opposite the affected side, reaches across the table, and passively flexes the knee. While stabilizing the lumbar spine to minimize sidebending, the therapist adducts and extends the hip across midline. A positive test is recreation of the patient's symptoms along the line of the nerve. Management of lateral femoral cutaneous nerve entrapment includes lying on the unaffected side, as this draws the uterus away from the compressed area. Neuromobilization may be performed in sidelying on the unaffected side. Lastly, soft tissue techniques to reduce stiffness of the iliotibial band may also be helpful.

Tarsal Tunnel Syndrome

Tarsal tunnel syndrome is compression of the posterior tibial nerve (a branch off the tibial nerve) posterior to the medial malleolus and occurs as a result of edema. Compression of this nerve produces numbness and tingling in the medial aspect of the foot and may also result in weakness of the intrinsic toe flexors.[7] Testing of the posterior branch of the tibial nerve can be performed either in supine or sidelying. The therapist passively dorsiflexes and everts the ankle, extends the knee, flexes the hip until slight tension is felt. The tension is released (slightly) and the great toe is passively extended. This positive is held for 5 to 10 seconds and should recreate the patient's symptoms. Management of tarsal tunnel syndrome includes elevation and active foot and ankle exercises help to decrease edema. Neuromobilization may be performed, and a posterior splint may be used to immobilize the ankle at night.

Peroneal Nerve Compression

The peroneal nerve wraps around the neck of the fibula and supplies the ankle dorsiflexors. Prolonged squatting may compress these nerves and cause foot drop.[7] To test for peroneal nerve irritation, the patient may be in supine or sidelying. The therapist dorsiflexes and inverts the ankle while passively performing knee extension and hip flexion. This position should recreate the patient's symptoms. Treatment of peroneal nerve irritation includes neuromobilization and soft tissue mobilization. In addition, pregnant women should be discouraged from prolonged squatting during exercise and delivery (see **Building Block 13-9**).

BUILDING BLOCK 13-9

Your pregnant patient complains of numbness, tingling, pain, and burning at the anterolateral thigh. What is your potential physical therapy diagnosis? How would you incorporate therapeutic exercises as an intervention for this condition?

Other Impairments

Other impairments that may result from pregnancy include temporomandibular joint dysfunction (TMD), patellofemoral dysfunction, weight-bearing joint discomfort or dysfunction, and varicosis. Although more detailed exercise interventions are presented in other chapters for some of these impairments, guidelines for pregnancy should be carefully followed.

Temporomandibular Joint Dysfunction

TMD may be related to pregnancy and caused by hypermobility resulting from increased laxity. In addition, it may appear after delivery because of excessive tension in the face during the "pushing" phase of delivery[63] (see Chapter 22). Differential diagnosis for TMD would include tests to rule out cervical dysfunction.

Patellofemoral Dysfunction

Patellofemoral dysfunction and pain may occur from the added stress of weight gain and fluid retention, especially with preexisting muscle weakness. Knee hyperextension and foot pronation are common in pregnancy, due to the change in the center of gravity. This results in additional stress on the knees. Kinematic studies show that patellofemoral force increases by 83% in a pregnant woman rising from a chair without the use of her upper extremities.[7] Enlargement of the uterus causes a reduction in hip flexion and repositions the center of mass farther from the axis of rotation. Greater muscular effort is therefore required to move from sit to stand, which translates into increased force across the joint. This muscular effort is reduced if the pregnant woman uses her arms to rise from a chair or avoids low seating (see Chapter 20). As such, improving the patient's upper body strength to assist with transfers may decrease patellofemoral pain. In addition, encourage the patient to avoid low seats and chairs without arm rests whenever possible.

Weight-Bearing Joint Discomfort or Dysfunction

Weight gain in pregnancy increases the stress on weight-bearing joints, causing discomfort in normal joints or potentially increasing dysfunction in joints with preexisting arthritis or instability. Stair-climbing produces forces of three to five times the body weight in the hip and knee joints. In a woman who increases her body weight by 20% in pregnancy, forces on her weight-bearing joints may increase by 100%[155] (see Chapters 19 and 20). Utilization of a hand rail when ascending and descending stairs may decrease some of the load.

Varicosis

Venous pressure in the lower body increases with advancing pregnancy. Venous distention and stasis contribute to varicosities of the lower extremities and vulvar region.[4] Frequent foot and ankle exercises help to alleviate edema and muscle cramps, especially if the patient is sedentary throughout the day. Ankle and foot active movements also help decrease the likelihood of lower extremity DVT. Patients should be advised to elevate the lower extremities higher than the heart to assist venous circulation (**Fig. 13-6**). The quadruped position reduces stress on the lower extremity vascular structures, and sidelying positions decrease compression of the inferior vena cava. Because long periods of static standing increase compressive forces of the weight of the fetus on the vascular system, the patient should sit instead of stand when she has the option. Immersion in water has also been shown to mobilize extravascular fluid and reduce edema.[156,157] Consider compression stockings to help manage fluid retention in the lower extremities.

FIGURE 13-6 Elevation of feet to reduce varicosis. Note: The feet are higher than the heart to assist venous circulation. Place a wedge under the right hip to prevent SHS.

THERAPEUTIC EXERCISE INTERVENTION FOR WELLNESS IN PREGNANCY

Every pregnant woman adapts differently to the physiologic changes in pregnancy, and for the same woman, every pregnancy is different. The physical therapist must consider age, level of fitness, previous and current exercise history, previous pregnancies and concurrent adaptations to the changes of pregnancy when designing a therapeutic exercise program for the childbearing client.

Research focused on recreational exercise during pregnancy indicates an overall positive impact on pregnancy outcome.[9,155,158] The interaction between the physiologic adaptations to exercise and pregnancy appears to improve maternal cardiovascular reserve, maternal heat dissipation, placental growth, and functional capacity.[9,155] Women who engage in active exercise during pregnancy have fewer of the common discomforts associated with pregnancy, such as swelling, leg cramps, fatigue, shortness of breath, somatic complaints, insomnia, and anxiety.[9,159,160] In low-risk pregnancies, there are no apparent adverse outcomes such as increased risk of miscarriage, preterm labor, preterm birth, or intrauterine growth restriction associated with exercise.[9] Preterm birth is a major determinant of neonatal mortality and morbidity and compared to sedentary pregnant women, women who exercise during pregnancy show significant reductions in preterm birth.[161] Other studies show a reduction in the duration of labor and incidence of obstetric complications during delivery in women who exercise during pregnancy[162–164] (see **Building Block 13-10**).

BUILDING BLOCK 13-10

Your patient/client is a 32-year-old pregnant woman who works as an engineer which requires extensive sitting and desk work. She complains of lower back pain and upper back and neck tension that builds up throughout the day. She would like to remain active throughout her day to help with pregnancy symptoms. Provide some suggestions on how to incorporate activity exercise into her day.

Studies on exercise during pregnancy vary regarding type, intensity, duration, and frequency of exercise and are therefore difficult to compare.[9,165] Current research, however, suggests that moderate aerobic exercise, carefully prescribed and monitored during pregnancy, is safe and beneficial for the mother (even if previously sedentary[166]) and the fetus.[6,7,9,33,155–160,162–164,166–175] Healthy, well-conditioned women can participate in a moderate- or high-intensity exercise program during pregnancy without adverse fetal or maternal outcomes.[176] A Cochrane review reported that regular aerobic exercise during pregnancy appeared to improve or maintain physical fitness.[177]

Concerns about exercise during pregnancy exist nonetheless (**Table 13-2**). Although many of these concerns are not substantiated by research, the guidelines for exercise err on the side of conservative management. Precautions and contraindications should be considered, and prudent guidelines should be followed when developing an exercise program for a pregnant woman.

TABLE 13-2

Exercise Risks During Pregnancy

MATERNAL	FETAL
Hypoglycemia	Hypoxia—possibility that blood flow will be shunted from the uterus in favor of exercising muscles
Chronic fatigue	Distress
Musculoskeletal injury from repetitive mechanical stress, changes in balance, and soft-tissue laxity	Intrauterine growth retardation from alterations in energy and fat metabolism
Cardiovascular complications	Malformations
Spontaneous abortion	Hyperthermia secondary to maternal hyperthermia, increasing risk of neural tube defects, and preterm labor
Preterm labor	Prematurity and reduced birth weight

Data from references 5–7, 40, 49, and 59.

Precautions and Contraindications

Pregnant and postpartum women should seek the approval of their health care providers (e.g., physician, midwife) before engaging in an exercise program. They should be screened for contraindications or risk factors for adverse maternal or perinatal outcome. Dietary intake, prepregnant BMI, and exercise history should be addressed.[178] **Displays 13-6** and **13-7** detail the absolute and relative contraindications to exercise during pregnancy. Limitations or modifications of the exercise program may be recommended at any time during the pregnancy.[6,7,155,167] For example, a pregnant woman with preexisting pulmonary disease may be able to exercise, but her intensity level may vary over time as pregnancy-induced changes affect the respiratory system. As another example, women with GDM benefit from exercise but should be educated in the signs of hypoglycemia. In the presence of a specific relative contraindication, decisions regarding exercise should be made in conjunction with the patient's physician and guidelines referenced in Displays 13-5 and 13-9.

Exercise Guidelines

ACOG and the Melpomene Institute for Women's Health Research have published guidelines for exercise both during pregnancy and after delivery (**Displays 13-8** and **13-9**).[7,47,94] Changing attitudes regarding exercise during pregnancy are reflected in ACOG's 2002 revision of its recommendations (reaffirmed in 2009). In this update, ACOG recommended moderate exercise, 30 minutes or more per day, on most days of the week. The guidelines recommend that previously sedentary women could start a new exercise program during pregnancy.

A gentle-paced water aerobics class may be an appropriate starting point for the first-timer exerciser. Exercise in water offers several physiologic advantages for the pregnant woman.[179–181]

DISPLAY 13-6

Absolute Contraindications to Aerobic Exercise During Pregnancy

- Hemodynamically significant heart disease
- Restrictive lung disease
- Incompetent cervix/cerclage
- Multiple gestation at risk for premature labor
- Persistent second- or third-trimester bleeding
- Placenta previa after 26 weeks of gestation
- Premature labor during the current pregnancy
- Ruptured membranes
- Preeclampsia/pregnancy-induced hypertension

Data from ACOG 2009 Guidelines. Available at: http://www.acog.org/Resources-And-Publications/Committee-Opinions/Committee-on-Obstetric-Practice/Exercise-During-Pregnancy-and-the-Postpartum-Period. Accessed May 18, 2015.

DISPLAY 13-7

Relative Contraindications to Aerobic Exercise During Pregnancy

- Severe anemia
- Unevaluated maternal cardiac arrhythmia
- Chronic bronchitis
- Poorly controlled type 1 diabetes
- Extreme morbid obesity
- Extreme underweight (BMI <12)
- History of extremely sedentary lifestyle
- Intrauterine growth restriction in current pregnancy
- Poorly controlled hypertension
- Orthopedic limitations
- Poorly controlled seizure disorder
- Poorly controlled hyperthyroidism
- Heavy smoker

Data from ACOG 2009 Guidelines. Available at: http://www.acog.org/Resources-And-Publications/Committee-Opinions/Committee-on-Obstetric-Practice/Exercise-During-Pregnancy-and-the-Postpartum-Period. Accessed May 18, 2015.

DISPLAY 13-8

General Exercise Guidelines

Frequency/Intensity

- Exercise regularly, at least three times per week
- Strenuous activity should not exceed 30 minutes; 15 to 20 minute intervals are recommended to decrease the risk of hyperthermia. Ketosis and hypoglycemia are more likely to occur with prolonged strenuous activity
- Do not exercise to exhaustion or undue fatigue
- Postpartum progression into prepregnancy routines should be gradual

Nutrition

- Maintain metabolic homeostasis by maintaining adequate caloric intake
- Fluids should be taken before, during, and after exercise to avoid dehydration
- Eat meals 1½ hours before exercise to avoid digestive discomfort

Program Guidelines

- Avoid ballistic movement, rapid changes in direction, and exercises that require extremes of joint motion
- Include warm-ups and cool-downs
- Avoid overexertion in high heat and humidity, during high pollution levels, and during febrile illness
- Modify intensity according to symptoms and stage of pregnancy
- Low resistance and high repetition exercise is recommended; avoid Valsalva during exercise

Positioning

- Change of positions may help with SHS symptoms
- Avoid sudden changes in posture
- May need to adapt to non–weight-bearing exercise such as pool exercise instead of weight-bearing exercise

Data from references 1–4, 6, 7, 8, and 160.

The hydrostatic force of water, proportional to the depth of immersion, produces an increase in central blood volume by pushing extravascular fluid (edema) into the vascular spaces.[156] This may lead to increased uterine blood flow and serves to keep the maternal heart rate and blood pressure lower than with land exercise. Additionally, the buoyancy of water is supportive, and water is thermoregulating.[156,179–182]

The above guidelines are for the general population.[3,7,8,94,155,167,183–185] They differ from those given to the elite or professional athlete, whose risks and precautions are similar but whose training level may be more intense if closely supervised.[7,158,186,187] Healthy, well-trained pregnant athletes may benefit from training at vigorous levels while facilitating a more rapid return to competition postpartum.[188] However, certain activities should be discouraged or avoided during pregnancy.[6,7,155,167] For instance, the pregnant female should avoid participating in collision or contact sports. The following activities have the potential for high-velocity impact that may cause abdominal trauma and should be discouraged:

- Horseback riding
- Snow and water skiing
- Snow boarding
- Ice skating
- Diving
- Bungee jumping
- Heavy weight lifting
- High-resistance activities

In addition, pregnant females should avoid any hyperbaric conditions, as in scuba diving, and activities that may promote extreme Valsalva maneuvers, such as heavy weight lifting. The pregnant woman should not partake in activities that pose an increased risk of damaging joints, ligaments, and discs secondary to hormonal changes that have already increased joint laxity (e.g., positions in which free weights may put joints into traction or stress the ligaments). The shift in the center of gravity along with increasing weight gain puts the pregnant woman at a higher risk of injury in sports that require balance and agility.[94] The pregnant woman should avoid activities and exercises in which loss of balance is increased (e.g., mountain climbing, gymnastics, downhill skiing, sliding into base), especially in the third trimester. Use caution when exercising at high altitudes during pregnancy, regardless of the trimester.[5,189,190] Be aware of warning signs that exercise should be terminated (Display 13-9).

DISPLAY 13-9

Warning Signs to Terminate Exercise While Pregnant

Vaginal bleeding
Dyspnea prior to exertion
Dizziness
Headache
Chest pain
Muscle weakness
Calf pain or swelling (need to rule out thrombophlebitis)
Preterm labor
Decreased fetal movement
Amniotic fluid leakage

Data from references 1–4 6, 7, 8, and 160.

Exercise Intensity

For the general population, the Centers for Disease Control (CDC) and the American College of Sports Medicine (ACSM) define moderate exercise intensity as three to four METS or the equivalent of brisk walking. It is recommended to exercise at a moderate level most days of the week to maximize health benefits.[191,192]

This recommendation also applies to the pregnant patient (without medical or obstetric complication). Previously, pregnancy guidelines for exercise intensity were based on a heart rate limit of 140 bpm. However, measuring heart rate does not necessarily correlate with exercise intensity. In a recent meta-analysis, there were no significant adverse effects with pregnant women exercising at very high intensity, suggesting women may participate in challenging cardiovascular activities.[193]

Endurance exercise has the additional benefit for pregnant women of preparing them for the increased exertion of labor and delivery. In addition, with dramatic fluctuation in the hormonal milieu, aerobic exercise is an excellent mood elevator. However, pelvic floor laxity may require modifications or support for continuation of aerobic exercise throughout pregnancy. For example, the patient may benefit from use of a sacroiliac belt for support during walking, running, or stair-climbing. Water aerobics or bicycling is an appropriate form of cardiovascular fitness that may decrease stress on weak muscles and vulnerable joints.[179–181]

Exercise Classes

Prenatal wellness can be greatly enhanced by prenatal exercise classes. Physical therapists' understanding of the musculoskeletal system makes them ideal instructors. An individual approach with a focus on essential muscles affected by pregnancy makes these classes different from other community-based classes. Special certification is not required to teach classes, but continuing education in this area is recommended.

Prenatal exercise classes should address the physiologic changes that occur during pregnancy and the therapeutic exercises that prepare the body for these changes. Compliance with exercise improves when clients understand that musculoskeletal dysfunction and associated discomfort may be prevented. Since women who have had one or more vaginal deliveries are at increased risk of chronic back pain, classes that target back pain prevention might be a cost-effective way to reduce disability and health care costs in the future.[194,195] Many women return to these exercise classes after delivery for continued socialization, support, and recommendations on safe exercises to do postpartum. In addition, it may be helpful to offer programming for postpartum women that allows them to interact with their child such as mother/baby exercise or yoga classes (see Chapter 4).

KEY POINTS

- The many physiologic changes that occur during pregnancy affect a woman's ability and motivation to exercise.
- By following precautions, contraindications, and guidelines, a safe therapeutic exercise program may be established for pregnant women.
- Exercise during pregnancy has many benefits and may prevent or assist in the treatment of common impairments.
- Therapeutic exercise during pregnancy focuses on key postural muscles most affected by the biomechanical changes of pregnancy.
- A high-risk pregnancy may require bed rest; however, specific exercises may be performed and are beneficial.
- Therapeutic exercise is beneficial to postpartum recovery, regardless of the type of delivery.

CRITICAL THINKING QUESTIONS

1. The pregnant woman is positioned in supine for a manual therapy technique. Her face begins to lose color, and she complains of faintness.
   a. Should you continue with the technique but move very gently?
   b. Should you offer the patient a glass of water?
   c. Should you have her lie on her side until the symptoms resolve?
   d. Would you proceed with the technique after the symptoms resolved?
   e. What are some possible position changes you could make other than sidelying that could alleviate symptoms?
   f. Can you treat the patient in positions other than supine?
2. A 32-year-old woman, 6 weeks after delivery of her second child, experienced severe lower quadrant pain while lifting a stroller into the trunk of her car.
   a. List possible causes for her pain.
   b. What specific muscle groups would you assess, and what treatment options would you consider?
3. The pregnant patient is being instructed in an exercise program to improve her posture. She begins to experience contractions.
   a. Should you stop the exercise and send the patient home?
   b. Should you have the patient lie in left lateral recumbent position until the contractions stop? Would you then proceed?
   c. Should you call the patient's doctor immediately?
   d. What is your advice to the patient regarding performance of her exercise program?

LAB ACTIVITIES

1. Your patient is 20 weeks' pregnant and complains of sharp pain in the right SIJ with transitional movements. With your partner, perform tests and measures to assess her dysfunction.
   - Discuss modalities that may be appropriate and safe to use on this patient.
   - Demonstrate positioning for treatment and exercise. Make appropriate modifications if SHS is present.
2. With your partner, demonstrate evaluation of the abdominal muscles for a DRA and the appropriate corrective exercise for a patient who is postpartum. Discuss other treatment options for a DRA; discuss the advice you would give to the patient who is postpartum with a DRA regarding basic ADLs.
3. Discuss possible reasons for a pregnancy becoming high risk. Demonstrate exercises that could be taught to a pregnant woman on bed rest.
4. Design an exercise class for healthy pregnant women. Use the general exercise guidelines in Display 13-8.
   - Consider the safety of your class participants. How will you screen participants for possible contraindications or restrictions to exercise?
     i. Develop a screening tool utilizing the information in Displays 13-6 and 13-7.
     ii. Would you require participants to get a physician referral/approval before being allowed to participate in the class?

(continued)

LAB ACTIVITIES (continued)

- Identify barriers to exercise your class participants might encounter.
- Describe the possible physical and psychological benefits of exercise to your class participants. Use the information in Display 13-1 to guide you.
- Describe the possible benefits of exercise during pregnancy on future health.
- How will you motivate your class to participate in exercise?
- Simply describe the physiologic changes that occur in various systems of the body during pregnancy.
- Consider the musculoskeletal changes associated with pregnancy. What strengthening exercises might you want to include in your class to target key muscles?
- What flexibility exercises would you include?
- What precautions might you provide to your class regarding flexibility exercise/stretching?
- Include modifications in your class for a variety of complications that might occur. These include: SHS, DRA, pelvic floor muscle weakness, urinary incontinence, pelvic floor muscle tension, PGP, lower extremity edema, the different stages of pregnancy.
- How will you incorporate promotion of cardiovascular fitness into your class?
- Instruct your class in methods to monitor exercise intensity.
- What signs and symptoms should your class be aware of as a signal to stop exercising and contact their health care provider?
- How will you prepare your class for the postpartum phase of childbearing?

CASE STUDY 13-1

The patient is a 34-year-old married woman in her second trimester of pregnancy. She has a 3-year old and 6-year old at home and she works part-time as an administrative assistant. During the past few weeks, she has noticed the progressive onset of pelvic pain and subsequent limitation in ADLs.

PMH: coccyx injury from slipping on the ice during her teen years, mild LBP during her previous pregnancy

Obs: waddle gait, + modified Trendelenburg

IMPAIRMENTS

Pain in the right SIJ with radiation into the right posterior thigh, pain at the pubic symphysis, instability of pelvic girdle joints, antalgic gait

ACTIVITY LIMITATIONS

Walking long distances, stair-climbing, getting dressed, getting in and out of the car, bed mobility, sexual activity

PARTICIPATION RESTRICTIONS

Unable to participate in her pregnancy exercise class, unable to perform household chores and care for her two children at home in their two-story house, unable to drive children to sports activities, unable to drive to work

QUESTIONS

1. What is the most probable physical therapy diagnosis for this patient?
2. What immediate advice might you give to this patient regarding her ADLs?
3. The patient and her family live in a two-story house. What suggestions might you give to the patient regarding her functional independence in the home?
4. Describe the important muscle groups you would emphasize during exercise instruction with this patient.
5. What adjunctive interventions might you consider for this patient?
6. Using the list of limitations and restrictions, create some functional goals for this patient.

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RESOURCES

American College of Obstetricians and Gynecologists (ACOG), 409 12th Street, SW, Washington, DC 20024-2188; (202) 638-5577.
American College of Sports Medicine, P.O. Box 1440, Indianapolis, IN 46206; (317) 637-9200.
American Physical Therapy Association, Section on Women's Health, P.O. Box 327, Alexandria, VA 22313; (800) 999-2782 ext. 3237.
Melpomene Institute for Women's Health Research, 1010 University Avenue, St. Paul, MN 55104; (612) 642-1951.

Sample Specialties of Therapeutic Exercise Intervention

UNIT 4

CHAPTER

14

Kinetic Chain Applications in Functional Movement

DANNY MCMILLIAN

Motor events are a long chain of cause and effect.
—Arthur Steindler, MD

The quote above captures the fundamental premise of this chapter. Movement has a complex series of both precursors and consequences, and rarely occurs in isolation. The purpose of this chapter is to identify the relationships that influence the kinetic chain (KC) of cause and effect.

The KC has been defined by Fonseca as mechanically coupled segments in which the forces arising in one segment are transferred to other segments, with the kinematic chain referring to the effect of mechanically coupled segments on motion.[1] In keeping with common usage in musculoskeletal medicine, this chapter will use the term KC to refer to both coupled forces and motions (**Evidence and Research 14-1**).

EVIDENCE and RESEARCH 14-1

Regional Interdependence

Kinetic chain effects are part of a larger concept and clinical model of interconnectedness, referred to as regional interdependence (RI)[2-5] The original RI concept[5] was directed primarily at the musculoskeletal system, but was expanded in 2013 to account for evidence that suggests a patient's primary musculoskeletal symptoms may be directly or indirectly related to or influenced by impairments from various body systems regardless of proximity to the primary symptoms.[4]

The revised RI model accounts not only for musculoskeletal interactions (active and passive subsystems), but also for the influence of neurophysiologic (neural subsystem), somatovisceral (support subsystem), and biopsychosocial effects (cognitive-emotional subsystem). Although such effects are important to movement and should not be underestimated,[6,7] the primary focus of this chapter is the KC and its role in functional movement and tissue stress.

Impairments within the KC commonly degrade movement elsewhere in the chain, often leading to injury or pain syndromes:

- In a prospective, cohort study, trunk displacement, proprioception, and history of low back pain (LBP) strongly predicted knee ligament injury in female athletes. Only a history of LBP was predictive in male athletes.[8]
- In another prospective study, acquired ligamentous laxity of a lower extremity joint predicted the risk of noncontact LBP.[9]
- Burkhart and colleagues have described the association of KC impairments and shoulder pathology. In throwing athletes with shoulder pathology, they have noted decreased mobility of the low back, decreased internal rotation of the contralateral hip (possibly limiting throwing follow through), and dysfunctional performance on single-leg stance tasks, with incidence of those impairments ranging from 39% to 48%.[10]

These examples demonstrate the effect of physical stress on musculoskeletal tissues. Through posture and alignment, muscle performance, and neuromuscular control, the KC heavily influences the degree of tissue stress incurred.[14] Those same factors are also key determinants of how effectively the KC creates functional movement and will frame the subsequent discussion. See **Building Block14-1** for a definition of functional exercise.

BUILDING BLOCK 14-1

Functional Exercise

Although functionality in rehabilitation and performance training is often contentiously debated, here it will be defined as any form of training that improves any relevant biomotor ability that is not detrimental to other biomotor abilities.[11] Such a broad interpretation of the concept of function is warranted based on the variety of interventions that have produced positive outcomes.[12,13] It is incumbent upon clinicians to justify the functionality of their interventions in relation to the patient's activity limitations and participation restrictions. How will you describe the concept of functionality in patient friendly language?

UNDERSTANDING THE KINETIC CHAIN

Biologic developmental and the childhood environment heavily influence characteristics of the KC. Maturation of the central nervous system alters motor patterns, which in turn influence structural development.[15] Developmental disorders or deprivation from normal stimuli during development might preclude optimal function of the KC. For example, Michaud has described how footwear and obesity during early childhood might alter formation of the sustentaculum tali, and subsequently diminish passive support for the medial longitudinal arch, possibly leading to a pathologic degree of pronation in some individuals.[16] Similarly, neurologic insult and musculoskeletal injury bring consequences for the KC, such as when anterior cruciate ligament (ACL) deficiency alters somatosensory input and the individual suffers a resulting decline in the KC's responsiveness.[17]

The neural subsystem orchestrates KC activity in large part by setting the conditions for responsiveness to the environment. Stergiou has described the role of rehabilitation in promoting responsiveness:

> Although our goals often do not explicitly target variability in movement, our implied expectation is that the functional movement that emerges will be adaptive and flexible enough to meet the everyday goals of our patients. To achieve this flexibility, our patients need adequate variability of the motor system. It follows that adequate variability should be a focal point of examination and intervention in order to achieve optimal function for the individual.[17]

The degree to which the KC's coupled segments are dependent upon one another is a key concern of KC analysis. When motion of one segment is independent of the motion of other segments, an open kinetic chain (OKC) is in effect. When motions of the segments are interdependent, a closed kinetic chain (CKC) is in effect.[1] For example, seated knee extension is an OKC event, given that the relationship of the femur and acetabulum is essentially independent of the movement occurring between the femur and tibia. In contrast, when rising from a seat or squatting, CKC mechanics are observed, with interdependent effects not only at the hip and knee, but also involve movements at the ankle, foot, pelvis, and low back.

CKC exercises began to gain favor in the 1980s, in response to evidence from the biomechanics literature demonstrating an increase in anterior shearing forces during the last 30 degrees of OKC knee extension.[18] Since anterior shearing had the potential to strain a healing ACL graft, clinicians desired a safer method to rehabilitate the quadriceps mechanism after ACL reconstruction. An influential in vivo study, measuring ACL strain during various exercises, found that isometric knee extension at 0 and 22 degrees placed more strain on the ACL than walking or stationary biking.[19] Subsequently, rehabilitation protocols shifted to emphasize CKC activities or use them exclusively.[20,21]

In addition to ACL graft concerns, analysis of forces at the patellofemoral joint showed that OKC knee exercises against resistance produce non-physiologic loading of patellar articular cartilage, because of decreasing contact surface between the joint surfaces that occurred as the moment increased from 30 to 0 degrees of knee flexion. The authors concluded that OKC extension exercises, even with the relatively small loads commonly used in knee rehabilitation, produce pressures far in excess of those produced in normal activities, such as stair-climbing or squatting.[22]

After those influential studies, CKC rehabilitation continued to gain in popularity as new investigations highlighted the ability of muscles to affect segments and joints far from their attachments.[23] For example, over 50% of the kinetic energy for a tennis serve was shown to be provided by the legs and trunk.[24] Similarly, for throwing, Burkhart has described force generation from the ground, legs, and trunk; force regulation from the shoulder; and delivery from the arm.[10]

The broad definition of function described in the introduction, together with more recent evidence, warrants utilization of both CKC and OKC exercises. Although some clinicians removed OKC exercise from their ACL rehabilitation protocols based on potential anterior shearing effects, Fitzgerald's 1997 review of the evidence called for a combination of OKC and CKC exercise when quadriceps femoris muscle function is a treatment goal.[25] Current evidence confirms that philosophy, with the caveat that OKC knee extension is restricted to 90 to 45 degrees.[26–28] Similar findings exist for treating patients with patellofemoral concerns, with recommendation that CKC exercises such as a squat should be performed from 45 to 0 degrees of knee flexion. Conversely, OKC movements can be performed from 90 to 45 degrees without a detrimental increase in patellofemoral joint reaction forces[29] (**Building Block 14-2**).

BUILDING BLOCK 14-2

Observation of a patient with the diagnosis of patellofemoral pain (PFP) syndrome during the gait cycle reveals an increase in the amount of frontal plane foot and limb motion.

1. Describe the relationship between the patient's diagnosis and limb mechanics
2. What posture should you exercise the hip and foot in to help decrease stress on the knee?
3. Describe a CKC exercise to eccentrically control hip internal rotation

Understanding OKC and CKC mechanics and, therefore, the degree to which the KC's coupled segments are dependent upon one another, aids in our understanding of energy flow and its potential effect on the movement system. Optimizing movement performance and tissue stress may be thought of as a matter of energy management. The efficacy with which the KC generates, transfers, and dissipates energy is critical to the effectiveness of the movement and the resulting stress on tissues.[1] An approach to energy flow and its effect on functional movement and tissue stress should consider the interrelated components of posture and alignment, muscle performance, and neuromuscular control.

Posture and Alignment

Posture and alignment are influenced by the active, passive, and neural subsystems. Sahrmann has stated "optimal alignment is the desirable if not the necessary requirement for optimal movement."[30] Alignment is particularly relevant to the KC during functional movement, and is supported by evidence that links kinematic variables with muscular activation,[31] joint kinetics,[32–36] and injury risk.[10,37–40]

Alignment and muscle performance interact reciprocally. Sahrmann has described how an anteriorly tilted pelvis might result from hypertrophy of back extensors and hip flexors in combination with relatively less passive tension in the abdominals.[30] In such a case, simply cueing a neutral pelvis or even strengthening the abdominals might not lead to a sustainable leveling of the pelvis if the relative tension of the anterior and posterior muscles is not also addressed.

Alignment also affects tissue stress.[14] For example, sitting with a posteriorly tilted pelvis will increase tensile stress to structures of the posterior spine, although it should not be assumed that such stress will necessarily lead to pain arising from those tissues. Conversely, alignment might be influenced by overstressed (and symptomatic) tissue, for example, when a patient assumes an unbalanced trunk posture to offload an irritated spinal nerve root (**Building Block 14-3**).

BUILDING BLOCK 14-3

Static and Dynamic Postures: Evaluation of static posture aids in understanding segmental relationship, but the degree of clinical relevance, if any, must be determined through a thorough evaluation that also includes movement analysis. Consider a patient presenting with persistent LBP who sits with a posterior tilt of the pelvis but stands with an anterior tilt. Do you expect that motor control of the pelvis and lumbar spine during functional movements will be adequate or impaired? If impaired, do you expect to find isolated motion and muscle performance impairments as well? Will you address those isolated impairments separately or in conjunction motor control training? Will posture and alignment need retraining?

Postural variations from stated norms might be of no clinical consequence.[12,41,42] For example, if a patient presents with a slightly depressed and abducted scapular posture of their dominant upper extremity, but demonstrates effective and pain-free component motions for elevation of the arm, the postural variation might not require intervention. To confirm that hypothesis the clinician is obligated to further examine the patient with a relevant degree of loading to functional movements.

Of particular relevance to this discussion of the effect of posture and alignment on tissues is Dye's concept of the envelope of function, which defines a range of loading compatible with the overall tissue homeostasis of a given joint or musculoskeletal system.[12] The concept considers the magnitude and frequency of the applied stress. The upper limit of the envelope represents a threshold between loads that are compatible with tissue homeostasis and loads that initiate the "complex biological cascade of trauma-induced inflammation and repair."[43] The lower limit to the envelope of function represents loading of the minimal magnitude or frequency required to sustain tissue health (see **Building Block 14-4**).

BUILDING BLOCK 14-4

The envelope of function concept supports the notion that a wide range of postures might support function and tissue health, as long as the involved tissues are capable of tolerating or adapting to the imposed stress. Consider how thoroughly identifying a patient's injury and activity history might aid in understanding their tissue response to stress. Will a patient's history of upper body greater than lower body activity suggest different degrees of tissue resilience between those regions? Consider the likely tissue response to a novel weight-bearing exercise program for someone whose primary means of exercise has been swimming. Contrast the likely tissue response for someone who has primarily hiked over rough terrain for exercise.

Although it is difficult to predict who will develop symptoms because of malalignment, evidence has revealed some specific alignment patterns that suggest the need for further evaluation and intervention. For example, frontal plane malalignment of the knee is well established as a predictor of disease progression in knee osteoarthritis.[44] Other malalignment concerns will be identified throughout this and other chapters.

Muscle Performance

The ability of muscles to generate and dissipate energy is an important determinant of KC function. Muscle performance is primarily a product of interactions of the active and neural subsystems, but is also influenced by the other subsystems of movement. Muscle activation patterns and the inherent orientation of their fibers serve to modulate stiffness of the muscle-tendon unit, with subsequent effects on the KC. For example, in a KC environment, segments with less stiffness move before segments with greater stiffness.[1] When tissue stiffness is ideal, movement is energy efficient without excessive stress to any particular tissue. It is ideal to have sufficient stiffness to resist excessive deformation, but enough compliance to absorb some stress rather than passing too much along to other links in the KC. Although this section will highlight the effects of muscle performance on tissue stiffness, note that passive restraint to lengthening connective tissues also contributes to tissue stiffness.

Consider two examples that demonstrate the effect of stiffness on the KC: first, squatting to lift a box from the floor, then rising to place it on a shelf at shoulder height. The upper extremities stiffen to grasp and hold the box, and the lower extremities stiffen to rise out of the squat. However, consider the trunk. If it is the least stiff of the three segments, motion, under load, will occur there first, potentially creating an injurious transfer of energy to spinal tissues.[45] Now, consider a runner with abnormally high stiffness of the foot. The lack of foot compliance to ground reaction forces will transfer a greater amount of stress up the KC relative to runners with less stiffness at the foot. Such mechanics have been associated with skeletal injury.[46]

Muscle performance is significantly influenced by the muscle's length, and length will change in response to the nature of its use, or lack thereof. For example, muscles immobilized in a shortened position will lose sarcomeres, and, even though the remaining sarcomeres lengthen to enable the muscle to develop maximum tension in its immobilized position, peak tension is only attainable near the position of immobilization.[47,48]

Conversely, muscles in a chronically lengthened position will add sarcomeres in series. To adapt to the new length, individual sarcomeres will shorten in order to maximize potential for creating tension in the lengthened position. Such an adaptation will likely predispose the muscle to active insufficiency at specific ranges of motion.[1,30] For example, if the muscles of scapular adduction are adaptively lengthened because of a chronic posture of thoracic kyphosis and scapular abduction, those muscles will likely generate less than normal tension when the scapula is in a neutral or adducted posture.

The previous example has important implications for clinicians. If a muscle has adaptively lengthened, postural corrections and the therapeutic exercises to reinforce those corrections must be carefully chosen and progressed so that the patient is not asked to sustain postures or generate forces that are impractical because of active insufficiency (see **Building Block 14-5**).

BUILDING BLOCK 14-5

Depression of one or both shoulder girdles is a common observation among patients who report neck or shoulder pain. Consider the effect of this common posture on the length of the upper trapezius and serratus anterior. Would upward rotation of the scapulae be affected? If that is observed when the patient is asked to elevate the upper extremities, what are the implications for initial therapeutic exercise? If the elongated muscles are incapable of generating force in a shortened range, what are the initial steps to restore their force production through a functional range of motion? Would the expected rehabilitation duration be brief or lengthy and why? How important is correction of the habitual posture of shoulder girdle depression?

BUILDING BLOCK 14-6

Consider the patient in Case Study 14-1 to answer the following questions.

1. Given the history and examination findings what are some signs and symptoms that are compatible with abnormal closed chain function?
2. Does the pathology match his abnormal closed chain mechanics? Why or why not?
3. Write some possible short-term and long-term goals for this patient.

In addition to length, muscle performance is highly influenced by activation of other subsystems of the KC. This is a key principle of proprioceptive neuromuscular facilitation. This effect is demonstrated when activation of the serratus anterior is facilitated by simply activating the lower extremity and trunk muscles during specific functional tasks.[49] Therefore, in addition to other facilitation techniques that are common to rehabilitation, clinicians might elicit the desired muscle response by setting the KC conditions for synergistic activation (**Case Study 14-1** and **Building Block 14-6**).

Neuromuscular Control

Coordinated movement is a product of a complex interaction between sensory organs, the central and peripheral nervous system, and skeletal muscle.[50] As such, it is primarily a product of the neural and active subsystems, but is influenced by all the movement subsystems. The importance of neuromuscular control to the KC is highlighted by studies that show improving muscular performance in isolation might not improve common clinical movement impairments until optimal movement patterns are also reestablished.[36,51,52] For example, the consensus statement from an international PFP research summit stated

Case Study 14-1

Patient Case Study #1: Patient is a 28-year-old male roofing contractor with complaints of L medial shin pain and the diagnosis of posterior tibialis tendinitis. States pain is worse at work with climbing ladders and working on a steep pitched roof. Pain has been getting worse over the past month. Recreational activities include jogging three times weekly 30 to 40 minutes which he has been unable to do secondary to the pain. Pain is a 5 on a 0 to 10 scale. Rest and NSAIDs have not been helpful.

PMH: Hernia operation 4 years ago, intermittent LBP

Obs: Patient ambulates with a toe out position on the left, with a normal base of support. Additionally his gait reveals an inverted position of the heel at initial contact with subtalar joint eversion to vertical and prolonged subtalar joint pronation through early to mid midstance without midfoot collapse and with minimal lowering of medial longitudinal arch height. During the later part of the propulsive phase of gait, the patient demonstrates a medial heel whip.

Examination:

MMT: normal throughout except: L hip abd 4/5, hip er 4–/5, posterior tibialis 4–/5 +P

Range of motion (ROM): normal throughout except: B decreased talocrural joint dorsiflexion by 50%

Plantar callus pattern: lateral border of the heel, pinch on great toe

Weight-bearing alignment: external tibial rotation, vertical calcaneal position.

Weight-bearing examination: neutral (subtalar neutral) calcaneal position 10 degrees varus, relaxed calcaneal position vertical. Navicular drop (sit to stand) 7 mm.

Activity Limitations:

1. Patient unable to work safely on pitched roofs.
2. Patient unable to climb frequently up and down ladders.
3. Patient unable to run/walk for more than 10 minutes.
4. Patient unable to stand for more than 40 minutes.

Participation Restrictions:

1. Has been decreasing hours at work over the past month.
2. Unable to participate in recreational activities.

"increasing hip abductor and knee extensor muscle strength does not affect altered lower extremity kinematics associated with PFP."[13]

The fact that improvements in strength do not necessarily improve integrated movement patterns should not come as a surprise, given the fundamentally different effects on the central nervous system between isolated strength training (OKC) and movement skill training (CKC).[53] Clinicians should interpret with caution reports of improved movement patterns based solely on isolated strength or muscle performance training. It is not uncommon for studies to highlight improvements in strength at one region (e.g., the hip) leading to improved outcomes at another (e.g., the knee), even though interventions included integrated training (e.g., alignment during landing, single-leg stance). Consider that the improvements may be due to motor learning effects, and not due to isolated muscle training.[54,55]

Individuals with an ACL-deficient knee represent an interesting cohort with which to examine the effects of neuromuscular control on the KC. Despite the widespread advocacy for reconstructive surgery in the athletic, ACL-deficient population, a sub-cohort of copers (able to resume all pre-injury activities, including sports, without episodes of knee giving way) exists.[56] This group manages to resume athletic activities without reconstructive surgery,[57–59] suggesting that outcomes after an ACL injury are a product of much more than simple joint laxity. Notably, each of the research groups that have documented a cohort with effective resumption of activity without surgery has emphasized neuromuscular training during rehabilitation.[57–59]

Prevention of ACL injuries also benefits from neuromuscular training. A systematic review of clinical trials has shown that such training significantly reduced ACL injury incidence in young, female athletes when combined with strengthening and proximal control exercises.[60] The same review found that preventive programs using only one training mode did not reduce ACL risk; therefore, multimodal interventions that include neuromuscular training are recommended.

Because neuromuscular control of any particular segment of the KC is influenced by all components of the movement system, compromise of any subsystem might degrade movement and expose the individual to injurious tissue stress. For example, a significant increase in musculoskeletal injury risk has been noted for up to 1 year following concussion.[61,62] Similarly, fatigue might induce lower extremity biomechanics and postural control deficits that have been associated with ACL injury[1] (**Evidence and Research 14-2**).

EVIDENCE and RESEARCH 14-2

Selected KC Interactions and Implications

KC Interactions	Implications
Ankle dorsiflexion (DF) ROM may influence movement variables at the knee. For example, decreased DF may limit the ability to perform a squat.[63,64] In contrast to a non–weight-bearing (NWB) method of measurement, ankle DF ROM assessed with a weight-bearing lunge (WBL) differentiated lower extremity kinematics between the normal and limited groups.[65]	These findings and broader understanding of KC interactions suggest that the WBL is a preferred method for evaluating DF ROM, and is likely a more sensitive tool for identifying those with high-risk movement patterns compared to NWB techniques.
Pronation of the feet, and forefoot varus with which it is often associated, have been shown to significantly increase hip internal rotation during gait and a single-leg squat.[66,67] Hip internal rotation and adduction have been frequently associated with PFP and ACL injury risk.[13,38]	Given that excessive hip internal rotation has been associated with knee injuries,[13,37] clinicians should evaluate foot alignment in patients with lower extremity movement impairments. However, caution is recommended when interpreting the results of such evaluation, since there is conflicting evidence regarding the clinical importance of rearfoot kinematics.[13] It is likely that some individuals tolerate an above-average level of foot pronation and others do not.
Mounting evidence suggests that mechanics of the lower extremities are heavily influenced by proximal factors, to include deficient control of the hip, pelvis, and trunk.[13,68–70] Females are generally more affected by these factors than males.[13,70]	Evaluation of lower extremity injuries, pain syndromes, and injury risk must include consideration of mechanics at the hip, pelvis, and trunk. Correction of proximal, mechanical factors that might be associated with injury may, in many cases, occur during the early stages of rehabilitation, when clinicians must protect healing tissues from excessive stress. For example, in the first weeks of ACL reconstruction rehabilitation, the patient can be working on core strength and trunk control in addition to the "typical" early phase of ACL rehabilitation.
A recent biomechanical study found that walking in the swayback posture was associated with higher peak hip extension angle, hip flexor moment, and hip flexion angular impulse compared to natural posture. Walking in a forward flexed posture resulted in a decreased hip extension angle and decreased hip flexion angular impulse.[32]	The findings from this study provide a plausible, mechanical rationale for KC alignment factors that direct excessive forces to anterior hip structures, such as those associated with femoro-acetabular impingement or hip flexor strain. Clinicians should observe for the related gait alignment factors described in this study and consider relevant interventions.

KC, kinetic chain; ROM, range of motion; PFP, patellofemoral pain; ACL, anterior cruciate ligament.

EXAMINATION AND EVALUATION

Because childhood development, movement experience (e.g., sport/activity participation), and injury history heavily influence the KC, clinicians benefit from a thorough history and systems review, which often identify factors that guide the subsequent physical examination. Both qualitative and quantitative techniques are used to evaluate the KC. Observation of gross, functional movement patterns provides information about several important factors, including:

- The subject's willingness to move
- Spatial and temporal characteristics of the gross movement (e.g., base of support, excursion, and speed of movement)
- Spatial and temporal characteristics of directly linked segments (e.g., ankle and knee)

Qualitative Examination

Display 14-1 describes KC observations that provide qualitative information. From these observations, the clinician forms a hypothesis regarding the contribution of perceived movement impairments to the patient's presenting problem. The initial observations also guide the choice of isolated and quantitative examination techniques, which then further guide the examination.

A systematic approach to qualitative assessment that has gained popularity is the Selective Functional Movement

DISPLAY 14-1

Qualitative Examination of the KC

Movement	Criteria and Rationale
Gait	■ Gait provides an opportunity to observe the entire KC during a functional activity. Observe both spatial and temporal characteristics of the entire KC. ■ Although a full evaluation of the KC in gait is beyond the scope of this chapter (see, Gait Analysis: Normal and Pathological Function by Perry),[73] the following are examples of common deviations that compromise the KC and identify the need for a more focused examination. ▪ If during initial swing, the heel rapidly rotates medially (also referred to as medial heel whip or abductory twist), suspect that excessive transverse plane stress is occurring throughout the lower extremity. Prolonged pronation during stance is a common reason for this deviation, although restricted motion at the first MTP joint and impaired muscle performance at the hip might also cause or contribute to this problem. ▪ Limited ankle dorsiflexion might manifest during gait as decreased step length or early heel rise. ▪ Knee impairments might manifest during gait with reduced stance time, lack of knee extension at initial contact, lack of knee flexion during loading response, and circumduction or hip hiking during swing phase, in order to create clearance for a knee that does not flex adequately. ▪ Excessive movement of the knee in the frontal plane during stance suggests increased risk for knee injury as well as PFP syndrome and suggests the need to further evaluate not only the knee, but the hip, foot, and ankle function.[74] ▪ Excessive lowering of the contralateral pelvis (adduction of the stance hip) suggests impaired gluteus medius function on the stance side and might contribute to both trunk and lower extremity pathomechanics.
Breathing pattern	■ The diaphragm and transversus abdominus muscles continuously contribute to the sometimes competing interests of respiration and postural control.[75] ■ Specific loading of the inspiratory muscles impairs postural control by decreasing lumbar proprioceptive sensitivity,[76] and differs significantly in a lifting task for individuals with LBP. However, inspiratory muscle training has been shown to improve postural control in individuals with LBP.[77] ■ These findings suggest KC effects and the need to evaluate the functionality of breathing patterns. Frank and colleagues have suggested the following,[15,78] with the patient seated: ▪ Place the second and third fingers lightly on the patient's lower ribs to detect movement of the rib cage during respiration, while the thumbs on the thoracolumbar paraspinal muscles monitor the intensity of their contraction. ▪ The fourth and fifth fingers are placed lightly on the lateral abdominal wall to monitor the resistance (eccentric contraction) of the abdominal wall against IAP changes during respiration. As the patient breathes in and out, the clinician observes the global posture in addition to monitoring movements at the ribcage and abdominal wall. Although objective measures are limited, some common observable and palpable faulty movement patterns include: (1) cranial excursion of the rib cage or shoulder elevation secondary to compensation of accessory muscles of respiration to make up for inadequate diaphragm activity; (2) excessive contraction of paraspinal muscles; (3) inadequate lateral rib cage expansion or resistance of the abdominal wall against IAP changes; and (4) inability to maintain the upright spinal alignment (either into flexion or extension). These faulty patterns are often magnified if the patient is cued to lightly brace his or her abdominals.

(continued)

DISPLAY 14-1

Qualitative Examination of the KC (*continued*)

Hip hinge	■ This movement involves hip flexion while maintaining the neutral position of joints above and below (the knee should remain flexed 10 to 20 degrees throughout the hip hinge). The hip hinge is a component motion of squatting and, therefore, many common functional tasks. It is also a technique for lifting items when a squat is contraindicated (e.g., knee impairment) or impractical (e.g., lifting an object from a shopping cart). ■ Inability to keep either the spine or the knees in neutral suggests that the patient will transmit energy to those segments during similar functional movements, rather than using the large hip joint and surrounding musculature. Such a movement habit might overload tissues of the spine or lower extremities.
Squat	■ Ask the patient to assume the stance width and directional orientation of the feet that they normally use to squat. ■ To squat, the knees flex synchronously with the hip hinge described above. The heels remain on the floor. The feet remain aligned with the transverse plane position in which they started, but not necessarily in parallel with the sagittal plane. ■ If the heels do not remain on the ground, limited dorsiflexion of the ankle or hypertonicity of plantar flexor muscles is suspected. However, poor coordination of the squat pattern, with excessively forward weight distribution, might also be the culprit. ■ If the feet excessively pronate, with noticeable forefoot abduction during the squat descent, suspect compensation at the transverse tarsal joint for limited ankle dorsiflexion. ■ In addition to the spinal neutral checkpoint noted for the hip hinge, also observe for frontal and transverse plane deviations of the pelvis and trunk. Such deviations might indicate impaired segmental motion of the spine, poor coordination of the KC, or unequal weight bearing in response to pain or dysfunction. ■ Knee deviations in the frontal plane are common and linked to an increased risk for knee injury as well as PFP syndrome. ■ Consider the functionality of the depth of the squat relative to the individual's movement requirements.
Single-leg stance (SLS)	■ The trunk should demonstrate only minimal sway. Ensure that the first and fifth rays of the foot maintain contact with the ground. SLS reduces the normal standing base of support and thus challenges balance. ■ In the sagittal plane, the knee is straight but not hyperextended (a sign of reliance on passive stability). ■ Also observe the knee for frontal plane stability. Excessive movement suggests increased risk for knee injury as well as PFP syndrome. ■ In the sagittal plane, the hip should remain in neutral. Realize that anterior and posterior pelvic tilting create hip joint flexion and extension, respectively, and suggest poor pelvic stability. ■ In the frontal plane, observe for hip adduction or abduction (lowering or raising the contralateral pelvis, respectively). Lowering of the contralateral pelvis (adduction of the stance hip) suggests impaired gluteus medius function on the stance side. ■ If excessive sway precludes using the SLS to observe the KC relationships described above, consider using the balance measurement tools recommended in Chapter 8. ■ If indicated, add further movement challenges to the SLS (e.g., hip hinge, squat, upper extremity reaches, contralateral leg swings).
SLS with heel raise	■ During the SLS heel raise, the clinician should observe relative rearfoot inversion, while the first and fifth rays of the foot remain in contact with the ground. Inability to do so suggests impaired ability to optimally stabilize the foot for propulsion during gait or other dynamic activities. ■ KC relationships described above for SLS should remain the same.
Step up/down	■ This movement combines some of the demands of SLS and squatting; therefore, many of the criteria for optimal movement are described above. ■ Observe hip and knee control in the frontal and transverse planes. ■ Observe sagittal plane motion of the pelvis; anterior tilting suggests impaired performance of the gluteus maximus.
Overhead reach	■ This movement allows the observer to evaluate the individual's ability to maintain a relatively neutral position of the trunk while reaching with one or both arms (simulate a functional task). Begin with parallel stance, but add challenge as indicated by changing the base of support (e.g., staggered stance) or adding a concurrent task such as stepping and reaching. Modify the speed and excursion of the task as indicated. ■ Inability to achieve independent limb and trunk movement decreases efficiency and might contribute to pathomechanics of the trunk or extremities.

KC, kinetic chain; MTP, metatarsophalangeal joint; PFP, patellofemoral pain; LBP, low back pain; IAP, inter-abdominal pressure; SLS, single-leg stance.

Assessment (SFMA).[71] The assessment begins with 10 movement patterns that are scored either categorically (functional or dysfunctional; painful or not painful) or using a criterion checklist (34 factors total for the 10 movements). Dysfunctional or painful movements then prompt further examination (complete coverage of the SFMA is beyond the scope of this chapter). Reliability testing of the SFMA showed excellent intrarater reliability for categorical scoring, and poor to good reliability when using the criterion checklist. Interrater reliability of the categorical scoring tool was slight to substantial, but was unacceptable for the criterion checklist.[72] To date, the SFMA has not been validated for clinical use, and therefore it is uncertain if the systematic approach of the SFMA adds additional value to KC examination.

Quantitative Examination

Observation of impaired KC function normally requires further examination of discrete segments of the musculoskeletal system. That examination will usually include both qualitative factors (e.g., determining the end-feel of a synovial joint) and quantitative measurements such as ROM or instrumented laxity measurements. The gross function of the KC may also be measured.

The most commonly used clinical tools for measuring KC function are hop tests and balance reach tests. Although products are available to enhance the measurement of such tests, this descriptions here will be limited to test that do not require equipment.

- Hop tests are primarily used to establish a limb symmetry index (LSI). To calculate the LSI, divide the distance hopped on the involved side by the distance hopped on the uninvolved side, and then multiply by 100. For timed hop tests, calculate the LSI by dividing the time to completion of the uninvolved limb by the time to completion of the involved limb, and then multiply by 100. Evidence has shown that for the single-leg hop, 93% of normal individuals have greater than 85% LSI, and 100% have LSI greater than 80% Therefore, most clinicians and researchers support the use of LSI return-to-play criteria ranging from 80% to 90%.[79,80]
    - The most well established hop tests have been used to measure readiness for return to full activity after ACL reconstruction. Reid reported that four hop tests—single hop, triple hop, crossover hop, and the 6-m timed hop—originally described by Noyes provided reliable and valid outcome measurement for rehabilitation and return to sport after ACL reconstruction.[80] Therefore, those specific hop tests can be used to inform return-to-play decisions.
    - Logerstedt reported that hop tests conducted 6 months postoperatively predicted self-reported knee function at 1 year, with the 6-m timed hop and crossover hop tests being most predictive. Using receiver operating characteristic curves to determine the overall discriminative accuracy of each single legged hop test, the optimal LSI was 88% and 95% for the 6-m and crossover hops, respectively.[81]
    - Since LSI could improve because of unwanted decrements in performance of the uninvolved limb, absolute gains are important to document. Rohman studied such potential effects and reported no performance decrement in the uninvolved limb of a large cohort, indicating the improvements seen in LSI were reflective of valid improvement in performance of the involved limb.[80]
    - In a systematic review of the literature, Hegedus has urged caution when using hop tests to evaluate knee function, because of conflicting or unknown evidence regarding their measurement properties.[82] In the same study, it was noted that the single-leg hop for distance is discriminative in males with ACL tears and that it is responsive to rehabilitation after ACL tear.[82]
    - Single-limb hop tests have also been used to evaluate the functional performance for patients with functional ankle instability (FAI), with conflicting evidence as to whether such tests are valid indicators of dysfunction.[83,84] As a result, Caffrey proposed four novel hop tests (figure-of-8 hop, side hop, 6-m crossover hop, and square hop) designed to better challenge ankle function relative to traditional hop tests designed to evaluate knee function.[85] Results from the original cross-sectional study showed that for subjects with FAI who reported giving way with activity, performance deficits were noted relative to both a control group and the uninvolved limb.
    - It is important to note that hop tests are not designed to evaluate movement quality. Though many clinicians note qualitative factors such as movement into knee valgus upon landing, as designed, the hop tests noted here are strictly quantitative evaluation tools.
- Star Excursion Balance Test (SEBT)
    - First described by Gray,[86] the SEBT is a practical tool for examining an individual's ability to maintain SLS while maximally reaching in various directions with the non–weight-bearing foot.
    - A systematic review by Gribble reported that the SEBT is a "highly representative, non-instrumented dynamic balance test for physically active individuals."[87] Reliability for the SEBT is good, with validity to predict lower extremity injury risk, identify dynamic balance deficits, and to be responsive to training in both uninjured and injured populations.[87,88]
    - Clinicians should note that only the anterior, posteromedial, and posterolateral reaches have been associated with injury risk.[89]
    - Like the hop tests, the SEBT is not designed to evaluate movement quality. Although it is useful for quantifying lower extremity reach excursion, the test itself does not have a means for evaluating movement quality.[90]
- The Landing Error Scoring System (LESS) was designed as a clinical tool for identifying movement patterns associated with lower extremity injury risk during landing.[91] The LESS requires a box with a height of 30 cm, two cameras, and a video analysis equipment. Because the LESS requires such equipment, the developers sought to enhance clinical utility by modifying the test to allow for analysis in real time, thus the LESS-RT, which appears to have comparable interrater reliability and precision.[92] Both the LESS and LESS-RT evaluate qualitative jump-landing performance factors such as knee valgus, lateral trunk flexion, and knee flexion

displacement Although the LESS has established reliability and correlation with three-dimensional laboratory analysis of landing kinematics,[91] it was unable to predict injury risk in a large, case–control study.[93] Such findings highlight the complexity of the KC and injury mechanisms, and should serve as a caveat to clinicians attempting to predict injury from biomechanical findings.

- The tuck jump assessment (TJA) was also designed to identify biomechanical deficiencies that predict risk for ACL injury.[94] Among those deficiencies described by Hewett and colleagues are ligament dominance, quadriceps dominance, leg dominance/residual injury deficits, trunk dominance, and technique deficits.[38] The tuck jump test requires the individual to perform as many jumps as possible in 10 seconds. Tuck jumps are defined by movement of the thighs to parallel with the ground at the highest point of the jump. Six common errors that suggest the biomechanical deficiencies noted above are: (1) medial knee collapse, (2) knees not reaching parallel to the ground, (3) asynchronous lower limb positions during flight, (4) landing with the feet too close together, (5) landing in an staggered stance position, and (6) failure to land with both feet at the same time. In addition to those faults, other factors noted are pausing between jumps, excessive noise upon landing, inconsistent landing footprint, and degraded movement within 10 seconds. The developers of the TJA have suggested that six or more faults (out of 10 total factors assessed) indicates a need for further technique training.[94]
- To date, the TJA tool has not been tested for predictive value, but Myer has shown that augmented feedback based on TJA faults improved landing performance on a separate vertical jump task, suggesting that motor learning of improved landing technique had occurred.[94]
- It is important to note that the TJA and LESS take into consideration the quality of movement, something the SEBT and hop tests do not.
- Close Kinetic Chain Upper Extremity Stability Test (CKCUES)
  - Reflecting the nature of the KC, most KC tests challenge the lower extremities to a greater extent than the upper extremities, but the CKCUES might be a useful evaluation tool for individuals whose upper extremity functional activities include CKC activities. For example, a carpet layer, who works on his hands and knees, may benefit from assessment via CKCUES. Although reliability[95–97] and reference values[98,99] have been published, the functionality of the test has been questioned and its possible inherent risk noted.[97]
  - The CKCUES test is performed from the push-up position, with the hands at 36 inches apart (a 1.5-inch strip of athletic tape normally serves as the reference point). To perform the test, use one hand to reach across and touch the tape under the opposing hand. After touching the tape, the hand is taken to the original starting position and the movement is repeated with the other hand. The score is the number of touches within 15 seconds. Note that the published performance standard to date has been the same for men and women.

CHOOSING THERAPEUTIC MOVEMENTS TO ENHANCE KINETIC CHAIN FUNCTION

Effective function of the KC requires effective performance of its components. When impairments of KC segments preclude optimal integrated movement, then interventions should target those impairments. As discussed previously, both OKC and CKC activities have a role in rehabilitation, with OKC exercise generally most appropriate to target isolated impairments in the stability stage of motor control. However, different stages of motor control can be addressed with the concurrent use of OKC and CKC exercise (**Building Block 14-7**).

BUILDING BLOCK 14-7

A patient with a quadriceps strength deficit may perform CKC activities in conjunction with their OKC activities as long as the demands of the CKC activities do not exceed their capabilities and render a faulty movement pattern in the patient. Describe some possible program modifications to CKC activities in such a patient.

Clinicians should note that discrete impairments of KC segments vary in their effect on other segments. A kinematic study of female runners with PFP found that rearfoot kinematics did not differ between the PFP and control groups.[68] However, the PFP group demonstrated greater hip internal rotation and adduction, as well as greater shank internal rotation, suggesting that pathomechanics at the knee and shank were driven more by proximal rather than distal factors.[68] These findings are consistent with reports from the two most recent international PFP research retreats.[13,100] This does not suggest that interventions directed at segments distal to the knee should be discounted for patients with PFP, but rather that clinicians should seek to prioritize, through research evidence and examination of the individual, those factors that are most relevant to a particular patient's clinical problem. For a more complete explanation of the factors that influence patient management, the reader is referred to Chapter 2.

As the patient advances through the stages of motor control, skill training addressing activity limitations and participation restrictions must be considered. In many cases, that will require rehabilitation tasks with higher energy demands and greater tissue risk. See **Display 14-2** for a discussion of factors that guide exercise prescription and progression.

The individual requirements for each of the factors discussed in Display 14-2 vary widely across occupational, recreational, and sports tasks. For example, a patient who wishes to return to participation in gardening (participation restriction) might benefit most from interventions that improve movement excursion, load carriage, and endurance. For the gardener, the speed and complexity of movement are likely less important and would not be rehabilitation priorities. In contrast, a patient who wants to resume playing tennis requires complex movements involving speed. Clinicians must carefully select interventions that best target impairments related to the patient's activity limitations and participation restrictions. This may prove challenging in an environment in which rehabilitation time is constrained (**Evidence and Researches 14-3** and **14-4**).

DISPLAY 14-2

Factors that Guide Exercise Prescription and Progression with Clinical Application

Factor of KC Exercise Selection and Progression	Clinical Application
Excursion	■ Training for control of movement normally starts with restricted motion, then, as stability through the restricted range is demonstrated, that range can be expanded incrementally through controlled mobility and skill. ■ Excursion refers to the functional ROM through which an integrated KC exercise is performed. In this context, it does not include isolated stretching or joint mobilization, although those modalities might be complementary. ■ Maximal excursion must be both consistently controlled and relevant to the movement demands of the patient.
Speed, acceleration, and deceleration	■ Training for control of movement normally starts with a slow speed. Slower speeds initially might promote better movement awareness for the patient, as well as afford the clinician a better opportunity to evaluate alignment and control. ■ Excessively slowing a movement might degrade it. Therefore, as long as tissue safety is ensured, clinicians might consider adding some speed in an attempt to elicit a better movement pattern. ■ Even activities of daily living involve substantial KC segment speeds, if not the entire KC. This suggests that clinicians should routinely add speed of movement to some degree for all patients. ■ For many occupational, recreational, and sports tasks, the speed demands are obvious. If rehabilitation is to ensure the restoration of function, training those tasks at progressive speeds, in a controlled environment, is imperative.

Complexity	■ Clinicians seeking to promote motor learning of integrated KC tasks may easily manipulate several variables that contribute to the complexity of a movement. Among these are:
	  ■ Base of support: Decreasing the base to increase the complexity.
	  ■ Number of planes in which movement must be controlled: Increase the number of planes to increase the complexity. The easiest plane in which to move is the sagittal, followed by the frontal, and lastly, the transverse plane.
	  ■ Surface: Unstable surfaces create greater complexity for movement control. However, somatosensory input to the central nervous system becomes, in effect, less reliable; therefore, visual and vestibular pathways are used for movement control to a greater degree than they would if the movement occurred on a stable surface. When selecting the surface, clinicians should consider both the objectives of the movement and the surfaces on which the patient will perform their goal activities.
	  ■ Environment. An open, changing environment increases complexity. For example, stepping and reaching movements are made more complex by manipulating an object, reacting to visual or verbal cues, or cognitive problem-solving.

Load	■ Training for control of movement normally starts with a low degree of loading, and then incrementally adds loads until a functionally relevant degree of loading has been applied and the patient has maintained the quality of the movement. ■ For integrated KC training, it is assumed that isolated strength deficits or imbalances have been resolved by resistance training earlier in rehabilitation. Therefore, for this discussion, it is assumed that the stress of progressive loading is shared throughout the KC and that all segments of the chain are unimpaired. ■ Progressive loading is achieved in a variety of ways. In addition to the obvious effects of external loading, note that increasing acceleration/deceleration (e.g., plyometrics, agility training) also increases loading.
Volume (endurance)	■ For movement control training, volume reflects the total number of repetitions for a given period of time. For conditioning exercise (e.g., running, swimming), distance or time may be used to measure volume. ■ The volume of activity (inclusive of rehabilitation and other activity) is an important determinant of the viability of the support subsystem. ■ Increasing the volume of training, along with increasing strength and movement control, will lead to a greater work capacity.

KC, kinetic chain; ROM, range of motion.

EVIDENCE and RESEARCH 14-3

Evidence for KC Exercise Interventions Based on Clinical Objectives

Objectives	Interventions and Effects
Type of Analysis	
Modify factors related to PFP *Consensus statement based on review of the literature*[13]	■ Strengthening posterolateral hip muscles reduces pain and improves function when performed alone, or in combination with multimodal therapy. ■ A dynamic warm-up including CKC quadriceps and gluteal strengthening exercises may prevent the development of PFP for active individuals. ■ Because pathomechanics differ between men and women, rehabilitation goals might need to be sex-specific.
Reduce risk of ACL injury for female athletes *Meta-analysis with subgroup analysis for exercise interventions categorized as balance, plyometric, strength, and proximal control*[60]	■ The greatest prophylactic effect was seen with strengthening and proximal control exercises. ■ Plyometric exercises reduced ACL injury incidences, but were not statistically significant. ■ Balance exercises alone did not demonstrate ACL injury reduction; however, this may be related to the number of exercises incorporated rather than the actual balance exercises. ■ Two studies that incorporated only a single exercise mode did not reduce ACL injuries. Studies that combined multiple exercise modes including plyometrics, strengthening, trunk and balance exercises demonstrated greater ACL injury reduction.
Modify factors related to hamstring strain *Clinical trials*	■ Progressive agility and trunk stabilization is associated with a decreased risk of reinjury.[101] ■ Training programs with an eccentric emphasis, have similar effects as progressive agility and trunk stabilization programs.[102] ■ Training that exposes the hamstring and KC to high loads at long muscle-tendon lengths enhances return to sport.[103]
Improve outcomes and prevent recurrence after ankle sprain *Systematic reviews*	■ Limited to moderate evidence suggests that functional training programs reduce chronic ankle complaints, and might prevent recurrence.[104] ■ After acute ankle sprain, balance and coordination training of at least 6 weeks resulted in a 20% to 60% relative risk reduction for lateral ankle sprain for up to 1 year.[105]
Retrain gait for injured and healthy runners *Systematic review*[106]	■ Real-time feedback was effectively used to (1) reduce variables related to ground reaction forces, and (2) positively modify lower extremity kinematic patterns associated with injury risk. ■ Both healthy runners and those with PFP or chronic exertional compartment syndrome might benefit from such real-time feedback. ■ No one method of feedback was identified as being superior. Mirror and two-dimensional video feedback were identified as potential methods for running gait modification in a clinical setting.
Reduce pain and disability associated with LBP *Systematic review with meta-analysis*[107] *Systematic review*[108]	■ Strong evidence that stabilization exercises are not more effective than any other form of active exercise in the long-term.[107] ■ Studies specifically compared isolated motor control exercise (generally targeting the transversus abdominus and multifidi) with a general core strengthening exercise intervention. Two studies documented better outcomes with the general exercise program, and the other four studies reported no significant differences between the two. The authors concluded that "it may be unnecessary to prescribe therapeutic exercises that are purported to selectively activate the local muscles."[108] That conclusion is supported by McGill's analysis that stability is generally not enhanced by attempted isolation of deep trunk muscles.[45]

KC, kinetic chain; PFP, patellofemoral pain; CKC, closed kinetic chain; ACL, anterior cruciate ligament.

EVIDENCE and RESEARCH 14-4

Evidence for Specific KC Exercises to Target Specific Muscles

Targeted Muscles	Exercises and Selection Factors
Quadriceps and hamstring co-activation	■ Quadriceps-dominant activation has been associated with ACL injury risk.[38] ■ Exercises that balance quadriceps and hamstrings activation are valued in ACL rehabilitation and injury prevention programs. ■ In one study, the most balanced quadriceps-to-hamstrings co-activation ratios were produced during the single-limb dead-lift, lateral-hop, transverse-hop, and lateral band-walk exercises.[109] Note that hops involved a single-limb landing. ■ Although the forward lunge with an upright trunk was not among the best exercise at balancing the ratio in that study, the exercise is heavily influenced by trunk position. Performing the lunge with a forward trunk lean increases activation of the hamstrings and improves the ratio.[110]
Gluteus maximus activation[111]	■ In a systematic review of the literature, Reiman analyzed the factors that influenced gluteus maximus activation, and suggested that clinicians consider trunk position relative to the base of support and the direction of movement as key factors. ■ The exercise with the highest gluteus maximus activation was the forward step up, with very high activation (>60% of maximal voluntary isometric contraction [MVIC]) (**Fig. 14-1**). ■ Variations of the lunge (except the lunge with backward trunk lean), squat, and dead-lift had moderate (21% to 40% MVIC) to high (41% to 60% MVIC) levels of gluteus maximus activation.
Gluteus medius activation	■ As part of Reiman's systematic review of the literature, gluteus medius activation was also analyzed. The exercises with very high gluteus medius activation were the side-bridge to neutral spine position and the single-limb squat.[111] ■ In a laboratory study, Distefano reported that the single-leg squat and single-leg dead-lift strongly activated both the gluteus maximus and medius.[112]

KC, kinetic chain; ACL, anterior cruciate ligament.

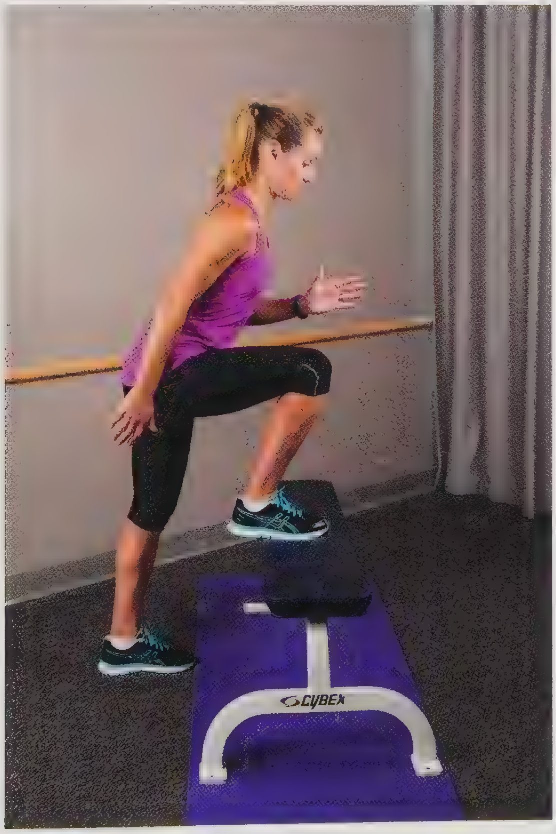


FIGURE 14-1 High step up to elicit gluteus maximus activation.

APPLYING THERAPEUTIC MOVEMENT

In general, biological systems, including humans, are complex, nonlinear systems with inherent variability in all healthy organisms.

—*Jan Walleczek*[113]

The quote above underscores the need for clinicians to not only treat individuals rather than generic pathologies, but also to ensure that intervention choices and application of therapeutic movements will facilitate a KC that addresses activity limitations and participation restrictions. The practical implication is that the exercises described in the following exercises serve as a starting point for exploration between clinician and patient. The patient's unique capabilities and goals guide the process, but clinicians that promote KC responsiveness to a wide-range of movement environments will add value (see **Case Studies 14-2**, **14-3**, and **Building Block 14-8**)

Selected KC exercises techniques are presented in this section to highlight key factors of execution and provide a theoretical framework for progression. The series of exercises begins with the hip hinge (**Self-Management 14-1**), an important component of squatting. From the squat in parallel stance, among the most functional of movements, the progression incorporates asymmetric stance activities (**Self-Managements 14-2** to **14-4** starting on page 372). Those exercises provide an opportunity for the clinician to manipulate each of the factors of progression discussed in Display 14-2.

CASE STUDY 14-2

Patient Case Study #2: Patient is a 60-year-old female who complaints of bilateral medial plantar heel pain L > R. The patient complains of significant heel pain the first thing in the morning or when she arises in the middle of the night requiring her to "shuffle to the bathroom." Once she is up and moving her heel pain subsides unless she is on her feet for sustained activities or for a prolonged amount of time. Pain is rated at a 6 on a 0 to 10 scale. Footwear includes 3-year-old casual shoes, open toe sling back sandals with a 1-inch heel, "unbranded" 2-year-old walking shoes.

PMH: Type II diabetic ×5 years controlled by diet and exercise. L bunionectomy ×2 years ago; high blood pressure which is controlled with medication.

Obs: Mild truncal obesity. Patient demonstrates a bilateral Trendelenburg gait pattern, with a wide base of support and an increase in the toe out angle of her gait. Additionally her gait reveals excessive and prolonged subtalar joint pronation with midfoot collapse throughout stance resulting in abduction of the forefoot on the rearfoot and loss of medial longitudinal arch height. During the later part of the propulsive phase of the gait cycle the patient demonstrates a medial heel whip thus shifting her weight to the lateral aspect of her foot.

MMT: Normal throughout except: B hip abd 4–/5, hip er 3+/5, hip ext 4–/5

ROM: Normal throughout except: B decreased talocrural joint dorsiflexion by 50% and decreased hip internal rotation and extension by 50%.

Non–weight-bearing FF to RF foot alignment: perpendicular

Weight-bearing alignment: B anterior pelvic tilt, with slight hip flexion, internal medial femoral rotation, knee valgus, external tibial rotation, calcaneal eversion, and lowered medial longitudinal arch.

Weight-bearing examination: neutral (subtalar neutral) calcaneal position 2 degrees varus, relaxed calcaneal position 10 degrees everted. Navicular drop (sit to stand) > 10 mm.

Activity Limitations:

1. Very painful first few steps in the morning
2. Patient unable to walk more than ¼ mile without stopping to rest.
3. Patient unable to be weight bearing longer than 20 minutes.

Participation Restrictions:

1. Patient unable to maintain household and perform gardening activities and volunteer activities.
2. Patient unable to participate in her regular exercise program, both a primary social outlet and necessary to control her type II diabetes.

CASE STUDY 14-3

Patient Case Study #3: Patient is a 17-year-old female high school soccer player who complains of R posterior lateral hip pain ×2 weeks, diagnosed withgreater trochanteric bursitis. The patient complains of hip pain while running which is worse when she begins running. Once she is warmed up and moving her hip, pain subsides unless she's on her feet for sustained activities or for a prolonged amount of time. Pain is rated at a 6 on a 0 to 10 scale. She is pain-free with NWB activities. She is trying to win a college scholarship in soccer.

PMH: Unremarkable, tonsillectomy age 5-year old.

Obs: Patient demonstrates a bilateral Trendelenburg gait pattern, with a wide base of support and an increase in the toe out angle of her gait. Additionally her gait reveals excessive and prolonged subtalar joint pronation with midfoot collapse throughout stance resulting in abduction of the forefoot on the rearfoot and loss of medial longitudinal arch height. During the later part of the propulsive phase of gait the patient demonstrates a medial heel whip thus shifting her weight to the lateral aspect of her feet.

MMT: Normal throughout except: B hip abd 4–/5, hip er 3+/5, hip ext 4–/5

ROM: Normal throughout except: B decreased talocrural joint dorsiflexion by 50% and decreased hip internal rotation and extension by 30%.

Non–weight-bearing FF to RF alignment FF varus 10 degrees

Weight-bearing alignment: B anterior pelvic tilt, with slight hip flexion, internal medial femoral rotation, knee valgus, external tibial rotation, calcaneal eversion and lowered medial longitudinal arch.

Weight-bearing examination: neutral (subtalar neutral) calcaneal position vertical, relaxed calcaneal position 10 degrees everted. Navicular drop (sit to stand) >10 mm.

Activity Limitations:

1. Patient unable to walk/run more than 10 minutes without stopping to rest.
2. Patient unable to be weight bearing longer than 20 minutes.

Participation Restrictions:

1. Patient unable to participate in her regular exercise program, both a primary social outlet and possible scholarship for college soccer.

BUILDING BLOCK 14-8

Consider the patients in Case Studies No. 2 and No. 3 to answer the following questions.

1. What are the common examination findings between both case studies?
2. What examination findings are different and significant to abnormal gait?
3. Using the principles of CKC function, how does the influence of the weak hip musculature in Case Study No. 2 contribute to her pathology? Does the pathology match her abnormal closed chain mechanics?
4. Using the principles of CKC function, how does the influence of the forefoot varus alignment in Case Study No. 3 contribute to her pathology? Does the pathology match her abnormal closed chain mechanics?
5. Describe two hip CKC exercises in the frontal plane to improve the valgus position at the knee.

SELF-MANAGEMENT 14-1
Hip Hinge to Squat

Purpose: To promote good alignment and neuromuscular control of the spine by using the hips to initiate movement. As the exercise progresses to a squat, it also serves to strengthen the legs.

Precautions and Contraindications: Limited weight-bearing status; pain on exertion.

Position: Stand in a tall posture with the feet wide enough to allow comfortable squatting. The feet may be directed straight ahead or rotated out for comfort. Initially, the buttocks are a few inches from the wall, trunk muscles are lightly engaged, the pelvis is in neutral, and the knees are straight but not locked backward.

Movement Technique:

- Direct the buttocks backward to lightly touch the wall, allowing the trunk to angle slightly forward.
  - To keep the trunk straight, pretend there is a stick connecting the back of the head, spine, and tailbone.
- Return to the starting position and repeat. Gradually step further from the wall.
- Progress to a squatting movement that includes flexing of the knees. You may use a chair to serve as a target for the squat depth.
- Alternately, you may use weights in the hands to simulate lifting of an object from the floor.
  - During the squat, pretend the knee caps are flashlights and your control of the movement keeps them shining in line with the direction the feet are pointing.
- Maintain rhythmic breathing and fluid movements.

Dosage:

Repetitions: ______________________

Frequency: ______________________

SELF-MANAGEMENT 14-2
Split Squat to Runner's Pose

Purpose: To promote good alignment and neuromuscular control of the spine and lower extremities; enhance balance and coordination; and promote leg strength/power.

Precautions and Contraindications: Limited weight-bearing status; impaired balance; pain on exertion.

Position: Split stance with the trunk muscles lightly engaged, the spine aligned, and the pelvis in neutral as well as squared to the front. The front foot is flat, with the rearward heel off the ground. Width of the foot placement should promote a balanced stance. Hands may be on the hips, at the side, or overhead (most challenging variation).

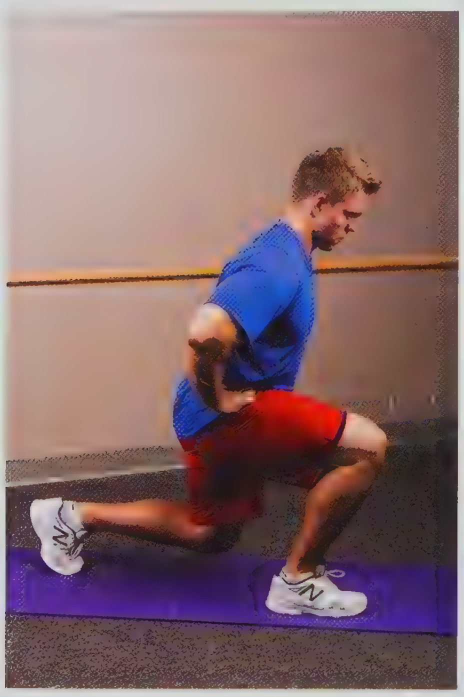
Movement Technique:

- Lower the body to a comfortable depth.
  - Pretend there is a stick connecting the back of the head, spine, and tailbone. The stick/trunk tilts slightly forward to maintain the majority of body weight on the front leg.
  - Pretend the front-leg knee cap is a flashlight and your control of the movement keeps it shining straight ahead.
- Return to the starting position by pressing through the entire foot of the forward leg.
- To progress this exercise, raise out of the split squat directly into a SLS on the front leg (runner's pose), pause for 1 to 3 seconds, then return to the split squat all in one motion.
  - Note the change in arm position
- Maintain rhythmic breathing and fluid movements.

Dosage:

Repetitions: ____________________

Frequency: ____________________



SLS, single-leg stance.

SELF-MANAGEMENT 14-3
Forward and Diagonal Lunge

Purpose: To promote good alignment and neuromuscular control of the spine and lower extremities; enhance balance and coordination; and stimulate leg strength/power.

Precautions and Contraindications: Limited weight-bearing status; impaired balance; pain on exertion.

Position: Stand in a tall posture with the trunk muscles lightly engaged, the pelvis in neutral, and the knees straight but not locked backward. Hands may be on the hips, at the side, or overhead (most challenging variation).

Movement Technique:

- Step forward and lower the body to a comfortable depth (**Fig. A, B**).
  - Pretend there is a stick connecting the back of the head, spine, and tailbone. The stick/trunk tilts slightly forward to maintain the majority of body weight on the front leg.
  - Pretend the front-leg knee cap is a flashlight and your control of the movement keeps it shining straight ahead.
- Return to the starting position by pressing through the entire foot of the forward leg and springing backward.
  - The stick/trunk remain tilted slightly forward throughout the movement.
- Alternatively, perform a walking lunge by stepping forward with the back leg.
- For the diagonal lunge, step forward and laterally (about 45 degrees), keeping the front foot entirely on the ground and pointed forward (**Fig. C**).
  - Allow the rearward foot to pivot naturally as the arm reaches across the body.
- Increase the challenge by adding trunk rotation and/or additional load such as a weighted ball (**Fig. D, E,** and **F**).
- For each of the lunges, maintain rhythmic breathing and fluid movements.

Dosage:

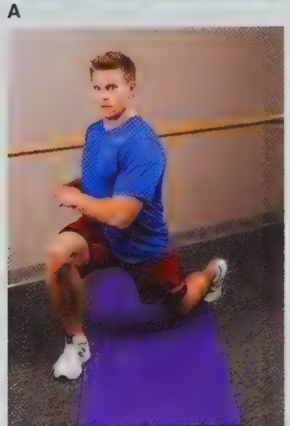
Repetitions: ______________________

Frequency: ______________________


A


B


E


C


D


F

SELF-MANAGEMENT 14-4
Single-Leg Run and Reach

Purpose: To promote good alignment and neuromuscular control of the spine and extremities; enhance balance and coordination

Precautions and Contraindications: Limited weight-bearing status; impaired balance; pain on exertion

Position: Stand in a tall posture on the right leg, with the trunk muscles lightly engaged, the pelvis in neutral, and the stance knee straight but not locked backward. The left leg is flexed to 90 degrees at the hip and knee. The left hand is at the side, whereas the right hand is at chin level. Both elbows are bent to 90 degrees

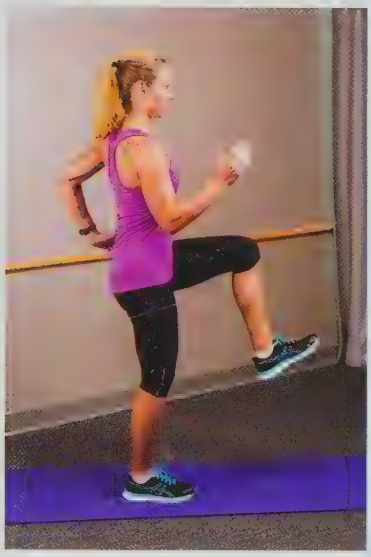
Movement Technique:

- Extend the left leg behind you while allowing the trunk to lean forward. As the trunk leans forward, reach forward/overhead with the left arm while the right arm reaches rearward to come in line with the trunk and left leg.
  - Pretend there is a stick connecting the back of the head, spine, and tailbone.
  - Gaze to a point on the floor that is 2 to 3 inches forward of your stance foot.
  - At the end of the reach, the pelvis is squared with the floor (a stick laying across the lower back would be parallel with the floor) and the elbows are straight.
- Hold the end range for 1 to 3 seconds, then return to the starting position. Perform the prescribed number of repetitions, then repeat on the opposite leg.
- Maintain rhythmic breathing and fluid movements.
- Extend the left leg behind you while allowing the trunk to lean forward. As the trunk leans forward, reach forward/overhead with the left arm while the right arm reaches rearward to come in line with the trunk and left leg.

Dosage:

Repetitions: ____________________

Frequency: ____________________



A series of exercises that place additional demands on the trunk and upper extremities are included in **Self-Managements 14-5** to **14-7** and **Figure 14-2A** and **B**. The KC exercise examples then conclude with a selection of plyometric and agility exercises (**Fig. 14-3A** and **B**; **Self-Managements 14-8** and **14-9**). Even though plyometric and agility exercises place high demands on movement control and high levels of tissues stress at various regions of the KC, they also offer the clinician the opportunity to promote motor learning through the skillful use of feedback.

SELF-MANAGEMENT 14-5
Wall Plank with Leg Raises

Purpose: To promote good alignment and neuromuscular control of the spine and extremities; strengthen lower leg muscles.

Precautions and Contraindications: Limited weight-bearing status; pain on exertion.

Position: Stand facing a wall with the trunk muscles lightly engaged, the pelvis in neutral, the spine and lower extremities aligned, and the stance knee straight but not locked backward. The arms are extended to support leaning into the wall.

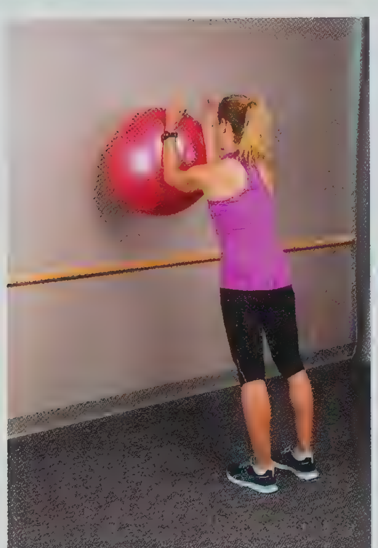
Movement Technique:

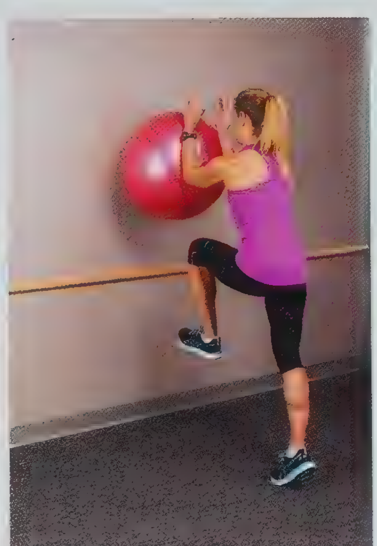
- Lift one knee toward the wall to about hip level while the heel of the stance leg raises off the ground. Hold for 1 to 3 seconds, then return to the starting position.
- Pretend there is a stick connecting the back of the head, spine, and tailbone.
- Perform the prescribed number of repetitions, then repeat on the opposite leg.
- To increase the stability requirement, lean into an exercise ball placed against the wall at about shoulder height, (contacting the ball with your forearms).
- Maintain rhythmic breathing and fluid movements.
- Lift one knee toward the wall to about hip level while the heel of the stance leg raises off the ground. Hold for 1 to 3 seconds, then return to the starting position.

Dosage:

Repetitions: ____________________

Frequency: ____________________





SELF-MANAGEMENT 14-6
Resisted Side Step and Reach

Purpose: To promote neuromuscular control of the spine and shoulder girdle.

Precautions and Contraindications: Limited weight-bearing status; pain on exertion.

Position: Stand facing along a wall from which an elastic band is anchored. Hold the other end of the band with both hands at the middle of the chest. The trunk muscles are lightly engaged and the pelvis is in neutral.

Movement Technique:

- Crouch slightly, then side step away from the wall.
  - Pretend there is a stick connecting the back of the head, spine, and tailbone.
  - Pretend you have lights on your knee caps and center of the chest, with all lights shining directly ahead.
- When you feel significant resistance from the band, stop and straighten the elbows, maintaining the hands directly forward.
- Hold for 1 to 3 seconds, slow side step back to the wall, then rise out of the crouch to return to the starting position.
- Perform the prescribed number of repetitions, then repeat in the opposite direction.
- Maintain rhythmic breathing and fluid movements.

Dosage:

Repetitions: ______________________

Frequency: ______________________

SELF-MANAGEMENT 14-7
Diagonal Ball Swings

Purpose: To promote good alignment, neuromuscular control, strength, and coordination of the spine and extremities.

Precautions and Contraindications: Limited weight-bearing status; pain on exertion.

Position: Stand in a tall posture with the trunk muscles lightly engaged and the pelvis in neutral. With both hands, hold a medicine ball or other appropriately weighted object above the right shoulder. The right foot is flat and supporting most of the body weight; the right knee is straight but not locked backward; the left heel is off the ground.

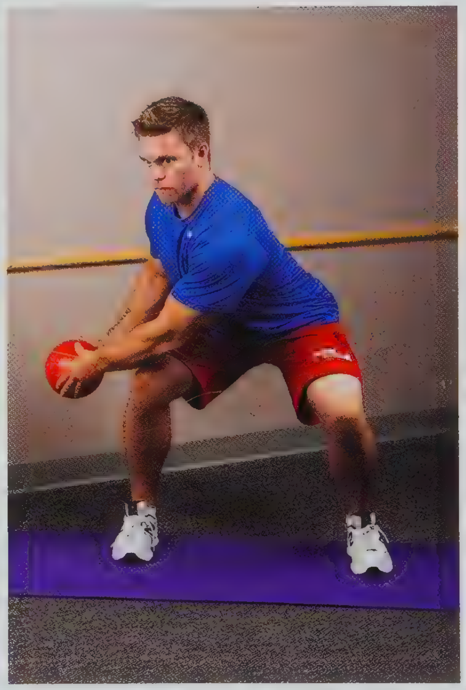
Movement Technique:

- In one motion, swing the ball down and across the body to end just outside the left thigh.
  - Allow your body to crouch as you break the momentum of the ball.
- Return to the starting position and a tall posture.
- Perform the prescribed number of repetitions, then repeat in the opposite direction.
- Maintain rhythmic breathing and fluid movements.
  - Stiffen the body to brake the momentum of the ball at both end range positions, but allow flowing movements during the ball swing.

Dosage:

Repetitions: ____________________

Frequency: ____________________



A B

FIGURE 14-2 **(A)** and **(B)** Reciprocal, rotational push pull with cables reinforces trunk stability with upper extremity functional movement patterns.

A B

FIGURE 14-3 **(A)** and **(B)** Agility drills focusing on proper landing within a specified target.

SELF-MANAGEMENT 14-8
Jump and Reach

Purpose: To promote good alignment, neuromuscular control, power, and coordination of the spine and extremities.

Precautions and Contraindications: Limited weight-bearing status; pain on exertion; insufficient strength to manage the high landing forces associated with this exercise.

Position: Stand in a tall posture with the trunk muscles lightly engaged, the pelvis in neutral, and the knees straight but not locked backward.

Movement Technique:
- Quickly crouch, then jump high while reaching overhead.
- Upon reaching maximum jump/reach, quickly bring the arms back down while preparing the legs to absorb the landing like springs.
  - During the landing and preparation to jump, pretend the knee caps are flashlights and your control of the movement keeps them shining straight ahead.
- Return to the starting position and perform the prescribed number of repetitions. Alternatively, your therapists may ask you to perform a continuous series of jumps without pause.

Dosage:

Repetitions: ______________________

Frequency: ______________________

SELF-MANAGEMENT 14-9
Lateral Hops

Purpose: To promote good alignment, neuromuscular control, power, and coordination of the spine and extremities.

Precautions and Contraindications: Limited weight-bearing status; pain on exertion; insufficient strength to manage the high landing forces associated with this exercise.

Position: Stand in a tall posture with the trunk muscles lightly engaged, the pelvis in neutral, and the knees straight but not locked backward.

Movement Technique:

- Step to your right side and quickly crouch on the right leg, with the left arm reaching across the body and the left leg lifted to the rear.
- Without pause, quickly hop to the left, landing in a crouch on the left leg, with the right arm crossing the body to the front.
  - During the landing and preparation to jump, pretend the leg is a shock-absorbing spring and the knee cap is a flashlight shining straight ahead.
  - Think of the landing spots as boundaries, and your body as staying within those boundaries.
- Perform the prescribed number of repetitions without pausing between hops.

Dosage:

Repetitions: ____________________

Frequency: ____________________

Most neuromuscular training programs designed to prevent ACL injury risk have used plyometric exercises, with verbal or visual feedback. Despite the fact that these programs have been effective to at least some degree in altering landing patterns in the frontal plane,[55,95,114] ACL injury incidence remains high.

Some researchers have expressed concern that techniques learned in rehabilitation or training program might not transfer well to the highly variable events that occur during athletics, and that improvements in feedback methods might facilitate better carryover effects.[115] Traditionally, internal feedback (focus on the movement) has been used more than external feedback (focus on the effect of the movement). However, an internal focus on the movement might constrain the motor system by disrupting automatic control processes.[116] To improve feedback during motor control training, Benjaminese and colleagues have suggested increased use of externally focused feedback.[115] Although much of their novel work has used technologies that might be cost prohibitive for many clinicians, dyad training using peers or a rehabilitation specialist to demonstrate the desired movement pattern has been suggested as a low-cost alternative.[117] During such training, clients observe effective execution of the goal movement, then attempt to mimic the movement with minimal if any instruction, though feedback is offered afterward (see Chapter 3 and **Self-Management 14-10** to **14-15**).

SELF-MANAGEMENT 14-10
First Ray Stability–Windlass Mechanism

Purpose: To strengthen the muscles supporting the arch of your foot.

Precautions and Contraindications: Pain on exertion, acute injury.

Position: Begin seated, progress to normal walking stride

Movement Technique: Maintain arch height.
Extend *only* the hallux.

Gently push the knuckle of your big toe into the floor.

Hold for ___ seconds.

Dosage:

Repetitions: ______________________

Frequency: ______________________

Starting position

Ending position

SELF-MANAGEMENT 14-11
Subtalar Joint and Midtarsal Joint Pronation

Purpose: To improve controlled movement of your heel and the arch of your foot.

Precautions and contraindications: Pain on exertion, acute injury.

Position: Begin seated, progress to normal walking stride.

Movement Technique: Extend *only* the lateral four toes in a smooth and controlled manner.

Gently try to lift the lateral border of your foot off the floor.

Take ___ seconds to complete this exercise.

Dosage:

Repetitions: ______________________

Frequency: ______________________

Starting position

Ending position

SELF-MANAGEMENT 14-12
Controlled Subtalar Joint Pronation

Purpose: To promote controlled movement of your heel and improve your balance.

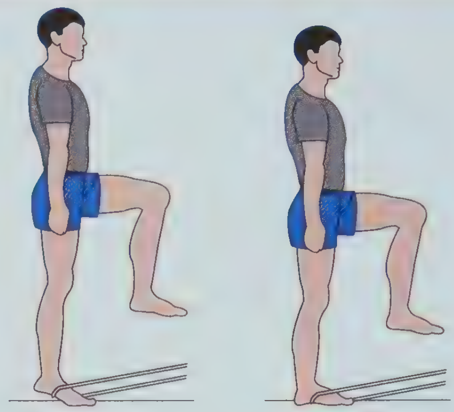
Precautions and Contraindications: Pain on exertion, acute injury, severe balance disorder.

Position: SLS

Movement Technique: Place the elastic band around the mid-foot or leg and anchor it medially to an immovable object. Ensure sufficient tension in the elastic to pull the foot toward pronation/lowering of the arch.

Perform heel raising and lowering with the knee straight but not locked and aligned with the 2nd/3rd toes.

Maintain the arch of the foot and ensure all toes remain on the ground throughout the movement.



Starting position *Ending position*

Dosage:

Repetitions: ______________________

Frequency: ______________________

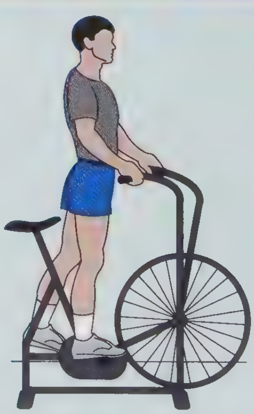
SELF-MANAGEMENT 14-13
Quadriceps Strengthening 0 to 30 Degrees (Standing Stationary Cycling)

Purpose: To strengthen the muscles around your knee and in the front part of your thigh.

Precautions and Contraindications: Pain on exertion, acute injury, balance difficulties.

Position: Standing on the pedals of the bike.

Movement Technique: Begin pedaling in an upright position. Use the quadriceps muscle to control the knee as it moves into extension.



Dosage:

Repetitions: ______________________

Frequency: ______________________

SELF-MANAGEMENT 14-14
Glenohumeral Dynamic Stability

Purpose: To stabilize the muscles around your shoulder as your shoulder pain lessens

Precautions and Contraindications: Pain on exertion, acute injury

Position: Quadruped injured hand weight bearing on soft 6-inch ball

Movement Technique: Weight shift on to injured arm and move ball in sagittal, frontal, and transverse planes

Enhance dynamic stability with controlled mobility by using axial compression and a moveable boundary

Dosage:

Repeat: ______________ seconds per minute

Frequency: ______________

Starting position

Ending position

SELF-MANAGEMENT 14-15
Thoracic Spine Extension Glenohumeral Joint Stability

Purpose: To improve the mobility of your thoracic spine and stability of your shoulder to improve your posture

Precautions and Contraindications: Pain on exertion

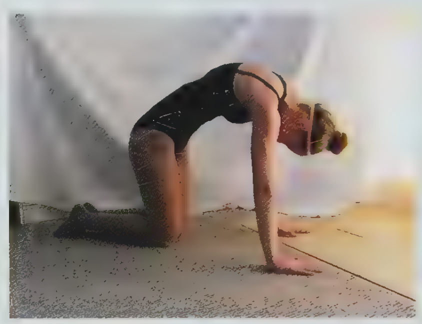
Position: Quadruped

Movement Technique:
Tighten abdominal muscles
Push into the floor spreading the area between your shoulder blades
Bring the top of your head and tailbone toward each other
Hold for 15 to 30 seconds
Reverse the movement squeezing the shoulder blades together sinking in the area between your shoulder blades
Lengthen through the top of your head and tailbone
Hold for 15 to 30 seconds
Repeat the exercise trying to move one vertebra at a time

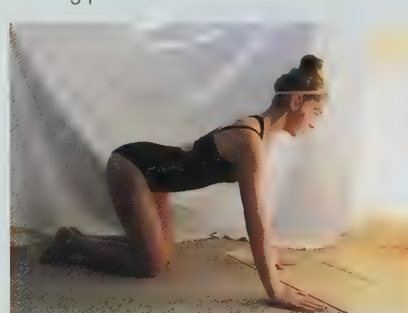
Dosage:

Repetitions: ______________

Frequency: ______________



Starting position



Ending position

LAB ACTIVITIES

1. The patient's base of support in any posture influences movement proficiency. Modify the base of support in various postures (e.g., quadruped, seated, standing) and observe the effect on movements.
2. The degree of neuromuscular activation also influences movement proficiency. Consider verbal, visual, and tactile cues to alter your patient's neuromuscular activation for more proficient execution of the following tasks:
   a. During an overhead reach, you notice that your patient moves from pelvic neutral into excessive anterior pelvic tilt.
   b. Your patient's split squat includes excessive knee valgus of the forward leg.
   c. Gait evaluation reveals that your patient fails to achieve hip extension or ankle dorsiflexion in terminal stance, despite adequate active and passive motion demonstrated previously at those joints.
3. To promote an external focus of attention, simply cue your client to objects in the environment (e.g., "as you step, direct your knee toward the cone) or prompt imagery that promotes the intended performance (e.g., "land as light as a feather"). Develop verbal or visual prompts that promote an external focus of attention to enhance the patient's motor learning of the following movements:
   a. Quadruped, reciprocal arm and leg lift
   b. Sit-to-stand-sit
   c. Diagonal step and cross-body arm reach
4. Using the factors of exercise selection and progression in Display 14-2, evaluate the relative need for each of those factors for:
   a. A gardener
   b. A tennis player
   c. A soldier
5. Consider the plane in which you will start activities and rehabilitation exercises for patient's recovering from the conditions listed below. Identify exercises that will provide low, medium, and high stress to the injured tissue. For the most challenging movements in your exercise progression, consider how you will mitigate the risk for reinjury.
   a. Inversion ankle sprain
   b. Medial collateral ligament injury of the knee
   c. L5 pars defect with anterior spondylolisthesis

KEY POINTS

- Kinetic chain (KC) performance is a product of all movement subsystems.
- The functionality of the KC must be considered in light of the physical demands of the patient's environment and their activity limitations and participation restrictions.
- Evaluation of the KC as whole, together with evaluation of its components, informs the assessment of the patient's problem and guides interventions.
- Kinetic chain interventions that include significant variety and focus on the effect of the movement rather than the movement itself are likely to offer the best outcomes.

CRITICAL THINKING QUESTIONS

1. Consider Case Study 14-1 on page 361.
   a. Describe the relationship between this patient's foot posture in weight bearing and during gait to theorize the cause of his symptoms.
   b. Given the concept of musculoskeletal regional interdependence, how might proximal factors influence or be associated with the findings at this patient's foot?
   c. Describe the first phase of the rehabilitation program for this patient. Where would your attention be directed first and why?
   d. Assuming that the patient improves in a linear fashion, how would you progress him back to work and recreational activities? How would you prioritize these and incorporate these goals into his treatment program?
2. Consider Case Study No. 4 in Unit 7.
   a. Describe the relationship between his shoulder and neck symptoms from a regional interdependence perspective. Would you prioritize neck or shoulder intervention or treat them simultaneously? Why?
   b. Design three exercises that the patient can do at home to improve mobility for:
      1. primarily shoulder
      2. primarily neck
      3. integrated neck and shoulder together
   c. When would you start strengthening exercise for the neck, shoulder, or both? Describe three beginning exercises for each key area.
3. Consider Case Study No. 6 in Unit 7.
   a. Describe the relationship between this patient's knee mobility impairment and its effect on the ipsilateral hip, ankle, and subtalar joints.
   b. Choose one of this patient's short- or long-term goals and design three different exercises you might use to address this goal.
   c. Design a return to activity progression.

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CHAPTER 15

Proprioceptive Neuromuscular Facilitation

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HISTORY AND BACKGROUND

The foundation for proprioceptive neuromuscular facilitation (PNF) was initially established by neurophysiologist Sir Charles Scott Sherrington in the early 20th century in his published work "On Plastic Tonus and Proprioceptive Reflexes,"[1] which delineated inhibitory and excitatory neurophysiologic properties of the neuromuscular system. These principles were further developed by neurophysiologist Dr. Herman Kabat near the mid-1940s, who at that time called it "proprioceptive facilitation" and published his initial papers using this term.[2] In 1946, Dr. Kabat began to look for natural movement patterns for rehabilitating the muscles of patients affected by polio and soon thereafter discovered that typical human movement patterns involved diagonal patterns employing multiple muscles and joints. Prior to "proprioceptive facilitation," rehabilitation was typically done one joint and one muscle at a time.

Around 1946, Dr. Kabat joined Henry J. Kaiser, an American Industrialist, in forming the Kaiser-Kabat Institute in Washington, DC, and around that same time joined with physical therapist Maggie Knott to work with him using his "proprioceptive facilitation" principles with patients with neurologic disorders such as cerebral palsy and hemiparesis. In 1948, the Kaiser-Kabat Institute opened in Vallejo, CA, now known as the Kaiser Foundation Rehabilitation Center, and Dr. Kabat and Maggie Knott moved westward to work at the Kaiser-Kabat Institute in Vallejo. That same year Maggie Knott began to teach other physical therapists about the neuromuscular principles involving "proprioceptive facilitation" and postgraduate training began with therapists coming from all over the world to learn these new principles and training techniques. Dorothy Voss was one of the first students to be trained and then joined Dr. Kabat and Maggie Knott at the Kaiser-Kabat Institute. In 1954, Dorothy Voss and Maggie Knott published the first paper in the scientific literature that used the term "proprioceptive neuromuscular facilitation" (PNF),[3] and the term PNF continues to be used to the current day.

Dr. Kabat and physical therapists Maggie Knott and Dorothy Voss continued to develop and refine the PNF principles we know today. In 1956, Maggie Knott and Dorothy Voss wrote and published the first edition of their textbook entitled "Proprioceptive Neuromuscular Facilitation". With a PNF textbook available, United States-based physical therapy programs began teaching PNF principles and techniques to their students in the 1960s. Today, PNF concepts, principles, and procedures continue to be taught to physical therapy students. Moreover, PNF is required to be taught in all Physical Therapy Education programs in the United States, as it is included in the Normative Model, established by the Committee on Accreditation of Physical Therapy Education.

Scientific publications related to PNF were first published in the 1950s.[2–9] Although PNF techniques were used to assess joint range of motion (ROM), reaction and response times, and muscle flexibility and strength, throughout the 1970s,[10–12] there were few research papers published in the scientific literature related to PNF. Therefore, even though some 30 years had passed since the advent of PNF, less than 20 papers were published in a handful of peer-reviewed scientific journals, so the evidence for the efficacy of using PNF for patients was quite limited. As such, PNF was considered much more of an art than a science.

There were as many PNF papers published in the scientific literature in the 1980s as there were in the previous 30 years combined. Many of these papers focused on improving ROM and muscle length using PNF stretching techniques.[13–18] For the first time, PNF techniques were appearing in sports physical therapy and sports medicine journals and being compared to traditional weight training for enhancing strength and athletic performance and minimizing sports injuries.[15,19] For example, Nelson et al.[19] reported that PNF resistance training resulted in greater gains in knee and elbow extensor strength, throwing distance, and vertical jump when compared to weight training.

PHILOSOPHY AND PRINCIPLES OF PNF

Proprioceptive neuromuscular facilitation uses proprioceptive input (sensory receptors found in muscles, tendons, joints, and the inner ear that detect body and limb motion or position) to improve (facilitate) neuromuscular function during human movement.[2,5] Neuromuscular function is enhanced by providing resistance during concentric, eccentric, and isometric muscle actions, thereby enhancing muscle strength and endurance, balance, posture, stability, and mobility. Neuromuscular function is also enhanced during stretching techniques, thus improving joint ROM and muscle length (flexibility).

The basis of the PNF philosophy is the idea that all individuals, regardless of their disease and disabilities, have untapped existing potential.[5] The treatment approach is always positive and focuses on what the patient can do, on a physical and psychologic level. The PNF approach is holistic, integrating sensory, motor, and psychologic inputs to ensure every treatment is directed toward the individual, not a specific problem. PNF attempts to provide a maximal response for increasing muscle performance, flexibility, balance, coordination, functional mobility, and functional performance. PNF patterns are more concerned with movements that require use of multiple muscles and joints as opposed to specific, isolated muscle actions. These patterns are composed of both diagonal and rotational exercise patterns that are similar to the motions required for activities of daily living (e.g., eating, rolling, scooting), functional mobility, and even athletic performance (e.g., using D1 and D2 diagonal patterns to enhance baseball pitching).

Although there are over 100 different PNF patterns, handholds, variations, and modifications as well as terminology, the most important thing is to understand the use of the appropriate procedures and basic techniques. This chapter discusses how to utilize PNF patterns in a simplified form to allow the learner to practice utilization of manual therapy. For further refinement of PNF skills, the learner is encouraged to pursue postgraduate continuing education.

PNF PHYSIOLOGY AND APPLIED CONCEPTS

A number of physiologic principles underlie the theory and application of PNF. These include principles to increase muscle performance (i.e., irradiation), muscle length (i.e., autogenic inhibition, reciprocal inhibition, stress relaxation), and pain (gate control theory of pain).

Irradiation refers to the overflow of response to a stimulus. This response can facilitate or inhibit a contraction in the synergistic muscles and patterns of movement; the muscular response will increase as the intensity and duration increase[1,4,5] (**Table 15-1**). Therefore, in theory, weaker muscle groups may gain strength from stronger muscles while working synergistically in muscle groups or movement patterns. For example, while performing a lower extremity diagonal PNF resistance pattern that involves hip flexion and ankle dorsiflexion, stronger hip flexors may facilitate weaker ankle dorsiflexors as overflow proceeds from proximal to distal. An overflow of response to a stimulus has also been investigated on the uninvolved contralateral side.[20–22] Gontijo and colleagues[22] demonstrated that trunk flexion and extension motions generate irradiated strength in the ankle dorsiflexors and plantar flexors, *respectively*. This technique may be helpful in certain patient populations (e.g., patients with hemiparesis) who cannot activate the dorsiflexors or plantar flexors directly. Cross education effects have also been demonstrated using PNF techniques in which activating muscles as a limb (e.g., right upper extremity) moves against resistance also activates muscles in the contralateral nonworking limb (e.g., left upper extremity).[20,21] This may facilitate healing or strengthening in limbs that cannot (hemiparetic) or should not (injury) work directly against resistance.

Four theoretical physiologic mechanisms for increasing ROM and muscle length with PNF stretching are (1) autogenic inhibition, (2) reciprocal inhibition, (3) stress relaxation, and (4) the gate control theory (via pain mechanisms).[23,24]

Autogenic inhibition is a decrease in a muscle's excitability because of inhibitory signals sent from the golgi tendon organ (GTO) of the muscle because of muscle contraction. The higher the muscle's tension the greater the inhibition. For example, contracting the hamstrings isometrically prior to stretching stimulates the GTOs in the hamstrings, causing inhibition of the hamstrings. This results in enhanced relaxation in the hamstrings during the subsequent hamstrings stretch. Hold-relax (HR) is based upon the theory of autogenic inhibition.

Reciprocal inhibition is a neurophysiologic phenomenon in which the contraction of agonist muscles causes a concurrent inhibition of their antagonist muscles. For example, when the knee flexors (agonists) actively flex the knee, the knee extensors (quadriceps) are reciprocally inhibited. This causes decreased activity in the quadriceps that are being stretched. When alpha motor neurons are provided excitatory stimulation in the agonists, the alpha motor neurons that control the antagonistic muscles are concurrently inhibited. Another example is stretching the left upper trapezius. When the neck is actively sidebent to the right (via the right upper trapezius), the right upper trapezius sends inhibitory signals to the left upper trapezius, fostering relaxation of the left upper trapezius.

TABLE 15-1

Summary and Examples of Physiologic Basis for PNF

PNF TECHNIQUE	DEFINITION	EXAMPLE
Irradiation	Overflow of the response to the stimulus to synergists.	The clinician resists submaximal dorsiflexion to enhance quadriceps contraction prior to performing a straight leg raise in a patient status post ACL reconstruction who is having difficulty performing a QS/SLR.
Reciprocal Inhibition	Contraction of the agonist results in a concurrent inhibition of the antagonist.	Contraction of the middle and lower trapezius causes a concurrent inhibition of the pectoralis major and minor muscle groups. Therefore, cueing a patient to perform gentle, isometric shoulder blade squeezes to address postural impairments results in inhibition of the pectoral muscles.
Autogenic Inhibition	The agonist (the muscle of interest) is inhibited during agonist contraction.	Contraction of the hamstrings immediately prior to stretching it will cause an inhibitory response, resulting in increased muscle length.

PNF, proprioceptive neuromuscular facilitation; ACL, anterior cruciate ligament; QS, quadriceps set; SLR, straight leg raise.

Additionally, reciprocal inhibition can be used in combination with autogenic inhibition. This is the theory behind hold-relax with agonist contraction (HR-AC). For example, to employ HR-AC for the gastrocnemius muscle, the patient would perform an isometric contraction of the gastrocnemius against resistance followed by an immediate isotonic contraction of the dorsiflexors to further lengthen the gastrocnemius. The isometric contraction of the gastrocnemius utilizes autogenic inhibition, while the active contraction of the dorsiflexors employs the theory of reciprocal inhibition.

Stress relaxation occurs when the musculotendinous unit is under a constant stretch (deformation). When held for a prolonged period of time, the stress within the tissue gradually decreases secondary to the viscoelastic properties of the musculotendinous unit, increasing the extensibility of the musculotendinous unit. A prone hang to increase knee extension following knee surgery utilizes the concept of stress relaxation. The position is held for 10 minutes or more, employing stress relaxation. Many dynamic splints utilize this theory to promote tissue elongation.

Finally, the *gate control theory* proposes that nociceptive and nonnociceptive signals are summated at the same interneuron in the spinal cord. Peripheral pain receptors have unmyelinated or small myelinated afferent fibers, while pressure receptors have larger, myelinated fibers. Since both afferent fibers connect to the same interneurons in the spine, the larger pressure afferent fibers arrive at the interneurons prior to the smaller pain fibers. This leads to inhibition of the pain signal. A classic example is stubbing your toe; pain travels on the small fibers and sends a pain signal. A natural response is to rub the affected area. Pressure and compression travel on large diameter fibers, and ultimately arrive at the interneurons prior to the pain signals traveling on the small fibers. The pain signal is masked, and the sensation of pressure is felt instead. As such, there is a scientific basis for rubbing an injured body part. This is also one theory behind patient reports of decreased pain when wearing compression sleeves for knee pain. In PNF stretching, muscles are stretched, but they also contract as part of the PNF technique. This causes a decrease in pain that is sensed which ultimately causes inhibition, produced by the GTOs. The GTOs adapt to the increase in length and force threshold, which allow for greater force production, enhancing the effectiveness of PNF stretching.[24] Although research does not directly support these four theoretic physiologic mechanisms for increasing ROM and muscle length, these theories haven't been disproven. However, there are limited data to suggest there may be additional physiologic mechanisms responsible for increasing ROM and muscle length when using PNF techniques. For example, decreases in the response amplitude of muscle stretch reflexes following a contraction of a stretched muscle may not be due to the activation of GTOs, as commonly believed, but instead may be due to presynaptic inhibition of the muscle spindle sensory signal.[25] Further research is warranted.

Research in PNF to Increase Muscle Length

Early research papers published in the 1990s related to PNF focused on stretching techniques, and successfully demonstrated that these techniques were as effective or more effective than static and ballistic stretching in increasing both passive and active joint ROM.[13,15,16,23,26–33] The concepts of contract-relax (CR), HR, and HR-AC were all reported to be effective in improving joint ROM.[13,15,16,23,28] and are defined in **Table 15-2**.

TABLE 15-2

Definitions of Classic PNF Terms

TERM	DEFINITION	EXAMPLE
Hold-Relax (HR)	The agonist is taken to its end-range position and this position is held for 10 s. The patient then performs an isometric contraction of the agonist against resistance provided by the clinician for 5–10 s. Immediately upon relaxation of the contraction, the muscle is taken further into end range.	To stretch the hamstrings, the patient lies supine, the clinician places the hip (with the knee extended) at end-range flexion (until a resistance in the hamstrings is felt). This is held for 10 s, followed by the patient contracting their hamstring for 5–10 s against resistance. When the patient relaxes, the clinician takes the leg further into hip flexion.
Contract-Relax (CR)	Similar to HR, with the exception of the rotation component. The rotators contract concentrically during this technique. The muscle is taken to a lengthened position and held for 10 s. This is followed by a concentric contraction of the rotation, followed by an isometric contraction for 5–10 s. Upon relaxation, the clinician passively moves the patient into the newly acquired length. This movement is multiplanar.	If we use the example of the hamstrings again, the patient's hamstrings (semimembranosus and semitendinosus) are biased. The leg, with the knee extended, is placed at end-range hip flexion with the hip in external rotation. This position is held for 10 s. This time, when asked to perform a contraction, the patient performs a concentric contraction, resisting rotation. This is achieved by having the patient fire the semimembranosus and semitendinosus, resulting in internal rotation of the hip. Once the hip has reached end-range internal rotation, an isometric contraction of the hip extensors as a group is performed for 5–10 s. This is followed by relaxation, where the clinician passively moves the leg into more hip flexion and external rotation.
Hold-Relax with Agonist Contraction (HR-AC)	Performed similar to HR, the patient isometrically contracts the agonist for 5–10 s against the resistance supplied by the clinician. Upon relaxation of the agonist, the patient actively contracts the antagonist isotonically to lengthen the agonist.	To stretch the hamstrings, the patient lies supine, the clinician places the hip (with the knee extended) at end-range flexion (until a resistance is felt). The patient fires their hamstrings for 5–10 s against resistance. The patient then immediately contracts their hip flexors isotonically to move the limb into more hip flexion, thereby increasing the length of the hamstrings. The clinician assists with the movement into hip flexion.

From Voss DE. Proprioceptive neuromuscular facilitation. Am J Phys Med 1967;46(1):838–899.

With each of these techniques, a contraction of the muscle of interest is performed by the patient. The intensity of this contraction does affect outcomes. In addition to improving muscle length, employing a higher intensity static contraction (e.g., 80% to 100% of maximum contraction) for 5 to 10 seconds has been shown to also result in greater muscular strength and power and improved stiffness in the musculotendinous unit.[13,15,16,23,28] Muscle length has been shown to improve with contraction durations between 3 and 15 seconds, although longer contraction durations (e.g., 10 to 20 seconds) have been shown to result in greater flexibility gains.[13,15,16,23,28] The greatest changes in flexibility generally occur after the first repetition; in order to achieve more lasting changes, PNF stretching needs to be performed at least once or twice per week.[13,15,16,23,28] It has been suggested that the increases in flexibility seen after PNF stretching may be due to increased stretching tolerance rather than actual changes in muscle length (**Evidence and Research 15-1**).

EVIDENCE and RESEARCH 15-1

Mahieu et al.[34] reported that the increased mobility observed after PNF stretching could not be explained by changes in the musculotendinous tissue that was stretched; rather, they believed the increased mobility was due to an increase in stretch tolerance. This theory was further supported by Mitchell et al.,[35] who demonstrated that an increase in stretch tolerance occurred after employing the CR PNF stretching technique. Moreover, these authors suggested that at least four repetitions of CR stretching are required to obtain the greatest gains in mobility.

Research has shown that performing PNF stretching techniques over time acutely enhances muscle length. In addition, some studies suggest that joint motion and muscle length improvements are greater with PNF stretching compared to static or dynamic stretching, whereas others show similar results.[23,24,34,36–38,39–76] Possible mechanisms for improved joint ROM and muscle length include changes in the ability to tolerate stretch and changes in the viscoelastic properties of the stretched muscle.

Most recently, a surge in performance-based PNF studies has occurred due to the interest of many strength and conditioning specialists, coaches, and athletes on the effects of static and dynamic stretching on sports performance.

In the sports environment, dynamic stretching and dynamic warm-up has replaced static stretching as a means of an athlete to warm up prior to competition. A review of the literature on the effects of stretching on performance addressed the impact of both static and dynamic stretching (**Evidence and Research 15-2**). And although dynamic stretching appears to be more beneficial than static stretching immediately prior to performance, this does not prove that static stretching is an ineffective intervention. This research simply does not recommend static stretching as an initial warm-up immediately prior to athletic competition (See Chapter 7).

EVIDENCE and RESEARCH 15-2

In a recent systematic review by Peck et al.,[77] the authors summarized the literature related to the use of static and dynamic stretching immediately prior to performance. Based upon the review of the 62 papers that met inclusion criteria, the authors made the following recommendations:

1. It is reasonable to recommend against static stretching immediately prior to strength and power activities. However, if the static stretching is followed by a general warm-up or some dynamic stretching, any negative effect on strength and power performance may be reversed, although this contention has been disputed.
2. The evidence indicates that dynamic stretching prior to a strength- and power-dominant activity is beneficial.
3. The majority of the literature suggests that static stretching prior to speed- and agility-dominant activities is detrimental to performance; however, an intervening period of a general warm-up or dynamic stretching may reverse this negative effect, similar to that seen with strength and power activities.
4. There is insufficient evidence to recommend for or against PNF stretching prior to speed- and agility-dominant activities.
5. The available evidence shows static stretching to have either no effect or a detrimental effect on endurance performance.

Because PNF stretching largely involves static stretching, it is plausible to expect the acute effects of PNF stretching on performance to at least have some similarities to the acute effects of static stretching on performance. Although increases in joint ROM and muscle length have been found, the duration of these benefits once stretching is concluded is unknown. In addition, the relationship between improvements in ROM and muscle length and stretching dosage parameters has not been established.

Research in PNF to Improve Muscle Performance

Employing PNF resistance techniques has been shown to be effective in enhancing the neuromuscular system.[78–95] Performing a reciprocal concentric contraction of a diagonal pattern such as D1 may increase the rate of force development in older individuals, which may in turn improve performance in functional activities such as stair negotiation.[95] In addition, this training may reduce the risk of falls.[95] Other PNF techniques, such as D1 and D2 (see **Tables 15-3** and **15-4** for a description of these patterns) lower and upper extremity diagonal patterns, with or without PNF stretching, have also shown to be effective in treating numerous health- and disease-related variables (**Evidence and Research 15-3**).

TABLE 15-3

PNF Summary of Upper Extremity D1 and D2 Diagonal Patterns

UPPER EXTREMITY PATTERN	D1 FLEXION	D1 EXTENSION	UPPER EXTREMITY PATTERN	D2 FLEXION	D2 EXTENSION
Scapula	Anterior elevation	Posterior depression	Scapula	Posterior elevation	Anterior depression
Shoulder	Flexion Adduction External rotation	Extension Abduction Internal rotation	Shoulder	Flexion Abduction External rotation	Extension Adduction Internal rotation
Elbow	Varies	Varies	Elbow	Varies	Varies
Forearm	Supination	Pronation	Forearm	Supination	Pronation
Wrist	Flexion	Extension	Wrist	Extension	Flexion
Fingers	Flexion	Extension	Fingers	Extension	Flexion

PNF, proprioceptive neuromuscular facilitation.

TABLE 15-4

PNF Summary of Lower Extremity D1 and D2 Diagonal Patterns

LOWER EXTREMITY PATTERN	D1 FLEXION	D1 EXTENSION	LOWER EXTREMITY PATTERN	D2 FLEXION	D2 EXTENSION
Pelvis	Anterior elevation	Posterior depression	Pelvis	Posterior elevation	Anterior depression
Hip	Flexion Adduction External rotation	Extension Abduction Internal rotation	Hip	Flexion Abduction Internal rotation	Extension Adduction External rotation
Knee	Varies	Varies	Knee	Varies	Varies
Ankle	Dorsiflexion	Plantar flexion	Ankle	Dorsiflexion	Plantar flexion
Foot	Inversion	Eversion	Foot	Eversion	Inversion
Toes	Extension	Flexion	Toes	Extension	Flexion

PNF, proprioceptive neuromuscular facilitation.

EVIDENCE and RESEARCH 15-3

The utilization of PNF resistance techniques has been documented in the literature to show effectiveness in treating numerous impairments related to many common diseases seen across the lifespan. Specifically,

- PNF stretching combined with lower extremity PNF diagonal patterns resulted in increased postural stability and balance.[96–98]
- PNF stretching both with and without aerobic exercise has demonstrated decreased pain and increased function in patients with patellofemoral pain syndrome.[99,100]
- PNF muscle relaxation and stabilization exercises decreased pain and increased function in patients with myofascial pain syndrome.[101]
- PNF pelvic patterns have resulted in decreased low back pain in obese patients.[102]
- PNF pelvic and scapular patterns resulted in increased motor function and gait symmetry during hemiparetic gait[103] and increased motor recovery in patients with chronic poststroke hemiparesis.[104]
- PNF respiratory exercises improved pulmonary function of normal adults and in patients after vertebral vascular accident.[105,106]
- PNF integration pattern exercises were more effective compared to general exercises in enhancing fall efficacy and gait ability in elderly who previously experienced injuries secondary to a fall.[107]
- PNF lower extremity techniques have been shown to increase lower extremity strength,[108–110] whereas PNF upper extremity patterns have been shown to increase the functionality of the supraspinatus.
- Compared to weight training, PNF resistance training resulted in greater gains in knee and elbow extensor strength, throwing distance, and vertical jump.[19]
- Aquatic PNF lower extremity patterns have been shown to enhance balance and activities of daily living in patients with a cerebral vascular accident.[111]

As such, incorporating appropriately applied PNF resistance techniques can be effective in improving strength, pain, postural stability and balance, motor function and gait symmetry, fall risk, performance, and patient function.

PNF PROCEDURES

The premise underlying basic PNF procedures is enhancing the patient's postural responses or movement patterns. The goal of each treatment is to facilitate or enhance a movement or posture. These procedures can be utilized with most patients regardless of medical diagnosis. The examination and evaluation will determine the specific procedures utilized as well as any necessary modifications.

Manual Therapeutic Exercise Using PNF Procedures

The clinician must utilize correct manual contacts, body positioning, verbal cues, and visual cues during PNF applications. One advantage of manual therapeutic exercise is the ability to continuously assess the patient's movement or posture. This ongoing assessment allows for immediate modification of the activity. During a treatment session, the clinician can influence the following:

- The magnitude of resistance
- The type of muscle contraction
- Traction (distraction) or compression (approximation) to a joint, promoting movement or stability, *respectively*
- The direction of the movement or pattern
- Whether the treatment is direct or indirect

Manual Contacts

The patient's response to the PNF intervention can vary based upon manual contacts and body position. Motor responses are often influenced by stimulation of skin and other peripheral receptors. The therapist can enhance the appropriate motor response through the proper use of manual contact. The patient's position must also be considered in an effort to avoid postural positions that may conflict with the desired movement (e.g., a patient with extensor tone may be placed in sidelying instead of supine when facilitating hip flexion). A few considerations regarding manual contacts:

- Strength or power: When the therapist applies proper contact to the segment being facilitated, the patient often demonstrates increased strength of contraction.
- A common grip to use is the *lumbrical grip*; this allows a broad surface of contact which controls motion, and avoids squeezing the patient (see **Fig. 15-1**).

FIGURE 15-1 Lumbrical grip.

Body Position and Mechanics

The clinician's body position and the use of good body mechanics are essential when using PNF. The clinician's body should be positioned at either end of the desired movement, and with the shoulders and hips facing in the direction of the movement. In other words, the clinician should place themselves "in the diagonal pattern." The clinician's forearms should always be pointed in the direction of the desired movement. The following key points on the use of proper body mechanics are important to provide an effective treatment and to prevent injuries to the clinician:

- The movement of the therapist must be a mirror image of the patient's movement.
- The clinician should maintain a neutral spine with movement occurring from the hips and legs.
- Weight shift should be in the direction of the movement.
- The resistance should come from the trunk and pelvis, not the extremities.

Verbal Cues

Verbal cues should be brief, clear, concise, use nontechnical jargon, and appropriate for patient comprehension. The volume of the command is dependent on the intent of the movement; the therapist should use louder commands for stronger contractions and softer commands for stability or relaxation. The timing is very important with the command usually given just before the movement takes place or repeated as needed to facilitate a weak component or for emphasis.

Visual Stimulus

Visual input increases motor neuron excitability in the muscles which are responsible for the movement. Vision facilitates coordination of the head and in turn will facilitate a stronger contraction from the trunk and extremity musculature (e.g., resisted shoulder abduction from 0 to 90 degrees will be stronger with more trunk activity when the subject is looking at and following the movement of the tested arm compared to when he or she looks away from the arm).

Appropriate Resistance

The most important fundamental basis when applying manual therapeutic exercises is the use of *appropriate resistance*. When asked how much resistance should be given, the answer is "just enough" to accomplish the desired movement pattern and training goal (e.g., strength, power, endurance, etc.) without overpowering the patient, resulting in faulty movement patterns.

Resistance is used to facilitate muscle contraction to improve motor control and strength. The magnitude of the facilitation is directly related to the amount of resistance applied. Facilitation of the agonist will increase the response of the specific muscle and synergistic muscles at the same joint and adjacent joints. When using minimal resistance, the antagonists are usually inhibited. Increasing the resistance in the agonist will cause muscle activity to increase in the antagonist groups as well, resulting in a cocontraction.

Manual therapeutic exercise allows the therapist to determine the amount of resistance that demands maximal effort from the patient without compromising the intent of the activity. The levels of resistance include passive range of motion (PROM), active assisted range of motion (AAROM), active range of motion (AROM), and resistive ROM which can be applied with graded resistance from minimal to maximal resistance; in addition, resistance can be applied to inhibit the antagonist (reciprocal inhibition). The advantage of manual resistance is that the clinician can assess and then vary the resistance throughout the range of movement depending on the patient's ability. In other words, the patient may require assistance or light resistance at the initiation of movement while resistance can increase in the mid-range followed by less resistance again at the end range. This is referred to as *accommodating resistance*.

The clinician can also select a specific range to emphasize volitional control of the patient. For example, in a patient with incomplete paraplegia, the therapist may choose to treat volitional control of hip extension from 70 to 30 degrees of flexion, knowing that at 15 degrees spasticity of the hip extensor muscles will occur.

Muscle Actions

Isotonic (dynamic) implies movement resulting from muscle contractions either from muscle shortening (concentric muscle action) or muscle lengthening (eccentric muscle action). With concentric action, the patient may be instructed to push against the clinician's hand to produce motion, resulting in shortening of the muscle. The greater the resistance applied, the greater the concentric muscle force generated. With an eccentric contraction, the patient begins with an isometric contraction in a shortened position and then controls the rate of motion, with the muscle lengthening as the therapist pulls or pushes to move the limb. The more the patient resists the therapist, the greater an eccentric muscle force is generated. Isotonic (dynamic) muscle actions produce active voluntary movement. The resistance must be applied so that the motion can occur in a smooth and coordinated manner.

Isometric implies a muscle contraction with no joint movement. The amount of resistance applied matches the force of the muscle contraction such that no joint motion occurs.

Traction and Approximation

Traction and approximation stimulate joint receptors and should be used with directional resistance. *Traction* is a manual distraction of the joint surface which promotes movement and is useful with pulling and reaching motions. *Approximation* is a manual compression of joint surfaces, facilitates cocontraction, which promotes stability; it is often used with pushing activities. Traction should be applied throughout the entire range of the agonist. Compression should be applied lightly, then progressively heavier to enhance stability.

Patterns of Facilitation

The brain generates and organizes mass movement patterns rather than individual muscle contractions. PNF utilizes mass movement patterns. Human motion is patterned and rarely involves straight plane movements because all muscles are oriented in a diagonal and spiral direction. Therefore, most human movement involves three planes of motion occurring at all joints:

- Flexion or extension: Major excursion of range
- Abduction or adduction: Medium excursion of range
- Rotation: Smallest excursion of range but the most important

With all extremity movement, whether unilateral or bilateral, there is at least a minimum amount of rotation of the trunk or pelvis. Rotation of the trunk in the spiral and diagonal pattern will produce greater strength and a longer lever arm than in the straight plane pattern. The longer the lever arm, the more efficient the movement pattern.

Quick Stretch

A quick stretch facilitates the muscle's ability to contract with greater force. The stretch reflex is evoked by a gentle but quick stretch to a muscle under tension (stimulating muscle spindles). A quick stretch can be applied in two ways. First, a quick stretch is applied to all components simultaneously of the entire pattern in its lengthened position to initiate the movement (e.g., wind-up of a pattern such as D1 extension, starting in flexion and moving into extension—hip: extension, abduction, internal rotation; knee: extension; ankle: plantarflexion, eversion, and toe plantarflexion). Alternatively, a quick stretch can be applied to a muscle that is already contracting in an effort to strengthen or evoke a response. For example, the clinician might be resisting D1 flexion in the upper extremity via slow reversal when the clinician feels the patient starts to decrease his force production. The clinician can offer a quick stretch in the middle of the movement pattern to facilitate contraction. It is important to maintain resistance immediately following the quick stretch to heighten the response. Quick stretch is a key component to PNF; however, it can be a difficult skill to master. The clinician should know the integrity of the joint capsule, ligaments, and nervous system prior to performing a quick stretch at the end ROM. If the practitioner performs quick stretch incorrectly, it may cause damage to other structures that are also on tension. As such, the clinician should only perform a quick stretch at end range once the skill is mastered as a mid-range intervention.

EVALUATION AND TREATMENT IMPLEMENTATION

Working within the PNF philosophy, the first emphasis is on what the patient *can do* in order to facilitate the functional goals. In other words, for a patient with a right hemiparesis, the clinician can utilize the strength and movement available in the left upper and lower extremity to facilitate movement, such as rolling to the right.

Be sure to note whether the patient's functional problem is *static* (inability to maintain position) or *dynamic* (loss of ability to initiate or control motion). Finally, identify the specific reason for the functional loss; that is, pain, immobility, weakness, loss of sensation, or lack of motor control. After identifying the patient's goals, determine whether treatment sessions should emphasize direct treatment or indirect treatment.

Direct Treatment

Direct treatment utilizes techniques on the affected limb, muscle, or motion (e.g., to increase right hip flexion strength the therapist may apply resistance directly on the right thigh, resisting hip flexion).

Indirect Treatment

Indirect treatment consists of the use of techniques on the unaffected limbs and muscles to facilitate the affected limbs and muscles (refer to the concept of irradiation). The literature has confirmed the effectiveness of indirect treatment initiated on the strong and pain-free part of the body to increase muscle tension and electromyographic activity on the affected parts of the body.[1,5,21–22,112] Therefore, the clinician can use techniques on the unaffected parts of the body to guide irradiation to the affected parts of the body (e.g., the patient with right hip flexor weakness, the therapist may involve the left lower extremity and resist bilateral hip flexion thereby facilitating right hip flexor activity).

MANUAL THERAPEUTIC EXERCISE USING PNF TECHNIQUES

The goals of the PNF techniques are to promote movement, facilitate stability, or to gain joint ROM and muscle flexibility. These techniques are grouped into movement, stability, and flexibility.

FIGURE 15-2 Replication (repeated contractions)—end range: elbow flexion. Command: "Hold." The elbow is then moved to mid-range (actively or passively). The patient then actively flexes the elbow to the start position.

Movement

Replication (Repeated Contractions)

The intent of replication (repeated contractions) is to teach the patient the expected outcome of the activity or movement; this technique may be helpful as part of a patient's reeducation after an injury (e.g., hemiparesis). It is also utilized as an excellent assessment tool for the clinician to "feel" the patient's ability to isometrically "hold" at the end ROM. The patient is placed in the end position (agonist muscle in its shortened length) and asked to hold while the therapist applies "demand" to all the components of desired direction resulting in simultaneous joint stimulation (see **Fig. 15-2**). The joint or extremity is then moved (either passively or actively) closer to mid-range of the diagonal and asked to actively return to the end position. This technique is repeated with the movement starting progressively closer toward the beginning of the pattern of movement to challenge the patient through a larger range of movement (see **Building Block 15-1**).

BUILDING BLOCK 15-1

Replication (Repeated Contractions)

Mr. Jones suffered a cerebral vascular accident and is having difficulty with eating using his right hand secondary to weakness in the right upper extremity, especially the hand. He often drops his eating utensils. Note his strength for performing the activity: shoulder flexion = 3-/5; elbow flexion = 3-/5; wrist flexion = 2+/5; he is able to close his grip and make a fist, but it is very weak. Create a strategy to improve this functional activity using replication.

Rhythmic Initiation

The purpose of rhythmic initiation is to teach the patient a movement pattern using passive, active-assistive, active, and resistive ROM. This is primarily used to enhance the patient's ability to initiate movement; it is also used during complex multi-joint movement patterns. In addition, it can be a useful tool when motor learning or communication problems exist by allowing the patient to visually observe as well as receive sensory input regarding the desired movement, thereby increasing understanding of the movement technique. This technique is also beneficial for patients who have a fear of moving because of pain. Rhythmic initiation allows the clinician to evaluate the patient's ability and willingness to be moved. This technique was originally developed to focus on the agonist muscle group only during unidirectional movement (see **Building Block 15-2**), but can be modified to use in teaching complex multi-joint diagonal movement patterns. Commands may progress as follows; "Let me move you," (PROM) "Help me move you," (AAROM) "Now, you do it" (AROM), "Now move against resistance" (RROM) (see **Fig. 15-3**).

BUILDING BLOCK 15-2

Rhythmic Initiation

Mr. Jones has right upper quadrant hemiparesis and is having difficulty rolling to his left. In assessing his rolling movement, the therapist noted that he is able to use his pelvis and lower body efficiently. However, his right upper extremity and his upper quadrant are lagging behind and his trunk is unable to engage in flexion. Describe how rhythmic initiation can be used to facilitate rolling in this case.

Combination of Isotonics

The intent of isotonic contractions is to emphasize control and quality of movement of the agonists by changing the muscle dynamic contraction intent (see **Display 15-1**). The intention of isotonic contractions is to employ combinations of concentric and eccentric muscle actions, without any relaxation, to promote smooth, coordinated functional movement (see **Fig. 15-4**).

Slow Reversals

The intent of a slow reversal is to facilitate dynamic movement by alternating between agonist and antagonist muscle contractions through a full ROM, thereby improving muscular strength and endurance. These reversals may or may not involve an initial "quick stretch" from elongated muscle tissue at beginning range. The patient is asked to dynamically move through a pattern to end range through a concentric muscle action from the agonist muscle group and then reverse and move in the opposite direction to end range through a concentric muscle action from the antagonist muscle group. The end of one pattern is the beginning of the other pattern (see **Fig. 15-5**). The movement can also be performed utilizing eccentric contractions in both directions. Each directional movement can be initiated by the clinician's command or "quick stretch" (see **Display 15-2**).

A

B

C

FIGURE 15-3 Rhythmic initiation: **(A)** "Let me move you." Therapist performs the movement passively (*bidirectional arrow*). **(B)** "Help me move you." The patient/therapist performs AAROM (*bidirectional arrow*). **(C)** "Pull up." The patient concentrically contracts against resistance (*unidirectional arrow*).

DISPLAY 15-1

Combination of Techniques: Rhythmic Initiation, Agonist Reversal with Isometric Hold

John is an 18-year-old baseball player who is at the end stages of his shoulder labral repair rehabilitation. He is now ready to begin a throwing program. Prior to surgery, his pain occurred during the deceleration and follow-through phases of pitching.

- Assess his throwing motion: His wind-up phase and acceleration phases are good, but during the deceleration and follow-through phases, he has inadequate elbow extension, shoulder extension, and shoulder horizontal flexion. This is producing decreased velocity and inefficiency.
- Position the player supine to the start of the upper extremity D2 flexion pattern: shoulder extended, adducted, and internally rotated, elbow extended (see Table 15-1 for upper extremity D2 flexion diagonal pattern).
- Move the patient through the pattern to the end position (shoulder flexion, abduction, and external rotation with the elbow still in extension), then return to the start of the pattern. Have the patient help perform the movement pattern as the clinician assists with the movement. The purpose is to teach the patient the D2 flexion movement pattern employing rhythmic initiation.
- At the starting position, give the command "Pull up!" (loud voice). This is the concentric phase while the muscles are shortening.
- At the end of the D2 flexion, give the command "Now Hold!" (normal voice) Isometric phase: muscles are contracting but there is no change in muscle length. This is the transition between the previous concentric phase and the subsequent eccentric phase.
- Now give the command "Let me bring you down slowly!" (a little softer tone) and return the patient to the D2 flexion starting position. In this eccentric phase, the muscles are contracting while lengthening similar to the decelerating and follow-through phases of throwing.
- Repeat six to eight repetitions, or until the patient loses form.
- Now reassess his throwing.

A B C

FIGURE 15-4 Combination of isotonics: **(A)** Concentric biceps—"Pull up!" (*left directional arrow*). **(B)** Isometric biceps—"Hold." **(C)** Eccentric biceps—"Let me pull you down . . . slowly" (*right directional arrow*).

A

B

FIGURE 15-5 Reversal of patterns. **(A)** Concentric biceps—"Pull up" (*unidirectional arrow*). **(B)** Concentric triceps—"Push down" (*unidirectional arrow*).

DISPLAY 15-2

Slow Reversal

Larry had a total knee replacement 3 months ago and he is still walking with a slow cadence and a stiff legged gait. He has full knee ROM, good strength in both quadriceps and hamstrings, and has no pain.

- Assess his knee movement in sitting and note that he slowly moves his knee into extension and returns into knee flexion slowly.
- Position him sitting on the table facing you.
- To facilitate knee extension, one hand will be on his anterior distal tibia; to facilitate knee flexion, one hand will be on the posterior distal tibia.
- Ask Larry to "kick up" and "pull back." Progressively increase resistance for strength and progressively increase movement speed for power. Employ lighter resistance and greater repetitions for muscle endurance.
- Reassess his walking.

Agonist Reversal

The purpose of agonist reversal is to require the agonist muscle groups to contract concentrically, followed by an eccentric contraction of the same muscle group. This is the theory behind most weight machines. For example, when performing resisted knee extension in the seated position on a weight machine, the patient contracts the knee extensors concentrically as the knee extends. This is immediately followed by an eccentric contraction of the knee extensors as the weight is lowered back to the starting position. This can be applied to PNF diagonal patterns via manual resistance. To enhance force in the posterior deltoid, middle, and lower trapezius muscles, the patient can resist (concentrically) the movement from D2 extension to D2 flexion. This is followed by the patient returning to the start position (D2 extension) while resistance is applied by the clinician to achieve an eccentric contraction of the same muscle group.

D1 and D2 Diagonal Patterns for the Upper and Lower Extremities

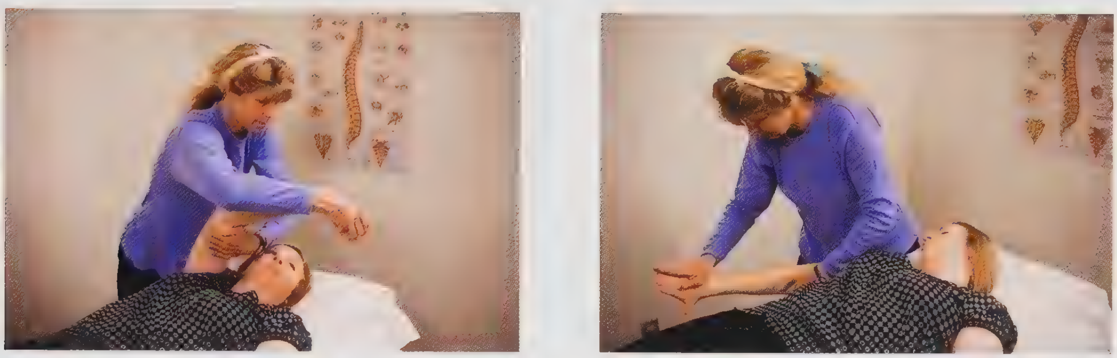
The purpose of using diagonal patterns is to facilitate functional movement patterns for the lower extremity (e.g., scooting, rolling, kicking, swing phase of gait) and upper extremity (e.g., eating, rolling, arm cocking in throwing, arm deceleration in throwing). There are primarily two diagonal movement patterns of motion for both the upper and lower extremities and they are antagonistic to each other, with each pattern having a major component of flexion or extension. Each diagonal involves movement toward and across the midline or movement across and away from the midline, and each diagonal also includes rotational components. Treatment techniques may be implemented with these diagonals to increase muscle activation or ROM. Sensory input, including manual contacts, is used to facilitate the diagonal patterns.

A summary of the upper extremity D1 and D2 diagonal patterns is shown in Table 15-3 and illustrated in **Figures 15-6** to **15-9**. The patterns are named for the ending position; for example, D1 flexion starts in extension and ends in flexion. The movements shown in Table 15-3 provide insights into the muscle groups recruited. For example, for D1 flexion, the scapula elevates in the anterior direction (protraction), thus recruiting the scapular elevators (e.g., upper trapezius, levator scapula) and protractors (e.g., serratus anterior). The glenohumeral joint flexes, adducts, and externally rotates, thus recruiting the glenohumeral flexors (e.g., anterior deltoid, clavicular pectoralis major), adductors (e.g., latissimus dorsi), and external rotators (e.g., infraspinatus). The forearm supinates and the wrist and fingers flex, recruiting the supinators (e.g., biceps brachii), wrist flexors (e.g., flexor carpi radialis and ulnaris), and finger flexors (e.g., flexor digitorum superficialis and profundus). Finally, the elbow is variable during the motion and may flex, thus recruiting the elbow flexors (e.g., biceps brachii), or may stay extended throughout the movement. Muscle recruitment patterns can similarly be assessed during the remaining three upper extremity diagonal patterns.

A summary of the lower extremity D1 and D2 diagonal patterns is shown in Table 15-4 and illustrated in **Figures 15-10** to **15-13**. The patterns are named for the ending position, so D1 flexion starts in extension and ends in flexion, and so forth. The movements shown in Table 15-4 provide insights into the muscle groups recruited. For example, for D1 flexion, the pelvis elevates in the anterior direction, recruiting the pelvic elevators (e.g., quadratus lumborum). The hip joint flexes, adducts, and externally rotates, thus recruiting the hip flexors (e.g., iliopsoas, rectus femoris), adductors (e.g., adductor longus), and external rotators (e.g., six deep external rotators, sartorius). The ankle

A B

FIGURE 15-6 Upper extremity diagonal patterns: **(A)** D1 flexion start position, **(B)** D1 flexion end position.



A B

FIGURE 15-7 Upper extremity diagonal patterns: **(A)** D1 extension start position, **(B)** D1 extension end position.

A B

FIGURE 15-8 Upper extremity diagonal patterns: **(A)** D2 flexion start position, **(B)** D2 flexion end position.

FIGURE 15-9 Upper extremity diagonal patterns: **(A)** D2 extension start position, **(B)** D2 extension end position.

FIGURE 15-10 Lower extremity diagonal patterns: **(A)** D1 flexion start position, **(B)** D1 flexion end position.

A B

FIGURE 15-11 Lower extremity diagonal patterns: **(A)** D1 extension start position, **(B)** D1 extension end position.

A B

FIGURE 15-12 Lower extremity diagonal patterns: **(A)** D2 flexion start position, **(B)** D2 flexion end position.

A B

FIGURE 15-13 Lower extremity diagonal patterns: **(A)** D2 extension start position, **(B)** D2 extension end position.

dorsiflexes, the foot inverts, and the toes extend, recruiting the ankle dorsiflexors (e.g., tibialis anterior), foot invertors (e.g., tibialis posterior), and toe extensors (e.g., extensor digitorum). Finally, the knee is variable during the motion and may flex, thus recruiting the knee flexors (e.g., biceps femoris), or may stay extended throughout the movement. Muscle recruitment patterns can similarly be assessed during the remaining three lower extremity diagonal patterns.

Scapular Patterns

The intent of the scapular patterns is to assess and treat stability, mobility, and coordination of the shoulder girdle, to facilitate upper extremity function, and to facilitate rolling. Scapular movement patterns are often performed in sidelying, but can also be adapted to prone, prone on elbows, sitting, or other positions. The four patterns are anterior elevation and posterior depression, which are performed in opposite directions, and posterior elevation and anterior depression, which are also performed in opposite directions (see **Fig. 15-14** to **15-17**). All the various PNF techniques previously discussed can be applied to these patterns. For example, to encourage improved postural awareness, repeated contractions can be utilized. With the patient in sidelying, the clinician can passively place the scapula in posterior depression, and ask the patient to isometrically hold that position. The clinician can then passively move the scapula into the direction of anterior elevation. The patient then actively moves the scapula back into the start position of posterior depression. This can be repeated, having the patient move through greater portions of the diagonal.

FIGURE 15-14 Scapular anterior elevation (*unidirectional arrow*).

FIGURE 15-15 Scapular posterior depression (*unidirectional arrow*).

FIGURE 15-16 Scapuar posterior elevation (*unidirectional arrow*).

FIGURE 15-17 Scapuar anterior depression (*unidirectional arrow*).

Pelvic Patterns

The purpose of pelvic patterns is to examine and treat stability, mobility, and coordination of the pelvis, to facilitate lower extremity function, and to facilitate rolling and scooting. These techniques are frequently performed in sidelying, but can also be adapted to prone, prone on elbows, sitting, tall kneeling, half kneeling or other positions. The two patterns are anterior elevation and posterior depression, and posterior elevation and anterior depression, which are performed in opposite directions (see **Fig. 15-18** to **15-21**).

FIGURE 15-18 Pelvic anterior elevation (*unidirectional arrow*).

FIGURE 15-19 Pelvic posterior depression (*unidirectional arrow*).

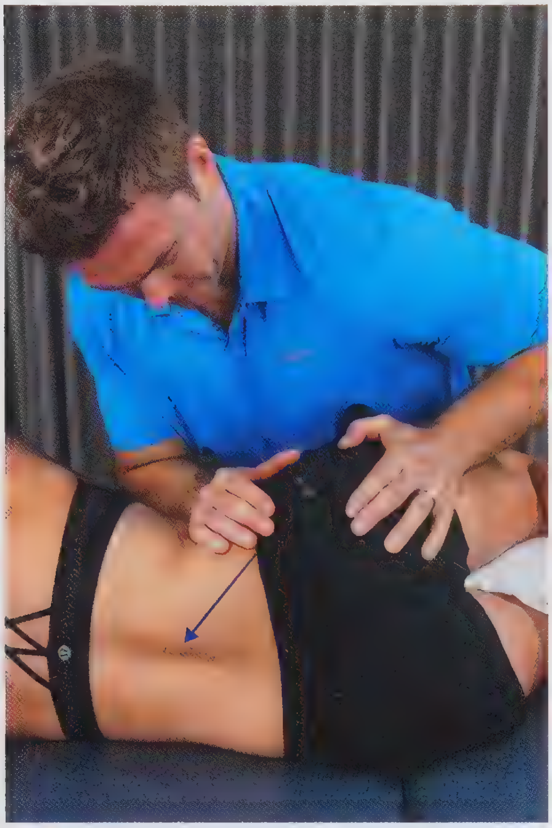


FIGURE 15-20 Pelvic posterior elevation (*unidirectional arrow*).

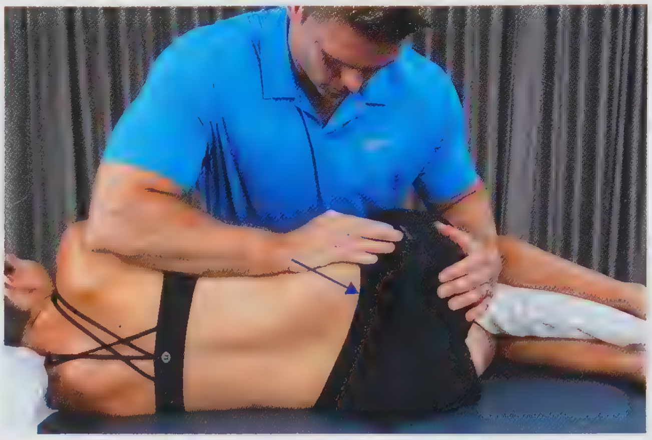


FIGURE 15-21 Pelvic anterior depression (*unidirectional arrow*).

Pelvic and scapular patterns can be combined. One combination is a reciprocal trunk pattern which involves scapula posterior depression combined with pelvis anterior elevation, and scapula anterior elevation combined with pelvis posterior depression. Examples of commands used during this technique are "scrunch" and "lengthen." To facilitate rolling, mass flexion (anterior depression of scapula combined with anterior elevation of pelvis) and mass extension (posterior elevation of scapula combined with posterior depression of pelvis) can be employed.

Stability

Alternating Isometrics

The intent of alternating isometrics is to promote stability of a body part in a specific ROM or position. Isometric holding is facilitated first in the agonist acting on one side of the joint, followed by isometric holding of the antagonist. No movement occurs while the patient tries to maintain body position. Muscle demands must be very slow and specific. For example, a physical therapist may apply simultaneous resistance to the anterior left and right shoulder for a few seconds before switching the resistance to the posterior left and right shoulder. The clinician's movements should be smooth, fluid, continuous, and predictable. The clinician may also provide traction or approximation, particularly when making rotational demand switches (see **Fig. 15-22**).

A B

FIGURE 15-22 Alternating isometrics for trunk rotational stability. **(A)** Resisted trunk rotation to the right; **(B)** resisted trunk rotation to the left.

BUILDING BLOCK 15-3

Approximation and Cocontraction

Wendy is a 14-year-old volleyball player with pain in the right shoulder and scapular winging. Assess her movement in shoulder elevation. Throughout the ROM, her scapula is unstable with "winging" and does not upwardly rotate adequately. Design an exercise to improve this problem using approximation and cocontraction.

SELF-MANAGEMENT 15-1

Improve Scapular Stabilization Progression

Purpose: To enhance the stability of the scapula by applying rhythmic stabilization for a home program to strengthen the upper and lower fibers of the serratus anterior and to improve scapular stability for upper extremity functional activities.

Position: Place the hands on the floor and get into a push-up plus (scapular protraction), neutral spine position with your feet in a wide base position

Movement Technique: Level 1: Maintain scapular protraction, neutral spine, and both hands on the floor, weight shift from right to left upper extremity. Perform the weight shifts 10 times to each arm without rest, or until fatigue sets in and you lose form.

Level 2: Using the same position as above, now use a narrow base with ankles touching. Perform the weight shifts 10 times to each side, or until fatigue sets in.

Level 3: Start in the same position as Level 2.

Lift one leg at a time approximately 3 inches off the floor. Perform alternate leg lifts 10 times each leg, or until fatigue sets in.

Level 4: Now place hands on a basketball, maintain the push-up plus position, and close your eyes. Perform alternate leg lifts 10 times each leg, or until fatigue sets in.

At no time between the changing muscle contractions is there relaxation of the body part being addressed (see **Building Block 15-3** and **Self-Management 15-1**).

Rhythmic Stabilization

The intent of rhythmic stabilization is also to promote stability of a body part in a specific range or position. This technique uses continuous alternating demands to isometric contractions and cocontractions, but emphasizes rotational stability control. Similar to alternating isometrics, the technique is performed without relaxation. For example, a physical therapist may apply simultaneous resistance to the anterior left shoulder and posterior right shoulder for a few seconds before switching the resistance to the posterior left shoulder and the anterior right shoulder.

Flexibility

Proprioceptive neuromuscular facilitation techniques are frequently used to increase muscle length and flexibility, utilizing the physiologic principles discussed previously (see Tables 15-1 and 15-2). These techniques rely on muscle contraction and relaxation to produce changes in muscle length and mobility.

Contract-Relax

The purpose of CR is to relax tight musculature that is inhibiting ROM (see **Display 15-3** and **Fig. 15-23**).

Hold-Relax

The intent of HR is to relax tight musculature that is inhibiting ROM. The stretching technique begins with a continuous static stretch (typically 15 to 30 seconds in duration) of an antagonist muscle group followed by a resisted isometric contraction (typically 5 to 10 seconds of moderate intensity) of the same antagonist muscle group (see **Display 15-4** and **Fig. 15-24**).

DISPLAY 15-3

Contract-Relax

Fred is a football player who suffered a moderate right ankle sprain about 6 weeks ago and has limited dorsiflexion on the right. He is ready to return to practice but you notice as he is running he has a short right step length.

- Position him supine on the table.
- The therapist stands at the foot of the table and dorsiflexes the right ankle to hold the Achilles on stretch for 10 to 15 seconds.
- At end of stretch, the therapist instructs the patient to contract his Achilles musculature by "pushing into my hands for 5 to 10 seconds" against moderate intensity resistance so that the ankle slowly plantar flexes via a concentric muscle action from the Achilles musculature.

When the patient relaxes after the 10-second contraction, the therapist passively moves the ankle into dorsiflexion combined with knee extension to lengthen the Achilles musculature. This new lengthened position is held for 10 to 15 seconds.

- This CR stretching process is related typically for three to four repetitions.
- Reevaluate his running.

A B

FIGURE 15-23 Contract-relax of a shortenend latissimus dorsi in a swimmer. **(A)** Therapist concentrically resists internal rotation of the shoulder followed by an isometric contraction of shoulder extension, held for 10 seconds. **(B)** As the patient relaxes the therapist passively moves the shoulder into external rotation and flexion.

DISPLAY 15-4
Hold-Relax

Julie is a sprinter on her track team who suffered a moderate left hamstring strain about 6 weeks ago. She is ready to return to practice but you notice as she is running with a short left step length.

- Position her supine on the table.
- Therapist stands at the foot of the table and raising her left leg in the straight leg position to end range and holding hamstring stretch for 10 to 15 seconds.
- At end of stretch instruct patient to contract her hamstrings by "pushing into my hands for 5 to 10 seconds" against moderate intensity resistance so that the hip stays in a fixed position via an isometric muscle contraction of the hamstrings.
- This HR stretching process is repeated three to four times.
- Reevaluate her running.

A B

FIGURE 15-24 Hold-relax stretching of the quadriceps. In prone, **(A)** the knee is taken to end-range flexion, and **(B)** the quadriceps contract isometrically, followed by further knee flexion.

Hold-Relax with Agonist Contraction

The purpose of using HR-AC is to relax tight musculature that is inhibiting ROM. The technique is the same as the HR technique, except the agonist muscle contracts to aid in the stretch of the antagonist muscle (see **Display 15-5**, **Building Block 15-4**, and **Fig. 15-25**).

BUILDING BLOCK 15-4

Improving Flexibility

Ms. Smith is a 50-year-old female who has a right shoulder adhesive capsulitis. She is improving with shoulder elevation and is now able to elevate her arm actively to 100 degrees and her end ROM is 105 degrees passively. Describe exercises for her using activities to increase flexibility.

DISPLAY 15-5

Hold-Relax with Agonist Contraction

Elisabeth is a 70-year-old woman who was immobilized with her right elbow in 45 degrees flexion following a radial head fracture. She now has shortening of her biceps muscles. She is having difficulty restoring full elbow extension.

- Position her supine on the table.
- Therapist stands next to the patient with her right elbow in end-range extension, holding for 10 to 15 seconds while the patient contracts her triceps muscles (agonist muscle group) to assist in the biceps stretch.
- At the end of the stretch, instruct the patient to contract her biceps by "pulling into my hands for 5 to 10 seconds" against moderate intensity resistance so that the elbow stays in a fixed position via an isometric contraction of the biceps.
- This stretching process is related typically for three to four repetitions.
- Reevaluate her elbow ROM.

A B

FIGURE 15-25 Hold-relax with agonist contraction to increase length of the wrist flexors. **(A)** The patient is taken to the end of range of the wrist flexors, asked to isometrically contract the flexors against resistance. **(B)** This is immediately followed by concentric contraction of the wrist extensors (*unidirectional arrow*).

LAB ACTIVITIES

Manual Contacts

DIRECTION OF MOVEMENT

1. Have your partner in the supine position with eyes closed.
2. Raise the right forearm to 90 degrees of elbow flexion and supination
3. Manual contact no. 1: Wrap entire hand around the forearm: Command: "Hold that position"
4. Manual contact no. 2 using a lumbrical grip on flexor surface only:
   Command: "Hold that position". . . now pull up!
5. Manual contact no. 3 using a lumbrical grip on the extensor surface only:
   Command "Hold that position. . . now push down!"
   a. Which manual contacts facilitated specific muscle activity?
   b. Which manual contact was difficult to facilitate the direct line of movement?

STRENGTH OF CONTRACTION

1. Use manual contact no. 2: apply light pressure and then slowly increase the pressure.
2. Repeat elbow flexion five times; start with a soft voice and raise your voice with each repetition.
   a. Does the patient respond to the pressure of the manual contact?
   b. Does the voice of the therapist facilitate the patient's contraction?
3. Now have the patient hold at 90 degrees of elbow flexion.
   a. Begin with light resistance to the biceps. Note biceps and triceps muscle tension.
   b. Now increase to maximal resistance. Note that although resisting elbow flexion, irradiation occurs into the triceps muscle as well.

APPROPRIATE RESISTANCE AND SPEED OF CONTRACTION

1. Try the following resistance guide to facilitate elbow flexion. Perform:
   a. PROM, AAROM, light resistance, medium resistance, and finally maximal resistance.
   b. Now control the speed of contraction from slow to medium speed to fast speed.

The result of each resistance should be a smooth and coordinated movement.

Irradiation

1. The clinician stands in front of a patient who is sitting at the edge of a table. Have the patient raise their arms to 90 degrees of shoulder flexion, elbows extended and fingers interlocked (in a "prayer" position—see figure).
2. The clinician provides resistance to both of the patient's arms and increases the static resistance and duration.
   a. Note the irradiation occurring in the hip flexors.
   b. Note the irradiation into the trunk.
3. Try resisting just one arm in the same position.
   a. Is there more or less trunk activity with one arm compared to both arms?
   b. Irradiation through the trunk will increase when involving two extremities.

Mass Movement Pattern

1. Stand facing your partner, throw a ball and follow through to the same side hip.
2. Throw the ball and follow through to the contralateral hip.
   a. Compare: Ball velocity of the throw.
   b. Compare the mass movement pattern from the feet, knees, hip, trunk, shoulders, and neck.

Manual Therapy

1. List the advantages of manual therapeutic exercises.
2. List the disadvantages of manual therapeutic exercises.

Patient Problem

Ms. Spock is a 54-year-old lady who suffered a CVA with mild to moderate right-sided hemiparesis. She is having difficulty with sit to stand.

Evaluation

- She has good ROM in all extremities.
- Upper body strength is 5/5 on the left, 4/5 on the right, weak grip
- Lower body strength is 5/5 on the left, 3+/5 on the right
- Balance: sitting: good slight lean to the right
- Balance: standing: fair +: leans to the right, and center of gravity is behind base of support. Requires a walker for

LAB ACTIVITIES (continued)

independent standing and gait. Requires stand by assist without walker

Functional Assessment: Sit to stand and return

- It takes approximately 10 seconds to sit to stand from a chair.
- She has a tendency to lean to the weak side as she is standing but is able to maintain balance.
- Weight is through the heels not the forefoot.
- Inadequate forward trunk lean.
- She uses a walker for gait.
- Return to sitting you note she "plops" back into the chair.

Goal: Safe and efficient sit to stand and return. Design a treatment plan and progression.

- What techniques would you apply in the treatment?
- How would you facilitate the progression: sitting forward trunk lean, sit to stand, weight shift to the forefoot, return to sitting with a controlled movement to the chair?
- Design a safe home program she can do independently.

KEY POINTS

- The advantage to manual therapeutic exercise is the ability to constantly assess the patient's movement or posture which allows for immediate modification of the treatment or resistance.
- The clinician can influence variables such as the magnitude of resistance, type of contraction, joint compression or distraction, movement or stability emphasis and the direction of the movement or pattern.
- Proprioceptive neuromuscular facilitation (PNF) is a manual therapy approach that attempts to provide a maximal response for increasing strength, flexibility, coordination, and functional mobility. PNF patterns are more concerned with mass body movements as opposed to specific muscle actions.
- These patterns are composed of both diagonal and rotational exercise patterns that are similar to the motions required for activities of daily living, functional mobility, and even athletic performance.

CRITICAL THINKING QUESTIONS

1. How does the clinician know they are applying too much resistance?
2. Which technique should always be utilized when facilitating movement?
3. Which technique should be applied when attempting to gain ROM?
4. Which technique should be applied to improve sitting balance?
5. Give an example of how to apply a direct treatment and an indirect treatment to facilitate trunk flexion.
6. What are two advantages to using manual therapeutic exercise?
7. What are two disadvantages of manual therapy exercise?

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CHAPTER 16

Aquatic Therapeutic Exercise

LORI THEIN BRODY

Although water has been used therapeutically for centuries, only recently has its use become widespread in the rehabilitation community. The unique buoyant and resistive properties of water make it a useful tool for therapeutic exercise, and the advantages of unloading and of immersion in a resistive medium are well recognized. As a result, the body of knowledge surrounding aquatic rehabilitation has expanded tremendously. As with land-based exercises, different techniques, schools of thought, and approaches have been developed. The Halliwick method, the Bad Ragaz Ring method, Watsu, and Ai Chi are all examples of approaches to rehabilitation in the water. Further information on resources for these techniques can be found in the Additional Resources section at the end of the chapter.

As with other approaches to therapeutic exercise, it is important to realize that water is a tool, with advantages and disadvantages. Not all patients are appropriate candidates for aquatic rehabilitation. The strengths and weaknesses of each treatment modality must be matched to the needs of the patient. Because water is such a unique environment, the clinician should get in the pool and experience the effects of different exercises before prescribing them for patients. Often, aquatic exercises that appear to be simple can be quite difficult, and exercises that are difficult on land are easy to perform in the pool. The trunk-stabilizing muscles are challenged with most arm and leg exercises and represent a very different task from the same activity performed on land.

Aquatic physical therapy can be defined as the use of an aquatic medium to achieve physical therapy goals. The purpose of this chapter is to acquaint the reader with the fundamental principles of therapeutic exercise in the water. It is intended to provide the framework for integration of water-based and land-based exercises to treat impairments, activity limitations, and participation restrictions.

PHYSICAL PROPERTIES OF WATER

The physical properties of water provide countless options for rehabilitation program design. Be familiar with these properties and the intended or unintended effects that may result from their interaction. For example, the effect of buoyancy on gait is that of unweighting, thereby reducing the amount of physical work of walking. However, this reduction may be offset by the frontal resistance encountered because of the water's viscosity. As such, the clinician and patient should clearly define the goals of any given exercise in the pool to ensure progress toward overall functional goals.

Buoyancy

Archimedes' principle states that an immersed body at rest experiences an upward thrust equal to the weight of the same fluid volume it displaces.[1] As such, rather than a downward force resulting from gravity and body weight, individuals in the pool experience an upward force (i.e., buoyancy) related to water depth and specific gravity. The specific gravity of an object (or an individual) is its density relative to that of water.[1] The density of water is almost exactly 1 g per cm^3; therefore, anything with a specific gravity >1 g per cm^3 sinks, and anything less than 1 g per cm^3 floats. This property forms the scientific basis for underwater weighing to determine body composition. The specific gravity of a person is determined by the relationship between lean body mass and body fat. Individuals with a higher relative lean body mass are more likely to sink, and those with a higher relative body fat have a tendency to float. These differences can be balanced by the appropriate use of water depth, flotation equipment, and waterproof weight equipment.

Buoyancy acts through the **center of buoyancy**, which is the center of gravity of the displaced liquid. If the body weight and the displaced fluid weights are unequal, a rotation about the center of buoyancy occurs until equilibrium is reached. The moment of buoyancy is the product of the force of buoyancy and the perpendicular distance from the center of buoyancy to the axis of rotation. As on land, the greater the distance, the greater is the force needed to move the limb.

Buoyancy is one property of water that can be used to progress therapeutic exercise. The four main variables that can be manipulated to alter assistance or resistance are

1. Position or direction of movement in the water
2. Water depth
3. Lever arm length
4. Use of flotation or weighted equipment

Position and Direction of Movement

As with gravity, patient position and direction of movement can greatly alter the amount of assistance or resistance. Activities in the water can be buoyancy assisted, buoyancy supported, or buoyancy resisted (**Fig. 16-1**).

- Buoyancy-assisted exercises are movements toward the surface of the water and are similar to gravity-assisted exercises on land. In the standing position, shoulder abduction and flexion, as well as the ascent phase of a squat, are considered buoyancy-assisted exercises. In a prone position, hip extension can be buoyancy assisted.
- Buoyancy-supported exercises are movements parallel to the bottom of the pool and are similar to gravity-minimized positions on land. These movements are neither resisted nor assisted by buoyancy. In a standing position, horizontal shoulder abduction is an example of such an activity. Hip and shoulder abduction in a supine position are also examples of buoyancy-supported activities.
- Buoyancy-resisted exercises are movements toward the bottom of the pool. In a supine position, shoulder and hip extension are buoyancy-resisted activities. The descent phase of a squat is resisted in a standing position and is another example of buoyance-resisted activity.

The ability to position the patient a number of ways allows for a multitude of assisted, supported, and resisted activities (see **Case Study 16-1** and **Building Block 16-1**).

Water Depth

The water's depth is another variable that can alter the amount of assistance or resistance offered. For example, performing a squat in chest-deep water is easier than in hip-deep water. The challenge of walking varies tremendously depending on the

FIGURE 16-1 **(A)** Buoyancy-assisted elbow flexion. In a standing position with the elbow at the side and a small buoyant cuff or noodle, elbow flexion is assisted by buoyancy as the triceps relax and allow flexion to occur. **(B)** Buoyancy-supported elbow flexion. In a standing position with the shoulder in abduction, elbow flexion is neither assisted nor resisted by buoyancy, but moves through a range perpendicular to buoyancy. **(C)** Buoyancy-resisted elbow extension. In a standing position, the motion from flexion to extension becomes resisted by the water's buoyancy.

CASE STUDY 16-1

HISTORY

The patient is a 57-year-old woman who fell 8 weeks ago and sustained a right bimalleolar fracture. She was treated with open reduction internal fixation and placed in a boot. Over the following 6 weeks, her weight-bearing status was gradually increased. She is now full weight bearing (FWB) and is instructed to wean herself from the walking boot. She is apprehensive about walking without the boot. She feels like her ankle is stiff and weak and that she has poor balance. She is otherwise healthy, although she has mild degenerative joint disease in both knees. She reports that her knees are bothering her more since walking in the boot and because she has been unable to exercise regularly. She hopes to return to walking 3 miles per day for routine exercise.

EXAMINATION

Patient 65-in tall, weighing 150 lb. Ambulates with a slight limp in walking boot. Unable to walk FWB without boot. AROM from 0- to 30-degree dorsi/plantar flexion and 10-degree eversion to 15-degree inversion. Decreased AP glide of talus in mortise. Joint stable. Significant atrophy and strength of 4/5 throughout with discomfort but no frank pain. No neurologic signs. Unable to single-leg balance on involved limb.

BUILDING BLOCK 16-1

Consider Case Study 16-1 given earlier. How might buoyancy be a useful tool for this patient?

individual's impairment or disability. For example, someone with pain because of degenerative joint disease may find walking in deeper water easier because of the additional unloading of buoyancy, while someone with muscular or cardiovascular weakness may find the additional viscosity-induced resistance of deeper water more difficult.

Estimates of percentage weight bearing at various depths have been obtained by Harrison et al.[2] While estimates have been given, the amount of weight bearing depends on the body composition of the patient, the water's depth, and the walking speed. Fast walking can increase the loading over the static condition by as much as 76%.[2] Occasionally, water-depth options are limited by the available facilities. Modifications can be made by adding buoyant equipment to unload or by adding resistive equipment to increase frontal resistance.

Lever Arm Length

Just as with exercise on land, the lever arm length can be adjusted to change the amount of assistance or resistance. Performing buoyancy-assisted shoulder abduction in a standing position is easier with the elbow straight (i.e., long lever) than with the elbow flexed (i.e., short lever). Conversely, buoyancy-resisted shoulder adduction is more difficult with the elbow extended because of the long lever arm (**Fig. 16-2**).

Buoyant Equipment

To further increase the amount of assistance or resistance, buoyant equipment can be added to the limb (**Fig. 16-3**). Similar to land, as the buoyancy of the equipment increases, the resistance also increases. However, the classification of "buoyancy assisted" and "buoyancy resisted" is not as straightforward as it seems. Just as the motion of lowering the arm on land is not a passive activity but rather an eccentric lowering action, similar effects occur in the water. A buoyant "bell" in the hand during shoulder abduction increases the "assistance" from buoyancy while increasing resistance to the adduction return motion. However, this is true *only* if the patient relaxes the shoulder during the abduction motion. If the patient controls the buoyant bell during the abduction motion, then the muscle activity becomes an eccentric resisted activity of the shoulder adductor muscles rather than a buoyancy-assisted exercise.

Buoyant cuffs can be added anywhere along the limb to adjust the quantity and location of assistance or resistance (**Fig. 16-4**). Buoyant equipment is also used to support individuals in supine or prone positions as they perform exercises.

Hydrostatic Pressure

The pressure exerted by the water at increasing depths (i.e., hydrostatic pressure) accounts for the cardiovascular shifts seen with immersion and for the purported benefit of edema control. Pascal's law states that the pressure of a fluid is exerted on an object equally at a given depth.[1] The pressure increases with

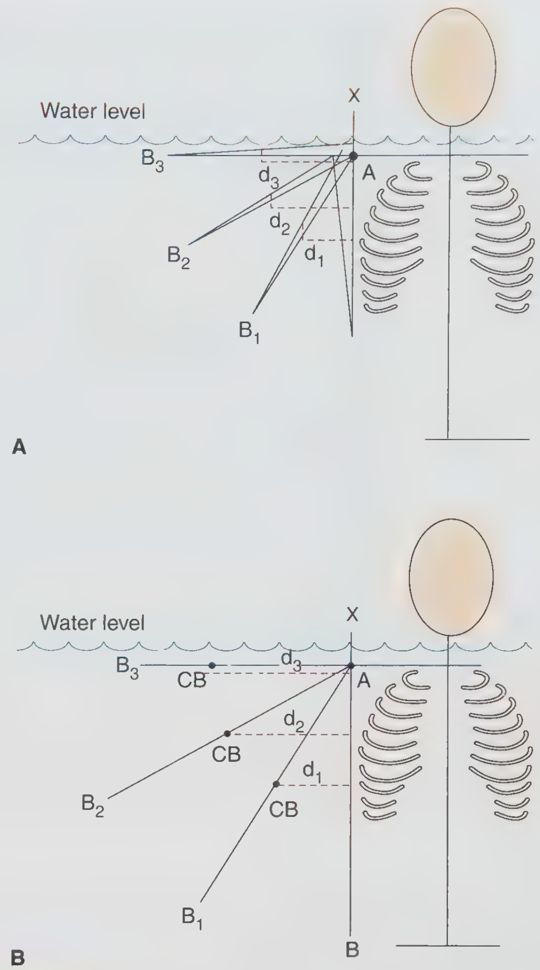


FIGURE 16-2 **(A)** The effect of buoyancy on shoulder abduction with a shortened lever arm (*elbow bent*). **(B)** The effect of buoyancy on shoulder abduction with a long lever arm (*elbow extended*). Increasing the lever arm increases the distance from the center of rotation, thereby increasing the resistance or assistance. (Adapted from Skinner AT, Thomson AM, eds. Duffield's Exercise in Water. 3rd Ed. London: Bailliere Tindall, 1983.)

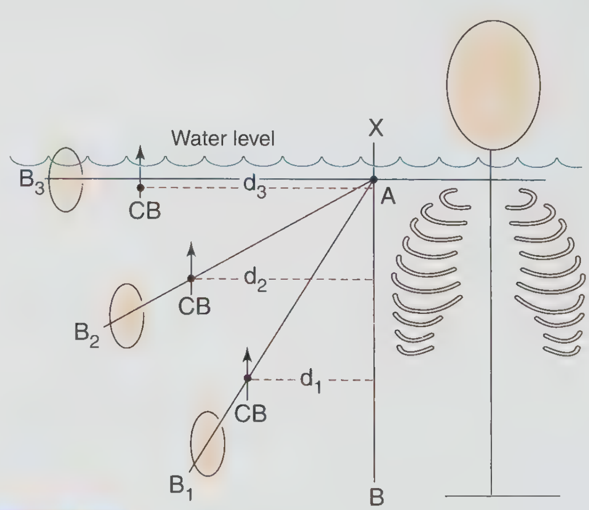


FIGURE 16-3 The effect of buoyancy with the addition of a float in the hand. The distance from the axis of rotation is further increased, thereby increasing the resistance or assistance. (Adapted from Skinner AT, Thomson AM, eds. Duffield's Exercise in Water. 3rd Ed. London: Bailliere Tindall, 1983.)

FIGURE 16-4 (A) Buoyant cuff added to the knee provides some assistance to hip flexion. (B) A buoyant cuff added at the ankle provides greater hip flexion assistance.

the density of the fluid and its depth. Hydrostatic pressure is greatest at the bottom of the pool because of the weight of the water overhead. As such, the pool may be a good exercise option for individuals with lower extremity edema or joint effusion. The hydrostatic pressure also produces centralization of peripheral blood flow, which alters cardiac dynamics. This is discussed later in this chapter under Physiologic Responses to Immersion.

Viscosity

The viscosity of a fluid is its resistance to adjacent fluid layers sliding freely by one another.[1] This friction causes a resistance to flow when moving through a liquid. Viscosity is of little significance when stationary. The viscous quality of water allows it to be used effectively as a resistive medium because of its hydrodynamic properties. Turbulent flow is produced when the speed of movement reaches a critical velocity.[3] Eddies are formed in the wake behind the moving object, creating drag that is greater in the unstreamlined object than in streamlined objects (**Fig. 16-5**). When using viscosity, consider several important factors:

- In turbulent flow, resistance is proportional to the velocity squared, and increasing the speed of movement significantly increases the resistance.
- When moving through the water, the body experiences a frontal resistance proportional to the presenting surface area, and so resistance can be increased by enlarging the surface area.

The clinician has two variables to alter resistance produced by viscosity: the velocity of movement and the surface area or streamlined nature of the object.

FIGURE 16-5 Using a plow while walking increases the surface area, creating eddies and drag.

Velocity of Movement

Turbulence and resultant drag are created when movement reaches a critical velocity. Slow movement through the water produces little drag, and resistance is minimal. When moving rapidly through the water, resistance is proportional to the speed of movement. Progress resistance incrementally by gradually increasing the speed of the exercise. This allows multiple gradations of an exercise rather than finite increases in weight, which is a common limitation in land programs.

Research into muscle activation patterns during shoulder elevation on land and in water highlights the relationship between viscosity and movement speed (**Evidence and Research 16-1**). When using viscosity as resistance, as the speed of movement through the water increases, so does the resistance. Slow movements produce muscle activation that is below those levels achieved against gravity on land, whereas fast movements exceed the muscle activation of comparably paced land-based movements.

EVIDENCE and RESEARCH 16-1

Research comparing shoulder muscle activation at 30, 45, and 90 degrees per second in the water and on land highlights the relationship between speed and muscle activation using viscosity.[4] The percent of maximal voluntary contraction of the shoulder muscles was consistently higher on land at 30 and 45 degrees per second, whereas those values were higher in water at 90 degrees per second (**Table 16-1**). These findings were replicated in additional research.[5]

Surface Area

In addition to altering the speed of movement, resistance can be modified by changing the object shape to provide more or less turbulence. The body can be positioned to alter turbulence, or equipment can be added. For example, less resistance is encountered in sidestepping than in forward or backward walking because of the more streamlined shape in frontal plane movement. Performing shoulder internal and external rotation with the elbows bent to 90 degrees with the forearms pronated ("slicing" the water) produces much less resistance than performing this exercise with the forearms in neutral (**Fig. 16-6A** and **B**). Adding resistive gloves further increases the resistance (Fig. 16-6C). Changing the pitch of the hand slightly between neutral and pronation alters the surface area and resultant resistance providing a multitude of resistive positions (**Evidence and Research 16-2**). Other equipment to increase the surface area and resultant turbulence are fins for the feet, resistive bells and boots, paddles or pinwheels, and a plow for resistive walking or other pushing and pulling activities (**Fig. 16-7**). A study using the Hydrotone (Hydro-Tone Fitness Systems, Inc., Huntington Beach, CA) boots showed increased drag compared with a barefoot condition[7–9] (see **Building Block 16-2**).

EVIDENCE and RESEARCH 16-2

A study of the Hydro-Tone (Hydro-Tone Fitness Systems, Inc., Huntington Beach, CA) resistive bells found that both their orientation and the velocity had a significant effect on force production.[6] Approximately 50% more force is produced when the bell is oriented at 45 degrees compared with 0 degrees at fast speeds. At slow speeds, the orientation made little difference in force production.

BUILDING BLOCK 16-2

The patient from the Case Study 16-1 is starting a walking program in the pool. Which walking movements will facilitate ankle mobility? What factors should be considered when determining the speed and depth for the walking exercise?

TABLE 16-1

Shoulder Muscle Activation (Electromyographic) During Arm Elevation in the Scapular Plane on Land and in Water

MUSCLE	TEST CONDITION	30 DEGREES/SECOND	45 DEGREES/SECOND	90 DEGREES/SECOND
Supraspinatus	Land	16.68	17.46	22.79
	Water	3.93	5.71	27.32
Infraspinatus	Land	11.10	10.76	15.03
	Water	2.28	2.89	21.06
Subscapularis	Land	5.96	6.83	7.45
	Water	1.49	2.26	10.73
Anterior deltoid	Land	15.88	18.82	22.09
	Water	3.61	43.49	32.83
Middle deltoid	Land	6.22	7.64	10.07
	Water	1.60	2.53	17.39
Posterior deltoid	Land	2.25	2.24	4.23
	Water	0.75	0.91	6.56

Data are mean percentage of maximal voluntary contraction.

A B C

FIGURE 16-6 The amount of shoulder horizontal abduction/adduction resistance is less with **(A)** forearm pronation than with **(B)** forearm neutral. **(C)** Resistance can be further increased by the addition of gloves.

FIGURE 16-7 A variety of equipment is available to increase the surface area of moving limbs.

DISPLAY 16-1

Physiologic Changes with Immersion to the Neck

1. Decreased:
   - Peripheral blood flow
   - Vital capacity by ~8%
2. Increased:
   - Heart volume by ~250 mL
   - Intrapulmonary blood volume from 33% to 60%
   - Right atrial pressure ~12 to 18 mm Hg
   - Left ventricular end-diastolic volume
   - Stroke volume ~35%
   - Cardiac Output ~32%
3. Decreased or unchanged heart rate

From Risch WD, Koubenec HJ, Beckmann U, et al. The effect of graded immersion on heart volume, central venous pressure, pulmonary blood distribution, and heart rate in man. Pflugers Arch 1978;374:115–118.

PHYSIOLOGIC RESPONSES TO IMMERSION

Significant physiologic changes occur with immersion at various depths. These responses may produce desirable effects (e.g., control of lower extremity edema) or undesirable effects (e.g., limitation of chest expansion). Choose the appropriate water depth on the basis of the specific health status of the patient and the patient's physical therapy goals.

Effects of Hydrostatic Pressure

Immersion alone is not a benign action. The hydrostatic pressure encountered results in changes in cardiovascular dynamics even before exercise is initiated (**Display 16-1**). Immersion to the neck results in centralization of peripheral blood flow.[10–14] The hydrostatic pressure creates a pressurized force increasing blood flow to the thorax, similar to how squeezing the bottom of a plastic bottle pushes the liquid to the top. The blood volume shift results in increased venous return to the heart, causing a cardiac preload.[11,12,14] The cardiac preload produces a stroke volume (SV) increase through the Frank-Starling reflex.[10,14] The heart rate (HR) remains unchanged or decreases because of the relationship of HR, SV, and CO such that HR × SV = CO. Risch et al.[13] demonstrated that raising the water depth from the symphysis pubis to the xiphoid process decreased the HR 15%. These HR changes depend on the depth of immersion, the individual's comfort level in the water, water temperature, and type and intensity of exercise. Heart volume–associated changes were similar between immersion to the diaphragm and supine positions.[13]

The disparity in HR changes with water exercise reported in the literature reflect the many variables impacting cardiopulmonary dynamics in the water. The cardiovascular changes resulting from centralization of blood flow are graded on the basis of the depth of immersion and body position, and they occur before the onset of exercise. The **hydrostatic indifference point** is located approximately at the diaphragm and represents the point at which the increase in hydrostatic pressure in the lower extremities and abdomen is precisely countered by the hydrostatic pressure of the water.[13] This principle can be used in a variety of clinical situations. For example, when the water level drops below the symphysis pubis, the positive effects of prevention of lower extremity edema are negated. The cardiopulmonary responses to the exercise program will more closely match that of land-based exercise. Exercise in deeper water will facilitate return of peripheral blood flow, which may be a desired outcome. A patient with no significant cardiac history and ankle swelling would benefit from immersion in deeper water, whereas a patient with known cardiac disease and no lower extremity edema should be treated in more shallow water. Be sure to match the needs of the patient (e.g., prevention of edema, cardiac history) with the risks and benefits of the various treatment modalities.

Effects of Water Temperature

Water temperature, as with hydrostatic pressure, alters the cardiovascular challenge to the immersed subject in a depth-related fashion. Water that is too warm or too cold can add a significant thermal load to the cardiovascular system. Choukroun and Varene[15] found cardiac output (CO) to be unchanged from 25°C to 34°C (77°F to 93°F) but significantly increased at 40°C (104°F); oxygen consumption was significantly increased at 25°C (77°F). Several studies have found a decreased HR in subjects exercising in cold water, and exercising in very warm water can increase HR.[16–20] Thermoneutral temperature is suggested to be approximately 34°C.[18–20] Most pool temperatures range from 27°C to 35°C (81°F to 95°F). Know the current pool temperature and potential effects on the patient before the onset of exercise.

PHYSIOLOGIC RESPONSES TO EXERCISE WHILE IMMERSED

In addition to the effects of immersion alone on cardiovascular dynamics, consider the combination of changes resulting from immersion combined with changes resulting from exercise. Training in water produces physiologic adaptations similar to training on land, and aquatic training can be used to increase or maintain cardiovascular condition in a variety of populations.[14,21–25] The aerobic and anaerobic benefits of deep- and shallow-water exercise have been verified in a number of populations.[26–29] The pool can be used as a cardiovascular training tool alone or in combination with land-based training, providing the individual recovering from injury with alternative training mediums.

When training in the pool, the cardiac preload resulting from central volume increases persists despite the vascular shifts known to occur with exercise.[11] Despite the increase in blood flow to the working muscles (i.e., peripheralization of blood flow), the increased cardiac load resulting from hydrostatic pressure (i.e., centralization of blood flow) still occurs. Most studies have found the HR to be lower or unchanged compared with similar cardiovascular activity on land[22,30–33] (**Evidence and Research 16-3**). The depth of immersion affects the degree of cardiac changes, with increasing depth producing greater cardiovascular changes (**Evidence and Research 16-4**). Running and jogging in waist-deep water produces the same HR and oxygen consumption changes as exercise on land.[39,40] However, exercise while immersed to the neck will produce an HR of 8 to 11 beats per minute lower than similar land-based exercise.[33,41]

EVIDENCE and RESEARCH 16-3

If working below the hydrostatic indifference point, exercise is more strenuous because of the increased resistance against the legs from viscosity. Subjects walking and jogging in ankle-, knee-, thigh-, and waist-deep water were found to work harder with increasing immersion up to the waist, at which point the increased resistance (resulting from increased surface area) was partially offset by buoyancy.[34] The cardiorespiratory changes due to buoyancy were not significant below waist level.

EVIDENCE and RESEARCH 16-4

Deep-water running has been shown to maintain an individual's maximum oxygen consumption and 2-mile run time over a 6-week training period.[25,27,35] Research has consistently shown a lower exercise heart rate with deep-water running compared with land-based running due to the water's hydrostatic pressure.[28,36,37] Similar results were found when comparing cardiorespiratory exercise immersed to the hip or to the breast when compared with land exercise.[38]

Both shallow-water running and deep-water running can be used for cardiovascular training. As with on land, a linear relationship between HR and cadence exists for deep-water running.[42] Mechanically, shallow-water running more closely resembles land-based running because of the foot contact on the bottom, but contact may also cause impact or friction problems. Muscle activation patterns will differ between shallow- and deep-water aerobic exercise because of the contact with the pool bottom.

When performing resistive exercise in the pool, be sure to realize that most muscle contractions are concentric because of the negation of gravity. Eccentric contractions can be generated if the water is shallow enough to minimize the effects of buoyancy, by manually resisting the force of buoyancy in an eccentric fashion, by using a lot of buoyant equipment or by direction changes requiring the person to slow, stop, and change directions. For example, performing a squat exercise in thigh-deep water requires eccentric contractions in the lowering phase, but performing the same exercise in waist-deep water negates most of gravity's effects. If enough flotation equipment is used, an exercise can require eccentric resistance against buoyancy. With large flotation devices in the hand, the motion of shoulder abduction becomes an eccentric contraction of the shoulder adductors, resisting the upward force of buoyancy.

EXAMINATION AND EVALUATION FOR AQUATIC REHABILITATION

Perform a complete land-based examination before initiating aquatic rehabilitation activities. This is the same evaluation the clinician performs when designing a land-based program. As always, choose tests and measures on the basis of the patient history and systems review. Additionally, be sure to consider the physical properties of the water and the physiologic effects of immersion when determining the appropriateness of aquatic physical therapy for the patient (see **Display 16-2**). Will the patient benefit from the properties of buoyancy or hydrostatic pressure (i.e., relief of weight bearing or swelling control)? Will the centralization of blood flow place the patient at risk? Look for impairments that might alter the patient's relative density and ability to float. For example, a patient with paraparesis may need flotation to keep his or her legs from sinking when supine. Identify pathology or impairments that might affect the patient's ability to tolerate the hydrostatic pressure against the chest wall. Patients with decreased lung capacity may have difficulty breathing resulting from this pressure. Watch for sensory impairments that might alter the patient's ability to tolerate the touch of the pool floor, walls, or water, or the visual or auditory sensory stimulation found in a pool.

Be sure to assess the patient's safety in the pool environment. Will the patient be able to traverse a wet shower room and pool deck? Will he or she be able to don and doff a swim suit? Are there safe mechanisms for transfer in and out of the pool, given the patient's physical capabilities? What is the patient's comfort level in the pool? Is he or she able to float and recover, blow bubbles, and immerse the face in the water? Is the patient able to regain balance comfortably if he or she loses it in the water? The patient's safety is paramount in the pool, just as on land (see **Building Block 16-3**).

DISPLAY 16-2

Patient Screen for Aquatic Rehabilitation

1. Basic safety
   - Ability to enter/exit the shower area, pool deck, and pool safely
   - Comfort in the water
   - Ability to put face in the water
   - Rhythmic breathing/bobbing
   - Ability to supine and prone float and recovery
   - Turning over when horizontal in the water
2. Precautions to aquatic environment
   - Cardiac history
   - Fear of the water
   - Any precautions to land exercise (i.e., diabetes)
   - Limited lung capacity
3. Contraindications to aquatic environment
   - Fevers, infections, rashes
   - Open wounds without Bioclusive dressing
   - Incontinence without protection
   - Unstable cardiac conditions

BUILDING BLOCK 16-3

What are the important aspects of the examination in terms of mobility and safety for the patient in Case Study 16-1?

THERAPEUTIC EXERCISE INTERVENTION

After determining the appropriateness of aquatic physical therapy with the patient, specific physical therapy goals must be developed. These goals should be written to address the specific impairments and activity limitations identified. Aquatic exercise has been shown to improve impairments and activity limitations in individuals with various diseases and to improve the fitness of older women[43,44] (**Evidence and Research 16-5**).

EVIDENCE and RESEARCH 16-5

Patients with rheumatic disease showed significant improvement in mean pre-test and post-test scores of active joint motion and the Functional Status Index.[43] The decreased pain and difficulty with daily activities contributed significantly to the overall increased functional status and active joint motion. Elderly women participating in a 12-week water exercise class demonstrated significant improvements in oxygen consumption, muscular strength, agility, skinfold thickness, and cholesterol as compared with a control group.[44] Aquatic exercise has been shown to improve gait stability in the elderly.[45,46] A group of patients with coronary artery disease improved stress test time, oxygen consumption, and muscle strength after a 4-month aquatic exercise program.[47] However, improvements were lost after a 4-month detraining period, suggesting the need for continued exercise through the lifetime.

Research in individuals with arthritis has shown aquatic rehabilitation to be efficacious and cost-effective. Significant reductions in pain along with improvements in strength and function have been noted in patients with osteoarthritis of the hip or knee.[48–50] Additionally, compliance with the water therapy tends to be higher than with land therapy.[49,51,52] Other research has found significant improvements in measures of range of motion (ROM), thigh girth, pain scales, and 1-mile walk test in patients with knee osteoarthritis, with the aquatic group showing significantly lower pain levels than the land group.[53] The results reinforce the notion that patients can improve strength and function effectively in either a land or aquatic environment. The key is the ability to provide a comprehensive program, whether on land, in the water, or some combination of both.

Pools are expensive to build, staff, and maintain. A study of the cost-effectiveness of water-based therapy for lower limb osteoarthritis found a favorable cost–benefit ratio as measured by a reduction in Western Ontario and McMaster Osteoarthritis Index (WOMAC) pain as the measure of benefit.[48] A Cochrane Review examining the effectiveness of aquatic physical therapy for the treatment of hip and knee osteoarthritis has shown the benefits of aquatic exercise in this patient group.[54] The Osteoarthritis Research Society International has recommended both land and water treatments for patients with knee osteoarthritis.[55] The following sections describe principles of aquatic physical therapy to treat common impairments.

Mobility Impairment

Exercises to improve joint mobility and ROM are easily performed in the water. The general muscular relaxation, support of buoyancy, and hydrodynamic forces occurring in water interact to provide an environment conducive to mobility activities. When designing a mobility program in the pool, the primary considerations are the following:

1. The force of buoyancy and its effect on the desired motion (assisting, supporting, or resisting)
2. The available ROM at the joint
3. The direction of the desired motion
4. The need for any flotation or weighted equipment

Avoid overstretching in the water; start with simple cardinal plane ROM exercises that address identified impairments. Progress to activities directed toward activity limitations and participation restrictions as tolerated. For example, progress exercises to increase hip and knee motion to normal ambulation as soon as possible.

Buoyancy is the physical property used most often to facilitate ROM. Use lever arm length and buoyant equipment to increase or decrease the amount of assistance from buoyancy. For example, hip flexion, shoulder flexion, and shoulder abduction are motions assisted by buoyancy in a vertical position. High marching steps can be performed with the knee flexed or extended, with or without flotation equipment to improve hip flexion ROM. As soon as motion and weight bearing allow, progress this activity to normal walking, running, or bicycling, depending on the patient's needs. Perform traditional stretching exercises using buoyancy or using static structures in the pool such as steps, pool sides, and bars (**Fig. 16-8**).

Be alert to the use of proper technique when performing any exercise in the pool. Because of the water's refraction, it may be difficult to see the patient's posture and mechanics during exercise. Maintain proper spine position and osteokinematics

FIGURE 16-8 Stretching exercises using **(A)** flotation equipment, **(B)** a railing or the pool edge, **(C)** a ladder for upper extremity stretching, and **(D)** a ladder for hamstring stretching.

during ROM activity to ensure that the mobility is occurring at the desired location. You may need to observe the patient's exercise mechanics on land to ensure proper performance before pool exercise. **Selected Interventions 16-1** and **16-2** present examples of aquatic exercises that may be prescribed for clients with mobility impairment (see **Building Block 16-4**).

Muscle Strength/Power/Endurance Impairment

Although buoyancy is the primary tool used to increase mobility, viscosity and hydrodynamic properties provide the greatest challenge to strength and endurance. These forces have been

SELECTED INTERVENTION 16-1

Aquatic Therapy to Improve Upper Extremity Mobility

See Case Study No. 4 in Unit 7.

ACTIVITY: Shoulder internal rotation stretching

PURPOSE: To increase mobility in internal rotation and extension

SUBSYSTEM OF THE MOVEMENT SYSTEM: Base

STAGE OF MOTOR CONTROL: Mobility

POSTURE: Standing in waist-deep water holding a buoyant barbell with both hands behind the back

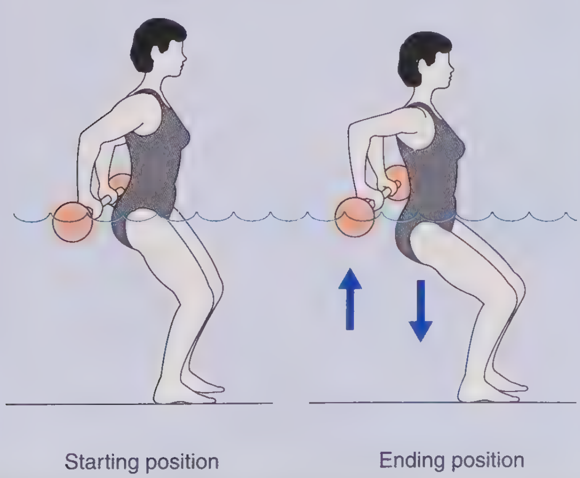
MOVEMENT: Squat slightly, bring the hands closer together, and allow buoyancy to passively slide the hands up the back to increase the stretch

SPECIAL CONSIDERATIONS: Substitution such as forward trunk flexion or scapular protraction must be avoided. The patient should feel a medium to moderate stretching sensation.

DOSAGE: The patient should hold stretch for 30 seconds.

EXPLANATION OF CHOICE OF EXERCISE: This exercise was chosen to increase shoulder mobility as one component of a comprehensive mobility, strength, and endurance program performed in the pool. This program is balanced with a home exercise program.

FUNCTIONAL MOVEMENT PATTERNS TO REINFORCE GOAL OF SPECIFIC EXERCISES: Reaching behind the back for hygiene, tucking in shirt, and hooking brassiere.



SELECTED INTERVENTION 16-2

Aquatic Therapy to Improve Lower Extremity Mobility

See Case Study No. 6 in Unit 7.

Although this patient requires comprehensive intervention as described in previous chapters, one specific exercise related to aquatic therapy will be described.

ACTIVITY: Lunge walking

PURPOSE: To increase mobility in the hip, knee, and ankle, and force or torque generation and endurance in the lower extremities

RISK FACTORS: No appreciable risk factors

STAGE OF MOTOR CONTROL: Controlled mobility

MODE: Mobility and resisted activity in a gravity-lessened environment

POSTURE: Maintain an upright trunk throughout the exercise

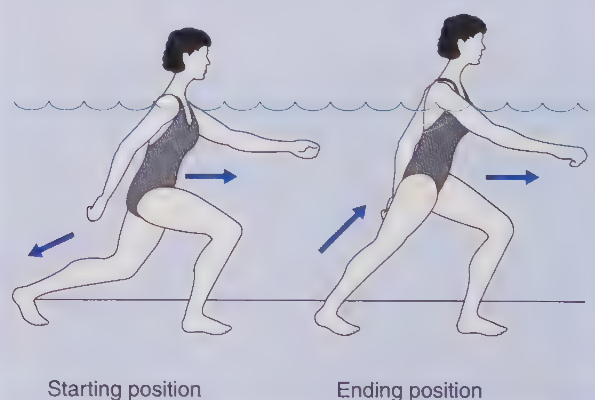
MOVEMENT: Walking in a normal heel–toe gait pattern, exaggerating the knee flexion of the loading response to 60 to 80 degrees of flexion, followed by full extension at midstance.

SPECIAL CONSIDERATIONS: Ensure an upright trunk avoiding forward lean. Avoid knee flexion beyond 80 degrees of flexion, and maintain a vertical tibia during the knee flexion component.

DOSAGE: Repetitions to form fatigue; performed two to three times per week

EXPLANATION OF CHOICE OF EXERCISE: This exercise was chosen to improve mobility at the hip, knee, and ankle, as well as dynamic muscular control at these joints. This movement was chosen to emphasize the knee flexion component in the loading response phase of gait.

FUNCTIONAL MOVEMENT PATTERN TO REINFORCE GOAL OF EXERCISE: Normal gait, ascending and descending stairs, and getting in and out of chair



BUILDING BLOCK 16-4

Describe an aquatic program to increase this patient's ankle mobility. Progress it from simple mobility exercises to more functional exercises.

proven to increase muscle performance following an aquatic resistive exercise program.[56–58] The turbulence created during motion produces resistance and is influenced by the surface area, object shape, and speed of movement. The strength training principles and progressions used in water-based activities are the same as those used on land. These include variables such as frequency, intensity, and duration. As with techniques to increase mobility, progress traditional strength and endurance training exercises to address activity limitations and participation restrictions as quickly as possible. For example, progress simple viscosity-resisted hip extension and knee extension exercises to land-based exercises, such as ascending or descending stairs or rising from a chair, as quickly as possible.

Because the patient is immersed in a resistive medium, exercise in any direction can be resistive if given a critical velocity. Calisthenics, open kinematic chain, closed kinematic chain, diagonal patterns, and motor control exercises can be performed effectively in the pool. A resistive motion in any direction requires a counterforce to stabilize against the turning effects of the center of buoyancy. For example, an individual standing in shoulder-deep water performing bilateral shoulder flexion from neutral to 90-degree flexion is pushed backward by the force generated with the arms (see **Self-Management 16-1**). The leg and trunk stabilizers must fire to counteract and keep the individual from falling over. This can be an effective technique to train trunk stabilization.

It is easy to overlook the additional muscular work necessary to provide stabilization against resistive movements in the pool, and this demand probably contributes to the overwork experienced by many patients. Be aware of which muscle groups are providing stability, the quantity of stabilization necessary, and the position or posture of the joints being stabilized. In the absence of external support (e.g., hand hold, wall support), nearly any upper or lower extremity exercise places significant demands on the hip and trunk stabilizers.

As with exercises to increase mobility, equipment can be used to enhance resistive exercise. Buoyant cuffs or bells can be used to increase the resistance against buoyancy, and paddles, gloves, and other surface area–enhancing equipment can increase the resistance resulting from turbulence. It is important that the quality of the exercise not be sacrificed for an increase in resistance (see **Self-Management 16-2**). As resistance is increased, patients may alter their technique or posture to accommodate the resistance change. For example, adding gloves to bilateral shoulder horizontal abduction and adduction can increase the postural sway so much that the patient cannot maintain balance.

Cardiorespiratory endurance can be increased in several ways, relying on the same principles of overload and progression used in land-based programs. The activity must be of sufficient intensity and duration, must use primarily large muscle groups, and should be performed three to five times per week. Deep-water activities are especially useful for individuals with weight-bearing limitations. Deep-water running, bicycling, cross-country skiing, and vertical kicking are only a few of the activities that can be performed continuously or as intervals. Traditional swimming strokes complement these lower-extremity–dominant exercises. Shallow-water running makes an excellent cardiovascular conditioning exercise if impact is tolerated. Appropriate aquatic footwear must be worn when shallow-water running for any length of time. This can include an inexpensive surf shoe or a more expensive aquatic exercise shoe. This minimizes the likelihood of impact injuries and friction injuries to the bottom of the foot (see **Building Block 16-5**).

SELF-MANAGEMENT 16-1
Bilateral Shoulder Flexion

Purpose: Increased muscular strength and endurance in shoulder flexors and extensors

Increased trunk stability

Position: Standing with the feet in stride, arms at the side, and palms facing forward

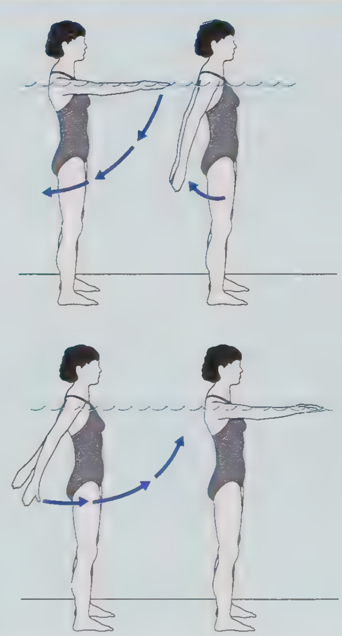
Movement Technique: Level 1: Bring arms forward together; then turn palms facing backward and push arms backward. Turn palms forward and repeat.

Level 2: As above, but with feet in stance

Level 3: As above, with addition of resistive equipment

Level 4: As above, but standing on one leg

Level 5: As above, with eyes closed



Dosage:

Repetitions: ____________________

Frequency: ____________________

SELF-MANAGEMENT 16-2
Bell Push-Downs

Purpose: Increased abdominal strength
Increased trunk stability
Increased shoulder and arm strength

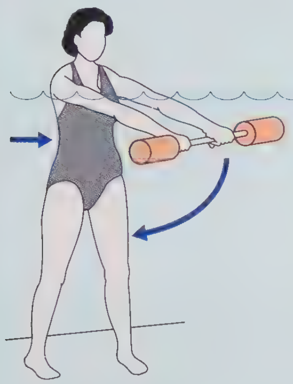
Position: Standing in chest-deep water, arms straight out in front with hands on a Styrofoam bell

Movement Technique: Level 1: Tighten abdominal muscles and pull bell straight down toward legs. Control the bell on the way back up.
Level 2: Move to deeper water.
Level 3: Increase size of buoyant bell.

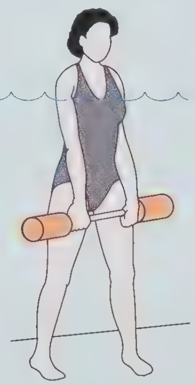
Dosage:

Repetitions: ______________________

Frequency: ______________________



Starting position



Ending position

SELF-MANAGEMENT 16-3
Single-Leg Lifts

Purpose: Increased hip mobility
Increased hip and knee muscle strength and endurance
Increased single-leg balance

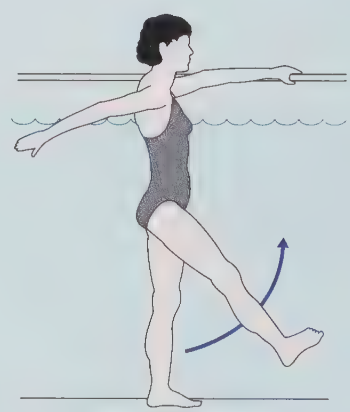
Position: Standing on one leg in a neutral spine posture with abdominal muscles tightened. The non–weight-bearing leg should be straight at the knee and flexed at the ankle. If working primarily on balance, stand near the edge, but do not hold on to steady yourself. Otherwise, hold on to the side for support.

Movement Technique: Level 1: Lift leg forward and back, ensuring proper spine position. Avoid arching your back as your leg comes back, and avoid letting your trunk sway. If the hip extends beyond its normal 15 degree range, low back pain may result.
Level 2: Add resistive equipment to foot or ankle.

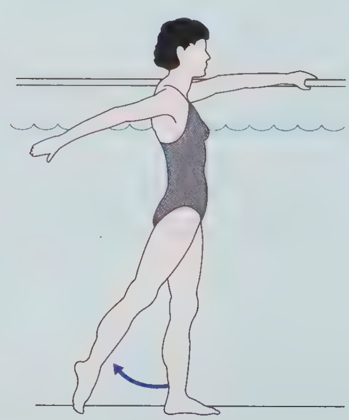
Dosage:

Repetitions: ______________________

Frequency: ______________________



Starting position



Ending position

BUILDING BLOCK 16-5

Design a beginning strengthening program for the case study patient, including activities that provide both direct resistance to the involved muscles as well as indirect challenges to the muscles.

Balance Impairment

The supportive medium of the water and its destabilizing forces provide an ideal environment for balance training. Other individuals in the pool create turbulence and destabilizing forces as well.[58] These forces can also be created by an individual's own movements. For example, lifting one leg forward produces a force pushing the individual backward (see **Self-Management 16-3**). The forward leg movement is countered with balance responses. The increased reaction time makes these types of training movements especially useful for individuals with poor balance. Movements occur more slowly in the pool because of the water's viscosity. As such, when balance is lost, the fall is slowed dramatically, giving the individual time to react and respond.

TABLE 16-2

Aquatic Balance Exercises

ACTIVITY	PROGRESSION ALTERNATIVES	COMMENTS
Bilateral shoulder flexion/extension	■ Narrow base of support ■ Single leg ■ Close eyes ■ Move head to engage vestibular system ■ Stand on immersible foam	Creates an anterior–posterior sway with sagittal plane motion ■ Add buoyant or resistive equipment to increase resistance
Bilateral shoulder horizontal abduction/adduction	■ Narrow base of support ■ Single leg ■ Close eyes ■ Move head to engage vestibular system ■ Stand on immersible foam	Creates an anterior–posterior sway with transverse plane motion ■ Add buoyant or resistive equipment to increase resistance
Bilateral reciprocal shoulder internal/external rotation	■ Narrow base of support ■ Close eyes ■ Move head to engage vestibular system ■ Stand on immersible foam	Creates rotation through transverse plane motion ■ Add buoyant or resistive equipment to increase resistance
Bilateral reciprocal shoulder abduction/adduction	■ Narrow base of support ■ Single leg ■ Close eyes ■ Move head to engage vestibular system ■ Stand on immersible foam	Creates frontal plane sway ■ Add buoyant or resistive equipment to increase resistance
Unsupported leg activities: ■ Knee flexion/extension ■ Hip abduction/adduction ■ Hip flexion/extension ■ Hip circles or figure 8s ■ Soccer kicks	■ Close eyes ■ Move head to engage vestibular system ■ Stand on immersible foam ■ Arms across chest ■ Arms overhead	■ Add buoyant or resistive equipment to increase resistance or challenge
Stepping activities: ■ Tandem walk ■ March in place and hold ■ Step and hold ■ 3-step stop	■ Close eyes ■ Arms across chest ■ Arms overhead ■ Move head to engage vestibular system ■ Increase speed of movement	Incorporating direction change increases the challenge because of the drag created by the movement through water
Hopping activities: ■ Hop in place with stable balance in between ■ Hop forward/back, side to side with stable balance	■ Close eyes ■ Arms across chest ■ Increased speed	Verbal cueing for movement direction can increase challenge by having the patient react to the therapist's instructions

A variety of balance activities performed on land can be adapted to the pool. Any single-leg stance exercise with concurrent movement of the arms, opposite leg, or both can provide a wealth of balance exercise. Single-toe raises, step-ups, and simple single-leg balance exercises can be performed with and without equipment (see **Table 16-2** and **Self-Management 16-4**). **Selected Intervention 16-3** presents a sample of an aquatic exercise that may be prescribed for the client with balance impairment. Research comparing the effects of balance training on land and in water found both mediums to result in improvements in the center of pressure variables, suggesting that balance training can be equally effective when performed in water[59] (**Evidence and Research 16-6**).

EVIDENCE and RESEARCH 16-6

The effects of a water-based program on balance, fear of falling, and quality of life was performed in community-dwelling older women with osteopenia or osteoporosis.[60] After a 10-week water-based and self-management program, the intervention group showed significant improvement over the control group in balance and quality of life, but not in fear of falling. In a similar study, 59 elderly individuals were randomly assigned to a land-based group, an aquatic-based group, or a control group; they exercised twice weekly for 6 months. The 8-foot-up-and-go test was improved in both groups, with the aquatic group showing significantly greater improvements than the land or control groups.[61]

SELF-MANAGEMENT 16-4
Three-Step Stop

Purpose: Increased dynamic balance
Increased trunk stability
Increased lower extremity strength
Increased single-leg balance

Position: Standing on both legs in a neutral spine posture, with abdominal muscles tightened. Take three steps forward beginning with your right leg, then stop and balance on your right leg. Step back with the left leg for three steps, stopping to balance on the left leg. After several repetitions, switch to stepping with the left leg first.

Movement Technique: Level 1: Use your arms as needed for balance.

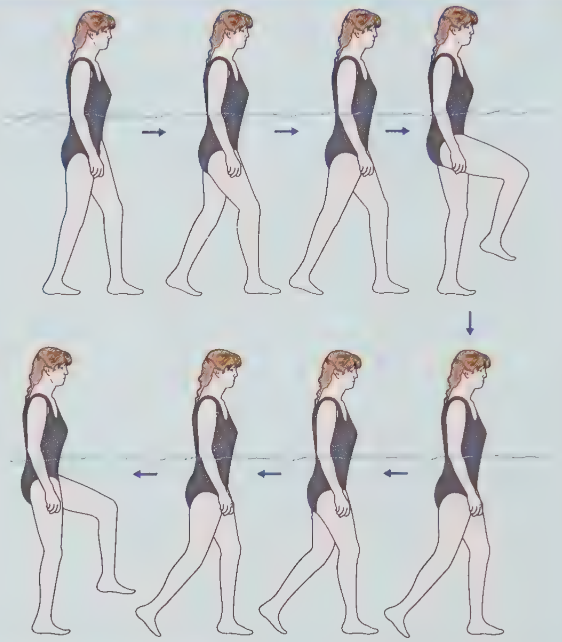
Level 2: Place your arms across your chest.

Level 3: Close your eyes.

Dosage:

Repetitions: ______________________

Frequency: ______________________



SELECTED INTERVENTION 16-3
Aquatic Therapy to Improve Balance

See Case Study No. 1 in Unit 7.

ACTIVITY: Single-leg balance in chest-deep water

PURPOSE: Train single-leg balance through entire lower extremity and trunk without full weight on the limb.

RISK FACTORS: No appreciable risk factors

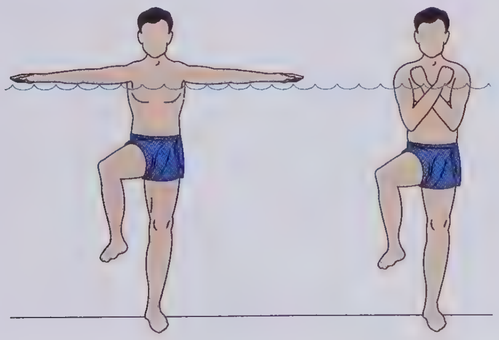
STAGE OF MOTOR CONTROL: Stability

POSTURE: Single-leg stance with arms in a comfortable position; lumbopelvic region in neutral and knee in slight flexion

MOVEMENT: None; simply maintain balance

DOSAGE: Repetitions to form fatigue or pain; attempt to hold as long as possible

FUNCTIONAL MOVEMENT PATTERN TO REINFORCE GOAL OF SPECIFIC EXERCISE: Single-leg stance of gait cycle



AQUATIC REHABILITATION TO TREAT ACTIVITY LIMITATIONS

Activity limitations represent restrictions in performance at the level of the whole person. Impairments involve losses at the tissue, organ, or system level, but may or may not contribute to activity limitations. As the patient makes improvements in impairments, activities in the pool should be modified to emphasize the activity limitations. Activity limitations related to posture or position can be addressed in the pool. If prolonged sitting is a functional limitation, a variety of sitting activities can be performed in the pool. Many pools contain steps where the patient can sit with various levels of depth (i.e., unloading). Chairs can be submerged in the pool, and buoyant equipment for sitting is available (**Fig. 16-9**).

FIGURE 16-9 Posture exercises and reaching activities can be performed while sitting on flotation equipment.

As sitting tolerance increases, the depth of water should be decreased, thereby more closely representing land situations. This same principle may be applied to deficiencies in prolonged standing or other positional limitations, such as bending over a counter.

Activity limitations related to specific movement patterns (e.g., gait, forward reaching) respond well to aquatic rehabilitation. Unloading the lower extremity or spine alone may be adequate to normalize gait mechanics. Verbal or tactile cuing may be necessary if gait changes have existed for some time. Research has shown improvements in gait stability in the elderly following an aquatic exercise program (**Evidence and Research 16-7**). Underwater treadmill walking has been shown to improve pain and gait mechanics in patients with knee osteoarthritis.[45] As normal pain-free gait mechanics are achieved, the water depth should begin decreasing to replicate the land-based environment.

EVIDENCE and RESEARCH 16-7

Research comparing forward walking with backward walking on an underwater treadmill have produced a great deal of information about gait. Masumoto et al.[62] and others[63] found that stride frequency was increased and stride length decreased in backward walking compared with forward walking. Additionally, measures of exertion, oxygen consumption, and cardiac responses were all higher with backward walking. Paraspinal muscle activity was greater when walking backward against a current than when walking backward without a current or walking backward on land.[64] Walking backward in the water elicits greater muscle activation than does walking forward, and the heart rate increased with increased walking speed.[65]

Similarly, other activity limitations in movement can be addressed in the same manner. For the individual with difficulty performing forward reaching, this activity can be assisted by buoyancy, which is progressed to buoyancy-supported and to buoyancy-resisted activity. Repetitive trunk flexion and extension, lifting, pushing, pulling, and squatting can be progressed in the same fashion (**Fig. 16-10**). Components of basic activities of daily living and instrumental activities of daily living can also be reproduced in the pool.

COORDINATING LAND AND WATER ACTIVITIES

One of the questions frequently asked by clinicians concerns the integration of water- and land-based activities. How much activity should be performed in the water, and when should land-based activity be incorporated? The advantages and disadvantages of aquatic rehabilitation and land rehabilitation should be matched to the needs of the individual patient, keeping in mind that humans function in a gravity environment. Because it is difficult to reproduce lower extremity eccentric muscle contractions in the pool, progress the patient with quadriceps strength impairments to land-based activities as quickly as tolerated. Early on, the patient may tolerate minimal land-based activity because of pain. Aquatic rehabilitation occupies most of the program at this time. As the patient is able to tolerate land-based activity, incorporate a greater percentage of land-based exercises into the program. The quantity of water-based activity may remain unchanged, increase if tolerated, or decrease as the quantity of land-based exercise increases. The exact proportion and quantity of both land and water activity is determined by the needs and response of the patient. Occasionally, individuals respond better to alternate days in the pool, but others can progress to daily land-based exercises and discontinue pool exercise. The exercise program should be matched to the needs of the patient, with the goal of progressing to land-based exercise.

PATIENT-RELATED EDUCATION

As with land-based exercise, patient education is a key component of the aquatic physical therapy program. The education program begins before entry into the water with a discussion of the fundamental properties of the water and the patient's expectations. Ensure patient comfort in the water; this is enhanced by educating the patient about the anticipated experience in the water. Identify the areas of entry and exit from the pool, the water's depth, and any other important safety features (e.g., drop-offs, gutters, bars). Also familiarize the patient with the exercise program on land before entering the water to ensure proper exercise performance.

As the patient enters the water and the rehabilitation program proceeds, use this time as an opportunity to teach the patient about the expected benefits of the exercise. For example, when

A B

FIGURE 16-10 Work conditioning exercises such as **(A)** pushing and **(B)** lifting can be reproduced in the pool.

performing activities in single-leg stance, the patient frequently complains of an inability to maintain balance. Emphasize that developing balance is the purpose of the exercise and that any modification of the exercise to further destabilize the person is a progression of the exercise. When surface area–enhancing equipment is added, explain to the patient that it will increase the difficulty of the exercise. This also educates the patient on appropriate exercise program progression, and when the program is continued independently, the patient is able to self-manage and progress his or her own exercise program.

PRECAUTIONS/CONTRAINDICATIONS

Some absolute and relative contraindications to exercise in the water exist. Individuals with excessive fear of the water, open wounds, rashes, active infections, incontinence, or tracheostomy should not be admitted to the pool. However, some physicians allow patients with open wounds to participate in aquatic rehabilitation with use of a Bioclusive dressing. This is commonly seen in patients with postoperative incisions.

Be aware of precautions to exercising in the water. The cardiovascular changes occurring with immersion should be of concern for the patient with a cardiac history. The hydrostatic pressure also limits chest expansion in those immersed in neck-deep water. This can create breathing difficulties for patients with pulmonary impairments or activity limitations. The hydrostatic pressure against the chest wall also can cause a sensation of an inability to breathe in persons who are uneasy in the water. The hydrostatic pressure produces diuresis, which can be avoided by emptying the bladder before entry to the pool.

Be alert to medical emergencies in the pool. It may be more difficult to respond to an emergency in the water, and an action plan must be in place. Be sure to know and practice safe removal of the patient from the water, and know the guidelines for implementing cardiopulmonary resuscitation in the pool.

Because of the sense of mobility experienced when exercising in the pool, many patients tend to overwork. Overexercise may occur because of the reduced gravity environment, the support of buoyancy, and the muscular relaxation associated with immersion, hydrostatic pressure, and water temperature. Frequently, the signs and symptoms of overwork do not manifest until later in the day or the next day. It therefore is better to err on the conservative side and underestimate the appropriate amount of exercise rather than overestimate. Once a baseline aquatic exercise program that does not exacerbate symptoms is established, the exercises can be safely progressed by increasing intensity, frequency, or duration.

KEY POINTS

- The pool provides a unique environment for the rehabilitation of individuals with a variety of impairments, activity limitations, and participation restrictions.
- The properties of buoyancy and viscosity can be used in a number of ways to achieve physical therapy goals.
- The effects of hydrostatic pressure and water temperature on the physiologic responses to activity must be considered to ensure patient safety.
- The water's viscosity provides much resistance and can be fatiguing for deconditioned individuals.
- Because a range of activities, from mobility and stretching to resistive and cardiovascular exercise, can be performed in the pool, aquatic therapy can progress from the early stages of rehabilitation through functional progression.
- Balance is challenged with nearly every arm and leg movement in the pool, and the effects of exercises on the trunk and leg stabilizers must be considered when designing the exercise program.
- The pool program must be balanced by a well-designed land-based program to ensure proper transition back to the land environment.

CRITICAL THINKING QUESTIONS

1. How can the difficulty of the first selected intervention exercise (single-leg balance) be increased using the following?
   a. Arms
   b. Legs
   c. Equipment
   d. Other sensory systems
2. What factors might limit the patient's ability to perform this exercise? How would you modify the exercise program to adjust for these factors?
3. How is this exercise changed in different water depths?
   a. Waist deep
   b. Neck deep
4. How is the exercise in Self-Management: Bell Push-Downs changed in different water depths? How would the exercise differ if performed with resistive gloves with the thumbs up? Palms down?
   a. Chest deep
   b. Neck deep
5. How can mobility in internal rotation be improved while keeping the shoulders immersed?

LAB ACTIVITIES

Pool Activities

1. Upper extremity
   a. Using a variety of positions (e.g., supine, prone, standing) and equipment (e.g., buoyant, resistive, wall, railings), develop an exercise program to increase a patient's shoulder, elbow, forearm, and wrist ROM in all available ranges. Do this for a variety of motion limitations (i.e., minimal loss to significant motion loss).
   b. Using a variety of positions and equipment, develop an exercise program to increase a patient's shoulder, elbow, forearm, and wrist strength and function. Progress from isometric exercise through a functional progression to activities of daily living, work-related activities, or different sports. Perform open- and closed-chain exercises.
2. Lower extremity
   a. Using a variety of positions (e.g., supine, prone, standing) and equipment (e.g., buoyant, resistive, wall, railings)

LAB ACTIVITIES (continued)

develop an exercise program to increase a patient's hip, knee, and ankle ROM in all available ranges. Do this for a variety of motion limitations (i.e., minimal loss to significant motion loss). Consider patient-specific issues such as precautions following total hip arthroplasty or patients with weight-bearing restrictions.

b. Using a variety of positions and equipment, develop an exercise program to increase a patient's lower extremity strength and function. Progress from isometric exercise through a functional progression to activities of daily living, a variety of work activities, or various sports. Perform open- and closed-chain exercises.

3. Trunk
   a. In an upright position, establish a neutral spine position and ambulate forward, backward, sidestepping, and braiding patterns. Vary step length and observe resultant changes in ROM. Vary speed and note changes in muscle activation.
   b. In an upright position, perform a variety of upper extremity exercises and observe the challenges to the trunk stabilizers. Perform exercises with a wide stance, narrow stance, and standing on one leg. Perform these same exercises with your eyes closed.
   c. In an upright position, perform a variety of lower extremity exercises and observe the challenges to the trunk stabilizers. Notice the differences between sagittal plane and frontal plane motions. Perform with your eyes closed and on an unstable surface.

Land Activities

Develop land-based and aquatic rehabilitation programs for the following patient problems. Progress the program from the acute phase through to a functional progression.

Patient No. 1

A 54-year-old man has L4–L5 discogenic back pain. The patient has had recurrent episodes of pain over several years but has always been able to self-treat with a home exercise program designed by a physical therapist. Two weeks ago, the patient took a vacation requiring a long flight, followed by sleeping in a bed with a poor mattress. This patient has been unable to relieve the symptoms with self-treatment. His primary complaint is low back pain with occasional radicular pain to the left knee. Symptoms do not extend beyond the knee. The patient desires to return to walking as exercise and recreational golf. He works at a desk job.

Examination reveals an easily correctable lateral shift to the right, with decreased active and passive ROM in extension, left side-bending, and left rotation. Active motion is limited in flexion. Dural signs are positive for radicular symptoms, but deep tendon reflexes and sensation are intact throughout. The low back is diffusely tender, with a protective muscle spasm in the left erector spinae. Lower extremity strength is 5/5 to single repetition testing throughout.

Patient No. 2

A 60-year-old woman presents after a right proximal humeral fracture, which was cared for with sling immobilization for 6 weeks. She has a history of mild degenerative joint disease at the acromioclavicular joint. She is right-handed and complains primarily of an inability to perform her daily activities because of motion loss and shoulder pain. Her goals are to return to activities of daily living, golf, and gardening.

Examination reveals loss of motion in all shoulder motions in a capsular pattern. Elbow, wrist, and hand motions are normal. Strength tests are limited by shoulder pain. Accessory motion is slightly decreased compared with the left in anterior, posterior, and inferior directions. Strength and sensation are normal throughout the rest of the right upper extremity.

Patient No. 3

A 17-year-old girl is seen 6 weeks after abrasion chondroplasty for an acute osteochondral lesion on the weight-bearing surface of her right knee medial femoral condyle. Her goals are to return to basketball, softball, and volleyball. She is partial weight bearing (50%) and can be progressed by 25% every 2 to 3 weeks until full weight-bearing is achieved.

Active motion of the knee is S:0-10-90 and passive motion is S:0-5-100 with an empty end-feel. She maintains a 1+ effusion and has 4+/5 strength to manual muscle test, with visible atrophy of the quadriceps. Hamstring muscle testing is 4+/5, gluteus maximus is 4+/5, and gluteus medius 4/5. She ambulates with an antalgic gait pattern with bilateral axillary crutches. Overall, she has a varus knee alignment.

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ADDITIONAL RESOURCES

Aquatic Physical Therapy Association: aquaticpt@assnoffice.com
Aquatic Resources Network: www.aquaticnet.com
Halliwick Method: www.halliwick.net
Ruoti R, Morris D, Cole AJ. Aquatic Rehabilitation. Philadelphia, PA: Lippincott Williams and Wilkins, 1997.

Functional Approach to Therapeutic Exercise of the Lower Extremities

UNIT 5

CHAPTER

17 The Lumbopelvic Region

CARRIE M. HALL

Low back pain (LBP) is among the most common reasons to visit a physician, and is a leading cause of disability in the western world, resulting in enormous personal, social, and economic burden.[1] It is estimated that approximately 60% to 80% of all people will suffer from LBP at some point in their lifetime.[2] A 2012 publication by the Centers for Disease Control and Prevention's National Center for Health Statistics reported that 28.4% of adults older than 18 years had experienced LBP in the previous 3 months,[3] with 24.7% reporting limitations in their physical functions,[4] translating to more than 7 million adults experiencing activity limitations because of low back-related conditions.[5] While the vast majority of LBP episodes resolve within 2 to 4 weeks (acute), 25% of patients will experience recurrent episodes within 1 year.[6,7] The prevalence of LBP has major socioeconomic impact with direct and indirect costs reported to be between $85 billion and $238 billion annually.[8–10] The cost to society as a result of LBP is greater than that for traumatic brain injury, arthritis, or stroke. This has led toward a push for evidence-based practice combined with a focus on the triple aim (see Fig. 2-1). This has prompted researchers to determine interventions that improve patient outcomes and reduce disability and work absenteeism at the lowest cost to the consumer and health care system.

LBP is usually defined as pain, muscle tension, or stiffness localized below the costal margin and above the inferior gluteal folds, with or without leg pain (sciatica) and classified as being "specific" or "nonspecific." Specific LBP refers to symptoms (such as herniated nucleus pulposus [HNP], infection, inflammation, osteoporosis, rheumatoid arthritis, fracture, or tumor) caused by a specific pathoanatomic or pathophysiologic mechanism. It is estimated that in only about 10% of the patients specific underlying pathoanatomic or pathophysiologic impairment can be identified.[11] The vast majority of patients (up to 90%) are labelled as having nonspecific LBP (NSLBP), which is defined as symptoms without a clear specific cause, that is, LBP of unknown origin. Spinal abnormalities on X-rays and magnetic resonance imaging (MRI) are not strongly associated with NSLBP, because many people without any symptoms also show these abnormalities.[12]

While management of LBP comprises a range of different intervention strategies, including surgery, drug therapy, cognitive-behavioral therapy, and nonmedical interventions; exercise therapy is probably the most widely used type of conservative treatment worldwide. Unfortunately, the results of clinical trials testing the value of exercise approaches relative to other interventions, including various forms of exercise, demonstrate that no management approaches are clearly superior.[13–15] The rationale for this may be due to the attempt to take a heterogenous population and study effects on the entire group. It is essential to identify and classify persons with LBP into specific and clinically relevant subgroups to match best practice with the patient-centered needs. This remains elusive to date due to the multidimensional nature of the condition and the various therapeutic models proposed.

General clinical guidelines have been established, primarily in the military settings, slowly making its way into civilian settings. Recommendations in clinical guidelines for acute and NSLBP in both military and civilian settings are to (1) avoid opioids as a first-line medication and (2) avoid advanced imaging procedures such as MRI or computed tomography (CT) scan.[16–20] However, research conducted mostly in civilian settings demonstrates that clinical practice remains inconsistent with these recommendations,[21] with excessive use of unendorsed care early in the treatment process contributing to the high costs of managing LBP, adverse negative psychologic effects, and increasing risk of chronicity.[6,21] Several guidelines suggest a delay in referral to physical therapy for 2 to 4 weeks to allow for spontaneous recovery,[16,19,20] but emerging research with civilian populations has found cost savings when referrals to physical therapy occur early in the care process for patients with acute LBP symptoms, particularly if the physical therapy care provided focus on active treatment approaches[22–24] (**Evidence and Research 17-1**).

EVIDENCE and RESEARCH 17-1

"Washout Effect" of Meta-Analysis on Effectiveness of Therapeutic Exercise Intervention with LBP

Therapeutic exercise is widely used as a treatment for LBP. The vast majority of patients with LBP fall into the nonspecific category; therefore, most research is based upon this group. A meta-analysis of the effectiveness of therapeutic exercise for reducing pain and disability in adult nonspecific acute, subacute, and chronic LBP compared with no treatment and other conservative treatments found exercise to be superior, but with a small effect size.[25] One of the criticisms of the standard meta-analysis is that treatment is not matched to specific subgroups of patient creating a "washout effect." The Cochrane Back Review Group proposed that identification of subgroups is a key priority of LBP management in order to address the problem of patient heterogeneity.[26] Recent research supports this claim, with evidence that subjects with NSLBP can be broadly classified based on psychologic factors,[27–29] movement and postural behaviors,[30–32] neurophysiologic factors,[33] and lifestyle behaviors (sedentary[34] vs. excessive activity[35]). Despite this knowledge, to date, the majority of studies that relate to the classification of back pain have focused only on a single dimension of the problem, rather than consideration being given to all dimensions of LBP.[36] What is clear from the scientific literature and clinical practice is that a multidimensional approach to dealing with LBP is required.[37,38] These dimensions consist of pathoanatomic, neurophysiologic, physical and psychosocial factors.[2] The relative contribution of the different dimensions and their dominance associated with a LBP disorder will differ for each patient and therefore trigger a truly patient-centered intervention.

Understanding the complexity of LBP, the role of the treating clinician is to consider all dimensions of the disorder based on an interview, thorough physical examination (assessing all subsystems of the movement system) combined with review of radiological imaging, medical tests, and screening questionnaires. A clinical reasoning process allows determination of which factors are dominant in the disorder and whether the patient has adjusted to the disorder in an adaptive (protective) or maladaptive (provocative) manner. Consideration of all the factors outlined allows for a diagnosis and mechanism-based classification guiding management of the disorder.

As physical therapists, our expertise typically falls under mechanically or symptom-driven causes, but we need to look beyond mechanical or chemical nociception and become aware of the cognitive/emotional aspects of LBP. Considered simplistically, the presence of localized and anatomically defined pain associated with specific and consistent mechanical aggravating and alleviating factors suggest that physical/mechanical factors are likely to dominate the disorder. This results in a primary peripheral nociceptive drive that will respond well to mechanical based classification models and interventions. Correlation between clinical examination of mechanical factors and pathoanatomic findings is useful to determine their significance and relationship to the disorder. If pain is constant, non-remitting, widespread, and is not greatly influenced by mechanical factors (or minor mechanical factors result in an exaggerated and disproportionate pain response), then inflammatory or centrally driven neurophysiologic factors (such as altered central pain processing) are likely to dominate the disorder. High levels of anxiety, hypervigilance, fear and emotional stress presenting as primary aggravating or precipitating factors in the disorder highlight the influence of psychologic and in some cases social factors indicating a dominant psychosocial driver of pain. In reality, all pain conditions have a combination of drivers and must be assessed not only on a case by case basis, but also one date of service at a time since some patients tend to fluctuate as to what factor is the primary driver at any given time.

Physical therapy interventions that are classification based and specifically directed to the underlying driving mechanism (cause) have the potential to alter these disorders and impact both the physical and cognitive/emotional drivers of pain. Exercise prescription should be based on individual and ongoing assessment of the activity and participation levels, multidimensional drivers, and associated body functions and structure. Despite the wide variety of exercises that are prescribed for the low back, evidence-based data to justify choices are not as complete as one may think or expect. Professional challenges regarding exercise prescription are based upon strong clinical decision-making processes built upon what we know about the multidimensional nature of LBP. This chapter will provide the tools for sound clinical decision-making with multiple examples of therapeutic exercise prescription to assist the practitioner as to why and when a specific targeted exercise may be useful.

REVIEW OF ANATOMY AND KINESIOLOGY

Prerequisite to sound clinical decision-making in the patient management process (see Chapter 1) is an extensive knowledge of anatomy and kinesiology. The anatomy and kinesiology of the lumbopelvic region have received considerable attention in the literature,[39–43] which has enhanced clinical understanding of the function of the lumbopelvic region and emphasized the integrated nature of normal movement between the trunk and extremities. To properly examine, evaluate, diagnose, and treat the lumbopelvic region, in-depth knowledge of all aspects of the movement system involved in LBP is essential. It is beyond the scope of this text to provide a complete review of the anatomy and kinesiology of the lumbopelvic region; thus, the review will be limited to myology. Further elaboration of anatomy and kinesiology can be found on thePoint.lww.com/BrodyHall4e.

Myology

Optimal function of the lumbopelvic region requires an integration of the musculature of the posterior and anterior aspects of the spine, pelvis, and hips. In addition, the latissimus dorsi influences lumbopelvic mechanics. Because of the integration of musculature spanning the lumbopelvic region, myology is addressed in an integrated format for the entire region.

Posterior Lumbopelvic Myology

The thoracolumbar fascia (TLF) and its powerful muscular attachments play an important role in stabilization of the lumbopelvic region.[44,45] Numerous muscular attachments into the TLF have been described, including attachments of transversus abdominis (TrA) and some fibers of the internal obliques (IO) into the lateral raphe portion of the TLF and attachments of gluteus maximus, latissimus dorsi, erector spinae, and biceps femoris into the posterior layer of the TLF (**Fig. 17-1**). This pattern suggests that the hip, pelvic, and leg muscles interact with arm and spinal muscles through the TLF.[44] The gluteus maximus and latissimus dorsi may conduct forces contralaterally through the posterior layer of the TLF, and the action of these two muscles may be linked to provide support to the sacroiliac joint (SIJ) and lumbar spine during gait and trunk rotation. This integrated system has also been proposed as a method of load transference between the spine and hips, in which the TLF is a centrally placed structure for the interaction of muscles from each region.

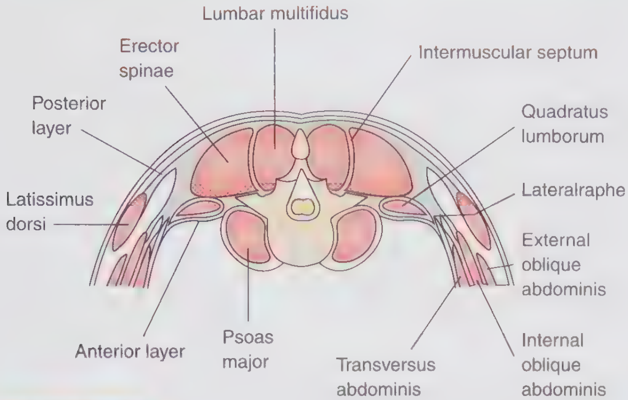


FIGURE 17-1 Cross section of the lumbar spine showing layers of the trunk musculature. (Adapted from Porterfield JA, DeRosa C. Mechanical Low Back Pain: Perspectives in Functional Anatomy. 2nd Ed. Philadelphia, PA: WB Saunders, 1998.)

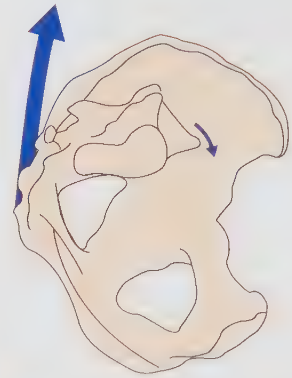


FIGURE 17-3 The attachment of the superficial erector spinae to the sacrum provides a potential force for sacral nutation (sacral flexion). Because nutation increases sacral stability, the superficial erector spinae may play a role in force closure of the sacroiliac joint. (Adapted from Porterfield JA, DeRosa C. Mechanical Low Back Pain: Perspectives in Functional Anatomy. 2nd Ed. Philadelphia, PA: WB Saunders, 1998.)

The spinal extensors may be broadly categorized as superficial muscles (i.e., iliocostalis), which travel the length of the spine and attach to the sacrum and pelvis, and deep muscles (i.e., longissimus and lumbar multifidus [LM]), which span the lumbar segments. Even though the superficial spinal extensors do not attach directly to the lumbar spine, they have an optimal lever arm for lumbar extension by virtue of their attachments (**Fig. 17-2**). By pulling the thorax posteriorly, they can create an extension moment at the lumbar spine. They function eccentrically to control descent of the trunk during forward bending and isometrically to control the position of the lower thorax with respect to the pelvis during functional movements.[46,47] The attachment of the superficial spinal extensors also influences SIJ mechanics. Because of the attachment of the erector spinae aponeurosis to the sacrum, the pull of the erector spinae tendon on the dorsal aspect of the sacrum induces a flexion moment (i.e., nutation) of the sacrum on the ilium (**Fig. 17-3**).

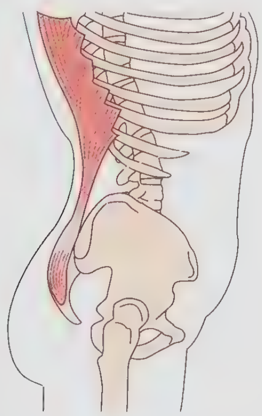


FIGURE 17-2 When viewed from the side, the superficial erector spinae can be seen to course superiorly and posteriorly from its point of origin at the pelvis to its attachment to the ribs. Elongation of the muscle occurs when the thorax (on the same side as the superficial erector spinae) is brought even further posterior, or the iliac crest on the same side is brought forward. Shortening of the superficial erector spinae occurs with thorax or pelvis movement opposite those just described. (Adapted from Porterfield JA, DeRosa C. Mechanical Low Back Pain: Perspectives in Functional Anatomy. 2nd Ed. Philadelphia, PA: WB Saunders, 1998.)

The deep erector spinae have a poor lever arm for spine extension but are aligned to provide a dynamic counterforce to the anterior shear force imparted to the lumbar spine from gravitational force (**Fig. 17-4**). The attachment of the LM to the spinous process provides a good lever arm for spinal extension (**Fig. 17-5**). During forward-bending motions, this muscle contributes to controlling the rate and magnitude of flexion and anterior shear.[48] Because of its deep location, short fiber span, and oblique orientation, the LM is thought to stabilize against flexion and rotation forces on the lumbar spine.[49,50] Several studies have illuminated its relationship with the vertebral segment.[51-53] In a study of normal subjects without LBP, it seems that the deep fibers of the multifidi, along with the TrA, are the first muscles to become active when a limb is moved in response to a visual stimulus and fire independent of limb movement direction to control intervertebral movement.[54] The superficial fibers are also activated before the muscles that move the limb.[54] The LM also contributes to dynamic stability of the SIJ. Because it is attached to the sacrotuberous ligament, tension on the ligament imparted as a result of LM muscle

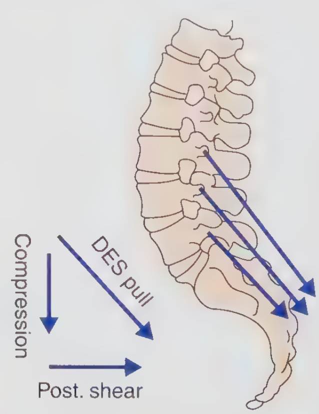


FIGURE 17-4 Because the deep erector spinae (DES) attach close to the axis of lumbar motion, the muscle group provides a dynamic posterior shear and compression force (*arrows*). This muscle can provide a force to prevent anterior translation. (Adapted from Porterfield JA, DeRosa C. Mechanical Low Back Pain: Perspectives in Functional Anatomy. 2nd Ed. Philadelphia, PA: WB Saunders, 1998.)

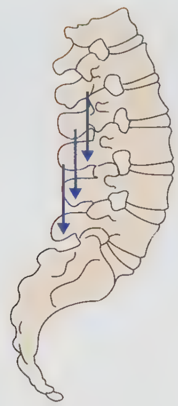


FIGURE 17-5 Because of lumbar multifidus (LM) insertion, there is a large vertical vector for extension, with a small horizontal vector indicating it is a stabilizer of rotation rather than horizontal rotation being its primary function. The primary vector is to provide posterior sagittal rotation. The primary rotators of the trunk are the oblique abdominals that, by virtue of their vertical vector, cause a flexion moment as well as rotation, which is stabilized by the LM. (Adapted from Bogduk N, Twomey LT. Clinical Anatomy of the Lumbar Spine. Edinburgh: Churchill Livingstone, 1987.)

contraction potentially increases the ligamentous stabilizing mechanisms of the SIJ (**Fig. 17-6**). The effect of dysfunction of this muscle, discussed in detail in a later section, further emphasizes its important role in spine stabilization.

Anterior Lumbopelvic Myology

One of the most important muscle groups contributing to mobility and stability of the lumbopelvic region is the abdominal wall mechanism. The abdominal wall consists of, superficial to deep, the rectus abdominis (RA), external oblique (EO), IO, and TrA. The RA, EO, and IO appear to serve a relatively more dynamic role than the TrA.

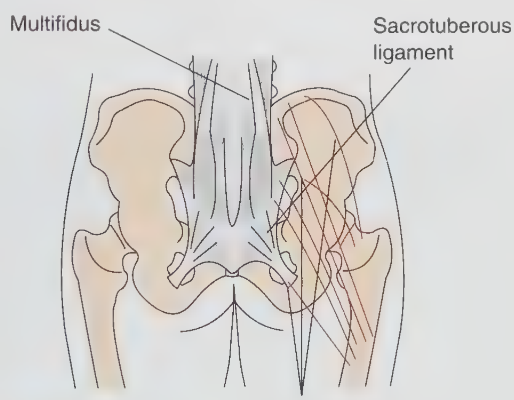


FIGURE 17-6 Anatomic relationship of lumbar multifidus (LM) to the sacroiliac joint, sacrotuberous ligament, and gluteus maximus. The LM attaches to the thoracolumbar fascia (TLF) primarily through a raphe separating the multifidus and gluteus maximus. The anterior border of the raphe is anchored to the sacroiliac joint (SIJ) capsule and the posterior border of the raphe becomes part of the TLF. Tendinous slips of the multifidus pass under the long dorsal SI ligament to join with the sacrotuberous ligament; these connections are thought to integrate the LM into the ligamentous support system of the SIJ. (Adapted from Porterfield JA, DeRosa C. Mechanical Low Back Pain: Perspectives in Functional Anatomy. 2nd Ed. Philadelphia, PA: WB Saunders, 1998.)

The TrA is circumferential, situated deeply, and has attachments to the TLF, the sheath of RA, the diaphragm, iliac crest, and the lower six costal surfaces.[55] The TrA has unique anatomic features, including its deep location, its link to fascial support systems, its fiber type distribution, and its possible activity against gravitational load during standing and gait. As a result, the TrA is an important stabilizing muscle for the lumbar spine.[56–64] The TrA activates before the onset of limb movement in persons without LBP, but this function is lost in those with LBP.[56,65] Current theory suggests that this muscle is a key background stabilizing muscle for the lumbar spine and that the emphasis of specific exercises for the abdominal wall should involve specific recruitment of the TrA instead of general strengthening or endurance. Exercises of this nature are described in detail in a subsequent section of this chapter.

The oblique abdominal muscles working synergistically provide an anterior oblique sling and, together with the posterior oblique sling (i.e., TLF and associated structures), they assist in stabilization of the lumbar spine and pelvis in an integrated system of myofascial support.[66,67] The right EO works synergistically with the left IO to produce rotation to the left and to prevent excessive rotation when necessary. The LM must synergically contract to prevent flexion imposed by the obliques so that pure rotation or transverse plane stabilization can occur. The inferior and medial directions of the fibers of the EO are positioned to prevent anterior pelvic tilt and anterior pelvic shear. With respect to the SIJ, the oblique abdominals provide compressive forces between the two pubic bones and at the SIJ posteriorly (**Fig. 17-7**).

Associated Pelvic, Hip, and Upper Extremity Myology

Twenty-nine muscles originate or insert into the pelvis. Twenty of these link the pelvis with the femur, and nine link the pelvis with the spine. This implies that significant forces can be generated through the pelvis and subsequently through the lumbar spine by various combinations of knee and hip muscle activity.

The iliacus and psoas major have significant attachments to the spine and pelvis. If not counterstabilized by the abdominal muscles, the iliacus can exert an anterior rotation force on the pelvis. If not counterstabilized by the deep erector spinae, LM,

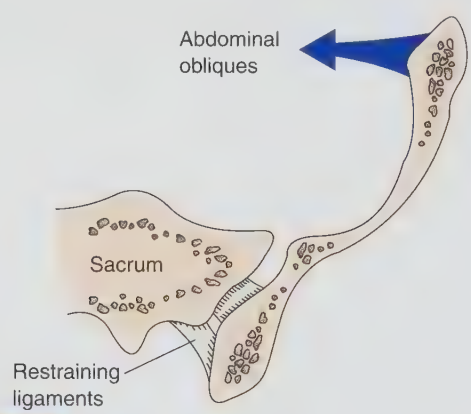


FIGURE 17-7 Contraction of the abdominal oblique muscles acting over the fulcrum of the interosseous ligament increases sacroiliac joint stability and pubic symphysis compression. (Adapted from Porterfield JA, DeRosa C. Mechanical Low Back Pain: Perspectives in Functional Anatomy. 2nd Ed. Philadelphia, PA: WB Saunders, 1998.)

and abdominal muscles, the psoas major can exert an anterior translational force on lumbar segments.

The fibers of the gluteus maximus muscle run perpendicular to the plane of the SIJ and blend with the TLF and the contralateral latissimus dorsi.[40] Compression of the SIJ occurs when the gluteus maximus and the contralateral latissimus dorsi contract. This oblique system crosses the midline and is believed to be a significant contributor to load transference through the pelvic girdle during rotational activities and during gait.[40,66] The TLF is tensed by contraction of gluteus maximus, latissimus dorsi, and erector spinae muscles.

In addition to the attachment to the ischial tuberosity, the long head of the biceps femoris attaches to the sacrotuberous ligament. Contraction of the biceps femoris increases tension of the sacrotuberous ligament and pulls the sacrum against the ilium, effectively increasing the stability of the SIJ.[60]

In standing and walking, the pelvic girdle is stabilized on the femur by the coordinated action of the ipsilateral gluteus medius and minimus and by the contralateral adductor muscles. Indirectly, by maintaining a relationship between the hip, pelvis, and lumbar spine in the frontal plane, the gluteus medius, gluteus minimus, and adductors contribute to lumbar spine stability. Although these muscles are not directly involved in force closure of the SIJ, they play a significant role in pelvic girdle function.

The piriformis is considered to be part of the deep hip lateral rotator group and pelvic floor. It appears to play a vital role in stabilization of the SIJ. The piriformis attaches to the sacrum, the anterior surface of the sacrotuberous ligament, and the medial edge of the SIJ capsule. This muscle anchors the apex of the sacrum and controls sacral nutation.

The link of pelvic floor function and lumbopelvic function should not be underestimated. The pelvic floor forms the base of the abdominal cavity, so pelvic floor muscles must contract during tasks that increase intraabdominal pressure to maintain continence. In subjects without LBP, strong voluntary abdominal muscle contraction caused pelvic floor muscle activity at the same intensity as maximal pelvic floor muscle effort. The pelvic floor does not simply respond to increases in intraabdominal pressure; instead, the pelvic floor muscles contract before the abdominal muscles.[68] One investigator found that some patients with chronic LBP (CLBP) were unable to recruit the TrA without prior contraction of the pelvic floor.[61]

Last, but certainly not least, is the importance of integrated function of the diaphragm. The diaphragm and deep stabilization muscles of the body have been described as an important functional unit for dynamic spinal stabilization.[69,70] In addition, proper use of the diaphragm assists with general relaxation of trunk muscle guarding patterns.[71] The diaphragm precedes any movement of the body by lowering and subsequently establishing abdominal pressure which helps to stabilize the lumbar part of the spine. Studies focused on diaphragm activation with the aim of posture stabilization have identified phase modulation which corresponds to the movement of the upper limbs.[72–75] Other studies show that healthy individuals have a bigger range of diaphragm motion with lower breathing frequency, better coordination within its movement, and better balanced postural and breathing components than those with LBP.[76] These factors are very important for maintaining intraabdominal pressure, which helps to support the spine in conjunction with the abdominal wall, posterior musculature, and pelvic floor. Studies support the difference in motor control of the respiratory and stabilization muscles in patients with and without LBP suggesting integrated motor control of the diaphragm, posterior, anterior, and pelvic floor muscles should be developed in patients with LBP.[72–77]

Gait

Gait is a vital functional activity. **Table 17-1** displays the biomechanics and muscle function of the gait cycle of the lumbopelvic region.

TABLE 17-1

Kinematics and Muscle Activity of the Gait Cycle in the Lumbopelvic Region

PHASES OF THE GAIT CYCLE	RANGE OF MOTION		MUSCLE ACTIVITY	
	LUMBAR SPINE	PELVIC GIRDLE[a]	LUMBAR SPINE[b]	PELVIC GIRDLE[c]
Initial contact	Sidebending ipsilateral/ rotation contralateral	Small cranial/caudal shear; ipsilateral innominate rotates posteriorly/contralateral innominate rotates anteriorly	Bilateral erector spinae	Hamstring (HS), gluteus maximus[d]
Loading response	As at initial contact			
Midstance	As at initial contact	Ipsilateral innominate rotates anteriorly toward neutral; contralateral innominate rotates posteriorly toward neutral		
Terminal stance	Preparing for initial swing	Ipsilateral innominate rotates anteriorly past neutral; contralateral innominate rotates posteriorly	Bilateral erector spinae[86]	
Preswing	Preparing for initial swing			
Initial swing	Contralateral side-bend/ ipsilateral rotation			

TABLE 17-1

Kinematics and Muscle Activity of the Gait Cycle in the Lumbopelvic Region (*continued*)

PHASES OF THE GAIT CYCLE	RANGE OF MOTION		MUSCLE ACTIVITY	
	LUMBAR SPINE	PELVIC GIRDLE[a]	LUMBAR SPINE[b]	PELVIC GIRDLE[c]
Midswing	As initial swing			
Terminal swing	As initial swing			

[a]The motion of the sacrum between the two innominates and adjacent fifth lumbar vertebra has been described as a complex, polyaxial, torsional movement that occurs about the oblique axes.[78,79]

[b]Discrepancy exists regarding activity of rectus abdominis and obliqui externus and internus, perhaps because of speeds of walking during testing conditions.[80,81] The transversus abdominis and lumbar multifidus appear to be linked with the control of stability of the spine against the perturbation produced by the movement of the limbs and should be considered as active during the gait cycle.[50]

[c]Much of the muscle activity occurring across the pelvic girdle during gait is discussed in Chapter 20. Additional information regarding the link between the hip, the lumbopelvic region, and the upper extremity is provided in this table.

[d]HS activity increases the tension in the sacrotuberous ligament and contributes to the force closure mechanism of the pelvic girdle with loading of the limb.[66,82,83] Gluteus maximus becomes active with counterrotation of the trunk and arm swing forward, resulting in lengthening of the contralateral latissimus dorsi muscle. Shortly thereafter, the arm swings backward, causing contraction of the contralateral latissimus dorsi. Lengthening and contraction of the latissimus dorsi contribute to increased tension in the TLF, thereby contributing to further force closure mechanism of the sacroiliac joint (SIJ).[84] Gluteus maximus activity is key to force closure stabilizing mechanisms within the pelvis; loss of function of the gluteus maximus can hinder stability of the SIJ.[85]

EXAMINATION AND EVALUATION

Patients suffering from spine pain can present with a wide spectrum of symptoms and examination findings, representing different degrees of clinical severity and pathological significance. In most people, LBP is benign and represents a simple back sprain or strain associated with a mechanical loading incident or a "pain flare" associated with psychosocial or lifestyle stresses. Serious etiologies of spine pain that include fractures, tumors, or infections are relatively rare, accounting for less than 1% of all medical cases seen during spine assessment.[87] However, because most spine pain patients present with a clinical picture that could be created by numerous different conditions,[87] it is imperative for clinicians to identify conditions or comorbidities that may deter a patient's recovery and function or place the patient at risk of serious medical consequences (red flags). A clinician must remain alert to potential clinical indicators that require more extensive testing, consultation, or referral (see **Table 17-2**).[88]

In approximately 5% to 10% of people with LBP, the pain may be associated with radicular features with or without neurologic deficit. This may be associated with compression of the nerve root, spinal cord, or cauda equina syndrome, which is linked to an underlying pathology, such as disk prolapse, lateral recess, and canal stenosis or advanced grade spondylolisthesis (discussed later in this chapter in more detail). A presentation of progressive neurologic deficits or signs of cauda equina syndrome (new urine retention, fecal incontinence or saddle anesthesia) warrants further investigation and referral to a medical specialist.[89]

As previously stated, 90% of patients with LBP do not have a specific pathoanatomic or pathophysiologic source and are considered to have NSLBP.[89] The goal of the physical therapy examination is to determine the multidimensional cause(s) of the patient's activity limitations and participation restrictions.

A multidimensional approach toward management of LBP combines a strong cognitive focus with an emphasis on reframing the persons' understanding of their back pain in a person-centered manner, with a simultaneous emphasis on changing maladaptive movement, as well as lifestyle behaviors

TABLE 17-2

Categorical Classification of "Red Flag" Findings During Medical Screening

Category I: Factors that require immediate medical attention

- Blood in sputum
- Loss of consciousness or altered mental status
- Neurologic deficit not explained by monoradiculopathy
- Numbness or paresthesia in the perianal region
- Pathological changes in bowel and bladder
- Patterns of symptoms not compatible with mechanical pain (on physical examination)
- Progressive neurologic deficit
- Pulsatile abdominal masses

Category II: Factors that require subjective questioning and precautionary examination and treatment procedures

- Age >50
- Clonus (could be related to past central nervous system disorder)
- Fever
- Elevated sedimentation rate
- Gait deficits
- History of a disorder with predilection for infection or hemorrhage
- History of a metabolic bone disorder
- History of cancer
- Impairment precipitated by recent trauma
- Long-term corticosteroid use
- Long-term worker's compensation
- Nonhealing sores or wounds
- Recent history of unexplained weight loss
- Writhing pain

Category III: Factors that require further physical testing and differentiation analysis

- Abnormal reflexes
- Bilateral or unilateral radiculopathy or paresthesia
- Unexplained referred pain
- Unexplained significant upper or lower limb weakness

Categorical Classification of "Red Flag" Findings During Medical Screening

Sizer PS Jr, Brismée JM, Cook C. Medical screening for red flags in the diagnosis and management of musculoskeletal spine pain. Pain Pract 2007;7:53–71.

contributing to their vicious cycle of pain. From a mechanical standpoint, targeting specific movement training is important to this approach in that it:

- Reveals to the examiner and the patient the type and direction of the mechanical stress that correlates with symptoms, empowering the patient with a sense of control
- Reveals potential physiologic impairments that contribute to the movement impairment
- Becomes the basis for a therapeutic exercise program and for posture and movement retraining

Patient History

To successfully manage a patient with LBP, it is imperative that the therapist has a clear understanding of the patient's medical history and current symptoms. In addition to the general data collected from a patient/client history as defined in Chapter 2, special questions regarding symptoms related to the low back and patient beliefs can begin the clinical reasoning process toward diagnosis. Research into the validity of history findings with respect to LBP generally uses a pathoanatomic classification system, but recently, emphasis on reflective interviewing has helped to understand psychosocial factors that are contributing to the experience of pain. **Display 17-1** presents examples of reflective interview questions for persons with LBP. The research presented in **Display 17-2** uses diagnostic labels of disk disease, zygapophyseal (ZJ) joint syndrome, SIJ syndrome, cauda equina syndrome, and stenotic syndrome. For detailed list of questions, please refer to Magee's text.[97]

DISPLAY 17-1
Reflective Interview Questions

- When did your back pain start?
- What do you think was the initial mechanism of injury?
- What are your beliefs about where the pain is coming from?
- What are you feeling in your body? Is there tension in your body? If so, where?
- Can you tell me about things that you are doing when your back feels better? Can you tell me about things you are doing when your back feels worse?

Additional Methods That Help Expand the Narrative

- Try to listen without interrupting or responding too quickly—if necessary, count to five slowly before making any comments and then see if the comment is necessary
- Invite elaboration and clarification (tell me more about. . .).
- Feel free to offer empathy if appropriate.
- Try not to comment, interpret, agree, disagree, or compare their views with yours or anyone else's; remember that this is not a conversation; the goal is to create a space for your patients' thoughts and not your own.
- Take notes so that you can reflect back on the major themes of the story.
- Paraphrase and summarize. For example, "Let me see if I have this correct. You said that. . ."
- If the patient has seen other health care providers, their care will be discussed as part of the history. Occasionally, the patient may be dissatisfied with their previous course of care, may appear frustrated over their lack of improvement, and may speak unfavorably of other health care providers. Listen without judging or making a comment regarding other health care provider's services.

DISPLAY 17-2
History Items in Patients with LBP

Disk Disease[90]

- LBP
- Burning, stabbing, "electrical" pain down the leg
- Numbness or paresthesia (sensitivity 30% to 74% for paresthesia)[91]
- Aggravated by increased intradiskal pressure or specific movements
- Substantial but not complete relief with rest
- Radicular distribution pain (sensitivity of 95% for sciatic distribution of pain)[11]
- Leg pain greater than back pain
- Pain superficial and sharp rather than less well-defined, dull, aching
- Sensitivity for sciatic distribution of pain of 79% to 95%[91]

Zygapophyseal (ZJ) Syndrome

- ZJs do not cause referred pain; pain is experienced exclusively in the central lumbar spine[92]
- ZJs may refer pain into the leg below the knee possibly due to segmental facilitation as a result of nociceptive input from a painful structure elsewhere in the affected segment[93]

Sacroiliac Joint (SIJ) Syndrome

- Groin pain[92]
- Pain inferior to the posterior superior iliac spine[94,95]
- Radicular symptoms may occur as a result of extravasation of inflammatory mediators through a capsular recess or tear to adjacent neural structures[95]

Cauda Equina Syndrome[96]

- Sensitivity of 95% for urinary retention[11]
- Sensitivity higher than 80% for motor weakness and decreased sensation in the legs[11]
- LBP
- Bilateral or unilateral sciatica
- Sensitivity of 75% for saddle area hyperesthesia[11]
- Sexual dysfunction (decreased sensation during intercourse, decreased penile sensation, and impotence)
- L5–S1 central disk herniation may cause no motor or reflex changes in the legs

Stenotic Syndrome[11]

- 60% sensitivity for neurogenic claudication
- 85% sensitivity for leg pain
- 60% sensitivity for neurologic abnormalities

Screening Examination

Symptoms originating in the lumbopelvic region often are experienced elsewhere in the lower quadrant and symptoms mimicking lumbopelvic origin dysfunction can originate in visceral tissues (see Appendix 1). It is for these reasons that a lumbopelvic screen is recommended before performing any lumbopelvic or lower quadrant examination. The purpose of the screening examination is to determine whether symptoms experienced in the lower quadrant are originating in the lumbopelvic region. If it is determined that symptoms are stemming from the lumbopelvic region, a more thorough lumbopelvic examination and evaluation is indicated. **Display 17-3** lists the tests that should be included in any lumbopelvic screening examination.

DISPLAY 17-3

Lumbopelvic Scan Evaluation

Observation: Posture scan in standing and sitting, local signs of skin color, texture, scars, soft-tissue contours

Active Range of Motion (with overpressure if indicated): In standing, flexion, extension, lateral flexion; in sitting, rotation

Stress Tests: Supine lumbar compression and distraction, supine sacroiliac joint compression and distraction, sidelying sacroiliac joint compression, prone lumbar torsion stress

Provocative Test: Prone posteroanterior pressure to the lumbar spine

Palpation: Palpate-related lumbar-pelvic-hip musculature, assessing for tone changes, lesions, and pain provocation

Dural Mobility Tests: Slump test, straight-leg raise, prone knee flexion

Neurologic Testing: Key muscle (see **Table 17-3**) reflexes, dermatomes

TABLE 17-3

Key Muscles and Corresponding Nerve Root and Peripheral Nerve in the Lumbopelvic Region

KEY MUSCLE	NERVE ROOT	PERIPHERAL NERVE
Psoas	L2 (3)	Femoral nerve
Quadriceps	L3 (4)	Femoral nerve
Tibialis anterior	L4 (5)	Deep peroneal
Extensor hallucis	L5 (S1)	Deep peroneal
Gluteus medius	L5 (S1)	Superior gluteal
Peronei	L5 (S1)	Superficial peroneal
Medial hamstring	L5 (S1)	Sciatic
Lateral hamstring	S1	Sciatic
Gastrocnemius	S1 (S2)	Tibial
Gluteus maximus	S2	Inferior gluteal
Bladder and rectum	S4	

Tests and Measures

The following sections describe, in alphabetical order, the tests and measures highlighted in any lumbopelvic examination/evaluation. The tests and measures must be individualized based on the data collected from the history, systems review, and screening examination. Additional tests and measures may be included on a case by case basis. The reader is referred to the *Guide to Physical Therapist Practice* for a detailed list of physical therapy tests and measures.[98]

Anthropometric Characteristics

Anthropometric characteristics may be of interest, whereas an individual's unique anthropometric characteristics can be a risk factor in developing certain types of lumbopelvic syndromes. For example, the anthropometric characteristics of a male with broad shoulders, narrow pelvis, and high center of mass promote lumbar flexion versus hip flexion during forward bend movements. This may pose as a risk factor in developing LBP.[99] In addition, if returning to a job requiring bending and lifting, he/she will need to pay attention to body mechanics limiting *excessive* or *highly repetitive* lumbar flexion forces—not necessarily avoiding them.

Ergonomics and Body Mechanics

An assessment of a patient's job-related duties and physical demands should include ergonomic and body mechanic assessment. This may include assessing material handling capabilities, such as lifting incrementally increasing weights at different heights. Assessment of non–material handling capabilities includes tasks such as sitting or standing tolerance, or work station ergonomics. These kinds of assessments are often termed functional capacity evaluations (FCEs). FCEs can be purchased or designed in the clinic and may use expensive mechanical devices interfaced with computers, or inexpensive handmade boxes, crates, and push/pull sleds. One important point to maintain concerning the validity of an FCE is that an FCE, conducted from 2 to 4 hours over 1 to 2 days of a person's life at a given point in time, cannot predict a person's capacity to work for 8 to 10 hours per day, 4 to 6 days per week, 52 weeks per year. At best, the FCE may simulate certain skills and capacities needed to perform the job. The FCE should be used as one aspect of the injured person's examination, not as a complete evaluation in and of itself.

Gait/Balance

Gait is a complex functional movement pattern that can indicate pathomechanical factors contributing to lumbopelvic signs or symptoms, particularly if the patient reports that walking increases or decreases symptoms. The relationship of other regions to the lumbopelvic region is important in ascertaining the mechanical stress imposed on the lumbar spine. For example, a hypomobile supinated foot that does not adequately pronate during the stance phase of gait may increase compressive stress on the lumbar spine, whereas a hypermobile pronated foot may induce a transverse plane stress on the lumbar spine by creating a short limb during the stance phase of gait. Even phones equipped with video applications can be used for full speed and slow motion video analysis. This can be an efficient tool to evaluate and provide patient feedback regarding the complex interaction of multiple regions on the lumbar spine during walking or running. Incorporating findings from a gait evaluation to other tests of measures can assist the practitioner in developing a specific exercise program to remediate the impairments related to gait deviation. Once quality of gait improves, it can be used as more effective activity to improve endurance and serve as a graded exercise to reduce fear-avoidance behaviors.[100]

Muscle Performance

The ability for the spine and pelvic girdle muscles to carry out functions of mobility and stability must be carefully assessed to ascertain the pathomechanics of the lumbopelvic region. Muscle performance testing includes tests of strength, power, and endurance adequate for each individual to carry out his or her desired controlled mobility (basic activities of daily living [BADLs]) and skill-level activities (instrumental activities of daily living [IADLs]).

Assessment of the force or torque-generating capability of the spinal extensor and abdominal muscle groups can be performed with traditional manual muscle testing procedures as described by Kendall et al.[101] Because of the numerous details regarding accurate assessment of the abdominal muscles, Kendall's work should be reviewed to ensure optimal manual muscle testing results.

Although objective information about muscle force or torque production can be gathered from isokinetic testing, gross strength testing by this method may not be sensitive to the function of the deeper musculature surrounding the spine. Whereas many studies demonstrate a relationship between impaired function of the deep abdominal and LM muscles and LBP, studies comparing gross trunk strength in normal subjects or patients with LBP have not consistently demonstrated such a relationship.[102–107] This difference may reflect the inherent limitations in conclusions that can be ascertained from studies examining maximal trunk strength in persons with LBP. For example, pain can hinder maximal effort, and a test of a patient with LBP may be more a test of the patient's tolerance to pain. This design problem may be responsible for the varied and seemingly contradictory results of trunk muscle strength reported in the literature. There is also growing evidence that altered movement patterns and increased trunk muscle cocontraction are associated with the recurrence and persistence of LBP, suggesting a need to think about excessive forces on the spine.[71]

Isokinetic testing of trunk muscle strength focuses largely on the assessment of muscles primarily involved in and capable of producing large torques about the spine (e.g., RA, thoracolumbar erector spinae) rather than on muscles considered to provide stability and fine control (e.g., TrA and LM).[108,109] Most studies focus on maximal voluntary contractions, which are rarely carried out during the ADLs. In the CLBP population, sudden, unexpected, and insignificant movement at low load can exacerbate symptoms just as commonly as tasks involving maximal exertion.[110,111] However, a recent investigation has shed light on the difference in torque production at various speeds between persons with and without herniated lumbar disks which may impact rehabilitation goals (**Evidence and Research 17-2**).

Isokinetic and traditional manual muscle testing may not be sensitive enough to assess the muscle performance of the deep trunk muscles (i.e., TrA and LM). Testing of trunk muscle strength should also consider the function of the deeper musculature. Tests that examine the ability of the deep trunk muscles to stabilize against various directional forces during active extremity movement can provide the clinician with an indication of their muscle performance.[36,113] When the spine is unable to remain stable against a specific direction of force, it can indicate a lack of motor control, force or torque production, or fatigue (depending on the focus of the test) of the associated trunk muscle(s). Additional methods of testing TrA muscle function involve palpation of the abdominal wall[114] and the use of a pressure cuff (pressure biofeedback unit, Chattanooga, USA) placed under the abdomen with the patient in a prone lying position.[115] This test represents an inner range concentric contraction of the TrA muscle to lift the abdominal contents and wall and thereby decrease the pressure in the pressure biofeedback unit. The multifidus muscle can be assessed by the palpation of muscle bulk and by the quality of voluntary contraction at each lumbar vertebral level.[115] The LM can be assessed using a biofeedback device as well. With the patient in supine hook-lying, the biofeedback device is placed under the lumbar spine; concentric contraction of the LM muscle increases the pressure in the biofeedback unit. Real-time ultrasound imaging is another method that is used in physical therapy clinical practice both for assessment of TrA and multifidus muscle function and size as well as for retraining purposes.[116,117] High repetitions of any test can provide an indication of the endurance of the trunk muscles.

In theory, resisted testing of the trunk muscles can also provide information about the integrity of the trunk muscles relative to imposed strain. However, resisted testing of the trunk muscles can also provoke other pain-sensitive structures and

EVIDENCE and RESEARCH 17-2

Isokinetic Testing of Extremity Muscles in LBP with Lumbar Disk Herniation

A cross-sectional study comparing normal subjects and patients with lumbar disk herniation (LDH) with sciatica was performed to simultaneously measure the isokinetic muscle strength of the trunk, knees, and ankles in both groups.[112]

Key Points

- Simultaneous trunk, knee, and ankle strengths were measured in patients with LDH with sciatica.
- In addition to decreased trunk strength, significant decrease in the knee flexion/extension and ankle plantar flexion strength, but not dorsiflexion strength, was demonstrated in the LDH group, regardless of the laterality of sciatica.
- At the test velocity of 180 degrees per second, knee extension torque was revealed to be significantly lower in the limb with sciatica than in the limb without sciatica in the LDH group.
- Reduction in knee torque at fast speeds may possibly be explained by the pain-related reduced walking activity of affected limbs associated with selective type II muscle fiber atrophy in the quadriceps muscles. Future histologic or morphologic studies are warranted.
- Results of the study provide clinical implications that a good and satisfactory rehabilitation/therapeutic program for patients with LDH or LBP should control the pain (back pain and leg pain) and that these patients should strengthen both the trunk and lower extremity muscles at different contraction speeds (especially the faster speeds) to ensure successful recovery.

result in a weak and painful test, making it difficult to use resisted testing as a differential diagnostic test for trunk muscle strain.

Muscle strength testing of pelvic girdle and pelvic floor muscles can provide pertinent information about factors that may contribute to lumbopelvic dysfunction. For example, weakness in the gluteus medius results in excessive hip adduction and pelvic drop in the single-limb support phase of gait, which can impose frontal or transverse plane stress on the lumbopelvic region and thereby contribute to lumbopelvic impairment or pathology. When healthy study participants performed sidelying hip abduction while concurrently performing lumbar stabilization, gluteus medius activity increased and quadratus lumborum activity decreased, causing a decrease in lateral pelvic tilt. The authors suggested that hip abduction with lumbar stabilization is useful to exclude substitution by the quadratus lumborum.[118] Chapters 18 and 19 respectively, provide recommendations for pelvic floor and pelvic girdle muscle performance testing.

Neurologic Testing: Tests for Motor Function and Sensory and Reflex Integrity

A thorough neurologic examination for the lumbopelvic region consists of three parts. An *upper motor neuron screening* is indicated when cord compression is suspected. An upper lumbar central herniation may result in spinal cord compression. A central herniation in the lower lumbar spine can cause compression to the cauda equina and therefore should not result in upper motor neuron signs.

Sufficient compression on the nerve root may result in decreased conductive function of the nervous system; *neuroconductive testing* may reveal segmentally related sensory changes, motor changes, and hypo- or hyperreflexia.[119] Testing motor function can indicate a pattern of muscle weakness from a specific nerve root level or peripheral nerve. Table 17-3 indicates the key muscles with the corresponding nerve root and peripheral nerve innervation.

The third part includes *neurodynamic tests* that examine the movement and tensile abilities of the nervous system. Examples of neurodynamic tests include the straight leg raise (SLR), femoral slump test (FST), and seated slump maneuver. The clinician administering these tests should be skilled in the specialized features of handling and sequencing the components of the test and must understand what is considered to be a normal or acceptable response. Butler[120] describes the technique and rationale for neurodynamic tests in the lumbopelvic region. Deyo et al.[121] noted a sensitivity of 80% and specificity of 40% for the SLR in the diagnosis of low LDH. The SLR test is most appropriate for testing the L5 and S1 nerve roots. Irritation of the higher lumbar roots is tested by the FST, which biases the femoral component of the nervous system.[122,123]

Pain

The clinician examines pain in the lumbopelvic region with respect to many variables:

- Measurement of pain with respect to the level of disability it imposes on an individual with LBP
- Screening for psychosocial prognostic factors for the development of CLBP following the onset of musculoskeletal pain
- Examination techniques used to diagnose whether the pain is originating in the lumbopelvic region and, when possible, determine the potential pathoanatomic source(s) of the pain
- Examination techniques to determine potential mechanical cause(s) of pain

Because the United States, in common with other western nations, is trying to restrain the costs of health care, it is more important than ever for clinicians to demonstrate that the care they deliver is both efficient and effective. Pain scales are a common method for assessing patient outcome in back pain. At least 22 scales have been reported in the literature.[124] However, the presence of pain alone is a narrow definition of health outcome that correlates poorly with physical function.[125] Waddell and Main[126] stated that in evaluating the severity of LBP, three recordable, clinical components must be differentiated: pain, physical impairment, and disability. (See "Work [Job/School/Play], Community, and Leisure Integration or Reintegration [Including IADLs]" for further discussion regarding measures of disability.)

Efficient allocation of health care resources can be augmented by an outcome measure that can predict those patients whose outcomes are likely to be poor. Those individuals can be redirected to more appropriate intervention. Waddell developed a list of nonorganic signs that can be used as a predictor of outcome for patients with lumbopelvic disabilities.[127,128] Waddell et al.[128] identified five nonorganic signs, and each can be detected by one or two tests. The tests assess a patient's pain behavior in response to certain maneuvers (**Table 17-4**). A patient presenting

TABLE 17-4

Waddell Signs

TEST	SIGNS
Tenderness	Superficial—the patient's skin is tender to light pinch over a wide area of lumbar skin
	Nonanatomic—deep tenderness felt over a wide area, not localized to one structure
Simulation tests	Axial loading—light vertical loading over patient's skull in the standing position causes lumbar pain
	Acetabular rotation—back pain is reported when the pelvis and shoulders are passively rotated in the same plane as the patient stands; considered to be a positive test result if pain is reported within the first 30 degrees
Distraction tests	Straight-leg-raise discrepancy—marked improvement of straight-leg raising on distraction compared with formal testing
	Double-leg raise—when both legs are raised after straight-leg raising, the organic response is a greater degree of double-leg raising; patients with a nonorganic component demonstrate less double-leg raise compared with the single-leg raise
Regional disturbances	Weakness, cogwheeling, or giving way of many muscle groups that cannot be explained on a neurologic basis
	Sensory disturbance—diminished sensation fitting a "stocking" rather than a dermatomal pattern
Overreaction	Disproportionate verbalization, facial expression, muscle tension and tremor, collapsing, or sweating

From Karas R, McIntosh G, Hall H, et al. The relationship between nonorganic signs and centralization of symptoms in the prediction of the return to work for patients with low back pain. Phys Ther 1997;77:356. Reprinted with permission of the American Physical Therapy Association.

with a high Waddell score (i.e., 3 to 5 of 5 positive nonorganic signs) is believed to have a clinical pattern of nonmechanical, pain-focused behavior. The patient has significant enough psychologic impairments that intervention focused on physiologic and anatomic impairments alone probably cannot produce a successful outcome. A high Waddell score can be used as a predictor of functional outcome, as indicated by a low rate of return to work.[129] However, the practitioner must interpret this finding with caution.[128] A high Waddell score only indicates a high degree of nonorganic or psychologic impairments. It does not signify malingering, which is a judgment, not a medical or psychologic diagnosis.[127,128] Patients with a high Waddell score may need to be referred to the appropriate mental health practitioner for treatment before or in conjunction with physical therapy intervention (**Evidence and Research 17-3**).

EVIDENCE and RESEARCH 17-3

Construct Validity of Waddell Score

In a 2012 study, researchers investigated the construct validity of the Waddell score.[130] Construct validity refers to the question whether the relationship between the Waddell score and scores for other factors is in agreement with theoretical expectations. The primary aim of this study was to examine the relationships between the Waddell score and factors measuring demographics, pain intensity, illness behavior, and physical and psychologic status. A wide range of factors can contribute to the expression of Waddell signs, such as illness worry, sick role, unemployment, hypochondriasis, depression, anxiety to examination, central sensitization, learned behavior, and the disease state. For example, recent research shows that in patients with CLBP, brain structure and function can alter[131] and the patient can display Waddell signs as a response to these changes.[132] Given the substantial interindividual variability of how people respond to health problems, the differences in social norms, cultural models, and health care systems, and the probably limited usefulness of the description of the Waddell score in traditional diagnostic domains, it is not very surprising that only weak relationships were found between the Waddell score and the domains measured. For clinical practice, the presence of Waddell signs does not indicate exactly what the specific problems are, and they must, therefore, be conceptualized and understood in the total clinical picture of the patient. It is evident that the Waddell score cannot be regarded as a straightforward psychologic "screener."[127] This research underscores the complexity of illness behavior as measured with the Waddell score.

In addition to measurement of pain in relation to outcome data, the clinician should also attempt to determine whether or not the lumbar spine or pelvis is indeed the source of nociception. After it has been determined that the lumbopelvic region is the region of origin, even if the exact source of the trigger cannot be diagnosed, attempts must be made to determine whether mechanical interventions can alter the experience of pain. During the examination process, the therapist can observe stabilization and movement patterns and correlate faulty patterns with pain provocation. If altering the pattern of stabilization or movement reduces or eliminates the pain, the specific faulty movement patterns responsible for the pain can be diagnosed and used as a platform for treatment.[31]

Posture

The therapist should perform a cursory evaluation of the patient's standing and sitting postures during the history portion of the examination. Posture also is examined formally as part of the evaluation process. During the examination, the patient may assume what he or she considers to be "proper posture" or a posture that depicts the painful or emotional state he or she wishes to portray. The posture portrayed during this examination may be unconscious or intentional, and the motivation is not always easily discerned. Observation of posture without the patient's knowledge can be more revealing of the true contribution of posture to his or her signs and symptoms.

More specific examination should include standing, sitting (supported and unsupported), and recumbent postures. Several things should be observed, including head position, shoulder girdle position, cervical, thoracic, and lumbar curves, and lumbopelvic, hip, knee, ankle-foot alignment; all should be examined in all three planes. In standing, the examiner is looking for asymmetry and possible relationships between segmental regions (e.g., foot pronation and genu valgum on the side of a low iliac crest and apparent short limb). Bony landmarks are assessed to visualize the position of the pelvis, including the iliac crest, posterior superior iliac spines (PSISs), anterior superior iliac spines (ASISs), and pubic symphysis. Ideal pelvic alignment is best visualized through the ASIS and pubic symphysis in the frontal plane.[101]

A hypothesis can be developed regarding the contribution of faulty lumbopelvic alignment to the pathomechanical cause of symptoms and the relationship of other body regions in perpetuating the faulty lumbopelvic alignment. Correction of alignment can reduce pathomechanical stress in the lumbopelvic region and therefore reduce or eliminate symptoms. This is an early step toward the diagnosis of a pathomechanical cause of lumbopelvic activity limitations and participation restrictions. However, static posture is not always a good indicator of the pathomechanical stress causing lumbopelvic symptoms. For example, a person with spinal stenosis may have a flat lumbar spine and yet incur symptoms with extension forces on the lumbar spine due to the narrowed spinal canal or lateral foramina.

Other hypotheses can be developed about muscle lengths. Assumptions can be made regarding muscle-fascial structures that are too long based on joint position, such as a long EO in an anterior pelvic tilt (**Fig. 17-8**). Muscle length testing is indicated to determine whether muscles are short because of joint position (e.g., specifically which hip flexors are short in anterior pelvic tilt). Additionally, the results of positional strength tests should correlate with muscle length hypotheses.

Posture can also indicate muscular holding patterns such as spinal extensor hyperactivity versus relaxed spinal extensors during sitting or standing. All of these observations can assist the practitioner in classifying patients into homogenous groups.

Range of Motion, Muscle Length, and Joint Mobility

Range of motion (ROM) tests of the lumbopelvic region should not only assess the ROM of the lumbar spine, but also the pelvic-femoral complex and the relationship between the ROM of the hip and lumbar spine. The interrelationship of ROM with other regions of the body (e.g., thoracic spine and upper extremity) is also of interest. Muscle length testing of the spine,

FIGURE 17-8 **(A)** Neutral spine and pelvic position and length of external oblique (EO). **(B)** The lordotic posture and anterior pelvic tilt elongate the EO.

upper, and lower quarters should also be included. Mobility tests of the lumbopelvic region determine the intervertebral mobility/stability (passive intervertebral motion [PIVM] testing) of the spine and mobility/stability of the SIJ.

Range of motion testing is performed in standing for flexion and extension, lateral flexion, and quadrant movements; it is performed in sitting for rotation. Overpressure can be used to reproduce symptoms. The intent of ROM testing is fourfold:

1. To determine the patient's willingness to move
2. To reproduce symptoms
3. To determine the quantity of motion in the lumbar–pelvic–hip complex
4. To determine the quality of movement by assessing the relationship between the various regions of the spine and the pelvic–hip complex

Chapter 19 describes hip ROM testing. The purpose of hip ROM testing is to determine reduced ROM in the hip that may contribute to compensatory spine motion, thereby imposing a pathomechanical stress on the lumbar spine. For example, a hip that has reduced ROM in extension may cause compensatory lumbar spine extension, particularly during the terminal stance phase of gait or in the final phase of return from a forward bend.

Active hip ROM testing can be used to assess movement patterns of the hip and stabilization patterns of the lumbopelvic region.[31] Faulty patterns can induce a pathomechanical stress on the lumbar spine and provoke symptoms. Correction of faulty patterns of lumbopelvic stabilization should reduce symptoms if the faulty pattern is contributing to pathomechanical stress on the affected structures. In this way, these tests can also be used to clear the hip joint of any possible involvement. If correction of lumbopelvic stabilization reduces symptoms, it is unlikely that the hip is the source of symptoms.

Thoracic ROM testing is described in Chapter 24. The purpose of thoracic ROM testing is to determine whether reduced ROM of the thoracic spine is contributing to compensatory motion in the lumbopelvic region (e.g., reduced or stiff thoracic spine rotation could induce increased stress to the lumbar spine during transverse plane movement patterns).

Tests of muscle extensibility across the pelvis and hip are described in Chapter 19. Data obtained from these tests provide the clinician with additional information about potential causes of pathomechanical stress on the lumbar spine. For example, during forward bending, stiff hamstrings (HSs) can restrict pelvic forward rotation, resulting in flexion stress (**Fig. 17-9B**) on the lumbar spine.

Although not direct measures of trunk muscle extensibility, lumbopelvic forward bending, backward bending, and lateral flexion can test for posterior, anterior, and lateral trunk extensibility, respectively. Assessment of postural alignment can lead

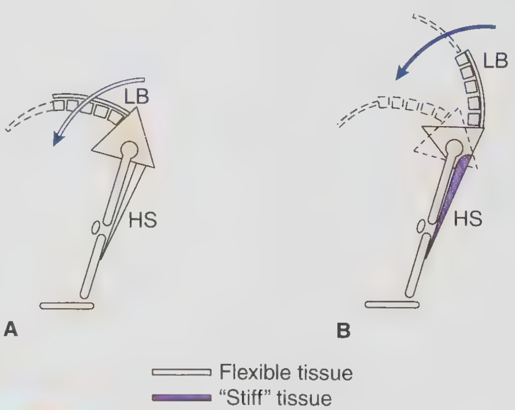


FIGURE 17-9 **(A)** Normal lumbopelvic rhythm. **(B)** Reduced extensibility of the hamstrings (HSs) can alter lumbar-pelvic range of motion. Stiffness from the HSs slows the rate and can potentially restrict the range of pelvic motion, resulting in excessive flexion stress of the lumbar spine. (Adapted from Calliet R. Low Back Pain. 3rd Ed. Philadelphia, PA: FA Davis, 1981.)

to a hypothesis about excessive trunk muscle length (see the "Posture Examination" section).

One type of ROM testing unique to the lumbar region was developed by McKenzie.[133] This method is based on the assumption that sustained or repeated movements may affect nuclear position, resulting in centralization or peripheralization of symptoms. McKenzie defined the centralization phenomenon as "the situation in which pain arising from the spine and felt laterally to the midline or distally, is reduced and transferred to a more central or near midline position when certain movements are performed."[133] Peripheralization is the opposite phenomenon whereby pain arising from the spine and felt proximally and to the midline is increased and transferred laterally and distally when certain movements are performed. McKenzie's theory presumes that as long as the annulus and disk are intact, an offset load on the disk in a lesion-specific direction of spinal movement may apply a reductive force on a displaced nuclear fragment, directing it toward a more central location (i.e., "centralization"), thereby reducing symptom-generating stress on neural or other nociceptive structures.[133]

Joint mobility tests of the lumbar region come in three categories: passive physiologic intervertebral motion (PPIVM), passive accessory intervertebral motion (PAIVM), and segmental stability tests. PPIVM testing is used to determine relative physiologic mobility (e.g., hypermobility versus hypomobility) and to stress the related spine and pelvic joints in an attempt to determine end-feel, assess irritability, assess stability, and provoke symptoms. PAIVM is defined as the passive assessment of accessory intervertebral joint through its glides (e.g., posterioanterior [PA] glide), whereas stability tests attempt to examine segmental translatory mobility that is excessive[119] (see **Evidence and Research 17-4**). Research shows at best moderate intrarater reliability and poor interrater reliability.[137] Reliability improves when a positive response includes both perceived changes in ROM and provocation of symptoms rather than just decreased mobility.[137,138] A combination of PPIVM and PAIVM tests correctly identified dysfunctional levels diagnosed with intraarticular infiltration.[139]

Regarding the SIJ, a battery of tests has been suggested to rule out or confirm a suspected diagnosis of SIJ dysfunction.[140] A criteria of at least three of four tests with positive results is required to determine the presence of SIJ dysfunction: standing flexion, prone knee bend, supine-to-long sitting, and palpation of the PSIS in sitting. Passive physiologic motion tests of the pelvis include anterior and posterior innominate rotation.[141] Passive accessory motion tests refer to the passive assessment of a joint by way of glides and in the SIJ can be used to test stability.[141]

All ROM, muscle length, and mobility/stability tests should assess the effect that altered motion or stabilization strategies of the examined region have on symptoms. For example, an increased extension moment may be imposed on the L5 segmental level during prone hip extension because of relatively less extension mobility available at the hip. By determining the spinal segmental levels (e.g., L5), the associated anatomic regions (e.g., the hip), and the sources of structural limitation (e.g., muscle, capsule, bone), a specific intervention plan can be developed to address the related physiologic impairments. Addressing the impairments associated with lumbar extension can improve the patient tolerance to walking or running (activity limitations and participation restriction).

EVIDENCE and RESEARCH 17-4

Prone Stability Test

The prone stability test uses the PA glide to assess segmental stiffness and pain provocation with muscles in a resting state and during an active contraction.[134] The first portion of the test is performed with the patient in prone with the lower extremities in contact with the ground while a PA glide is performed at each lumbar segment to see if pain is produced at that segment. If a painful segment is identified, the second half of the test is performed at that segment in conjunction with active lumbar and hip extension to lift the legs from the ground. The prone instability test is considered positive if pain is provoked in the resting state and eliminated during active muscle contraction. Reliability of the prone instability test has been described as high ($\kappa = 0.87$).[134] Recently, spinal stiffness was measured during the application of a PA force when doing either the abdominal drawing in maneuver or abdominal bracing in individuals without lumbar spine pathology.[135] Both instances increased spinal stiffness greater than resting, but the abdominal brace increased spine stiffness greater than the abdominal drawing in maneuver. These findings are consistent with modeling of lumbar spine function during muscular contraction.[136]

Work (Job/School/Play), Community, and Leisure Integration or Reintegration (Including IADLs)

This category of tests and measures includes the measurement of participation restriction. Waddell and Main[126] proposed that in evaluating the severity of LBP, three recordable clinical illness components must be differentiated (see "Pain" category), one of those being disability. The following list is limited to validated functional questionnaires that were designed by selecting items relevant to back pain:

1. Oswestry Low Back Disability Score[142]
2. Million Visual Analogue Scale[143]
3. Roland Morris Disability Questionnaire[144]
4. Waddell Disability Index[126]
5. Clinical Back Pain Questionnaire (Aberdeen Low Back Scale)[124]
6. Lumbar Spine Outcomes Score (LSOQ)[125,145,146]
7. STarT BackScreening Tool (see http://painhealth.csse.uwa.edu.au/pain-self-checks. html)
8. Short Form Orebro Musculoskeletal Pain Screening Questionnaire (https://www.aci.health.nsw.gov.au/__data/assets/pdf_file/0003/212907/OMPSQ-10.pdf)

Descriptive information for the selected measures is given in **Table 17-5**. Problems in the assessment of outcome for patients with LBP have been subject to considerable recent investigation with little agreement in the literature concerning which outcome measure to use, with few reports using the same criteria for assessing patients.[147,148] The LSOQ appears to be acceptable to patients, easy to administer, highly reliable, valid, and responsive (see **Display 17-4**). It provides information on demographics, pain severity, functional disability, psychologic distress, physical symptoms, health care utilization, and satisfaction. It should be considered for use in both clinical and research applications as well as regulatory review involving patients with LBP complaints. The STarT Back Screening Tool is designed for use in a primary care setting and is a validated tool that stratifies patients into

TABLE 17-5

Descriptive Information for Selected Back-Specific Functional Instruments

INSTRUMENT	CONTENT	SCORING	COMPLETION TIME (min)
Oswestry Low Back Disability Score	Pain intensity, interference with sleep, self-care, walking, sitting, standing, lifting, sex life, traveling, social life.	0–100	5
Million Visual Analogue Scale	Pain intensity, interference with physical activities, interference with work, overall handicap.	0–100	5–10
Roland Morris Disability Questionnaire	Physical activities, housework, mobility, dressing, getting help, appetite, irritability, pain severity.	0–24	5
Waddell Disability Index	Heavy lifting, sitting, walking, standing, social life, travel, sex life, sleep, footwear.	0–9	5
Low Back Outcome Score	Current pain, employment, domestic and sport activities, use of drugs and medical services, rest, sex life, five daily activities.	0–75	5

Adapted from Kopec KA. Measuring functional outcomes in persons with back pain. Spine 2000;25:3110–3114.

DISPLAY 17-4

The Low Back Outcome Score

Please mark on the line below how much pain you have had from your back on average over the past week.

0 1 2 3 4 5 6 7 8 9 10

No pain at all — Maximum pain possible

Please tick the answer which most closely describes you on each of the following six sections.

At present are you working

Full time at your usual job	☐ 9
Full time at a lighter job	☐ 6
Part-time	☐ 3
Not working/unemployed	☐ 0
Disability benefit	☐ 0
Housewife/student/retired	☐ score as for chores

At present can you undertake household chores or odd jobs

Normally	☐ 9
As much as usual but more slowly	☐ 6
A few, not as many as usual	☐ 3
Not at all	☐ 0

At present can you undertake sports or active pursuits (e.g., dancing)

As much as usual	☐ 9
Almost as much as usual	☐ 6
Some, much less than usual	☐ 3
Not at all	☐ 0

Do you have to rest during the day because of pain?

Not at all	☐ 6
A little	☐ 4
Half the day	☐ 2
Over half the day	☐ 0

How often do you have a consultation with a doctor or have any treatment (e.g., physiotherapy) for your pain?

Never	☐ 6
Rarely	☐ 4
About once a month	☐ 2
More than once a month	☐ 0

How often do you have to take painkillers for your pain?

Never	☐ 6
Occasionally	☐ 4
Almost every day	☐ 2
Several times each day	☐ 0

Please tick the box that best describes how much your back pain affects the following activities.

	No Effect	Mildly/Not Much	Moderately/ Difficult	Severely/ Impossible
Sex life	☐ 6	☐ 4	☐ 2	☐ 0
Sleeping	☐ 3	☐ 2	☐ 1	☐ 0
Walking	☐ 3	☐ 2	☐ 1	☐ 0
Traveling	☐ 3	☐ 2	☐ 1	☐ 0
Dressing	☐ 3	☐ 2	☐ 1	☐ 0

Pain scale readings are equivalent to the following scores: 0–2 = 9; 3–4 = 6; 5–6 = 3; 7–10 = 0. Patients are placed in one of four outcome categories based on overall scores: 65 or higher (excellent), 50 or higher (good), 30 or higher (fair), and lower than 30 (poor).

Adapted from Holt AE, Shaw NJ, Shetty A, et al. The reliability of the Low Back Outcome Score for Back Pain. Spine. 2002;27:206–210.

risk groups: low-risk (LBP with little distress), medium-risk (moderate levels of pain, disability, and distress), and high-risk patients (high levels of pain, disability and distress). These risk groups are predictive of chronicity, disability, and work absenteeism, providing a basis for targeted stratified care.[149] The Short Form Orebro Musculoskeletal Pain Screening Questionnaire also identifies people with high psychosocial risk status.[150] As this questionnaire includes occupational risk factors, it may be more suited to use for work-related LBP.

THERAPEUTIC EXERCISE INTERVENTION FOR COMMON IMPAIRMENTS OF BODY FUNCTIONS

The evidence supports a patient-centered approach to LBP care that addresses the multidimensional influences on the disorder and empowers patients to self-manage. Therapeutic exercise as an intervention is a powerful tool to empower patients to treat, manage, and prevent, or lessen the impact of future exacerbations. The heterogenous nature of the underlying drivers of LBP makes it impossible to provide a one-size-fits-all exercise regimen for the treatment of LBP. What we do know is that early intervention that fits the right treatment to the underlying drivers can reduce symptoms, improve function and participation, and reduce cost. Therapeutic exercise intervention must be prescriptive and based upon each individual's unique combination of systems and subsystems affected, staging of the condition, and functional and participation restrictions. As a general philosophical approach, acute LBP should follow basic principles of intervention (see **Display 17-5**).

Because this text is not presenting a treatment approach related to a specific classification system, the exercises are based on the impairments of body functions detailed in Unit 2 and are presented in alphabetical order. Impairments of body functions have been separated for clarity of presentation, though, in reality, patients most often present with a complex interaction of pathology and structural, physiologic, and psychologic impairments. The exercise examples are not meant to demonstrate a comprehensive approach to the treatment of physiologic impairments; they were chosen to illustrate principles and a reasonable approach to the use of exercise for the lumbopelvic region. Principles related to work-conditioning programs, although often used in addressing lumbopelvic dysfunction, are not covered in this text.

Aerobic Capacity Impairment

Aerobic capacity impairment can be considered a secondary condition resulting from the incapacitation associated with CLBP or a lifestyle risk factor contributing to the development of CLBP. Research supports the fact that aerobic exercise alone is not enough to prevent recurrence of LBP, although aerobic exercise is beneficial for patients with lumbopelvic syndromes.[57] Aerobic exercise enhances healing, assists with weight loss, and has favorable psychologic effects, such as reduction in anxiety and depression.[151]

Typically, the patient is limited by musculoskeletal pain in working at the optimal target heart rate necessary for producing aerobic gains. Aerobic exercise is initially prescribed "to tolerance" and is progressively increased as the patient's signs and symptoms improve. The goal is to exercise at 60% to 80% of age-predicted maximal heart rate (220—age) for 30 to 50 minutes, three to five times per week. The mode of exercise (e.g., biking, swimming, walking, jogging) should be based on the patient's desires and the postures and movements that do not aggravate symptoms. For example, if walking does not increase or relieve pain, but sitting increases pain, walking should be encouraged and biking should be discouraged. If weight-bearing aerobic exercise is chosen, the physical therapist may need to counsel the patient in choosing proper footwear to ensure the best weight-bearing dynamics possible. Orthotic prescription may be necessary to optimize ground reaction forces (see Chapter 21). If weight-bearing exercise is unbearable, water is often a well-tolerated medium for aerobic exercise by a person with lumbopelvic dysfunction (see Chapter 16). Another option is to walk with some type of unloading mechanism either through harness apparatus or the use of crutches, walker, grocery cart, or stroller.

DISPLAY 17-5

Activities and Exercises to Recommend to Patients with Acute LBP

Advice for Patients

"Pain with movement does not mean you are doing harm"
"Gradually increase your activity levels to build tissue tolerance and allow time for tissue adaptation"
"It is safe to exercise and work with back pain—you may just have to modify what you do based on aggravating factors in the first several weeks"

The Guidelines Below May Assist This Process

Relaxation

Encourage diaphragmatic breathing (see Chapter 24)
Facilitate awareness of tension in the muscles of the trunk and encourage mindful relaxation

Mobility Exercises

Encourage gentle flexibility-based exercises for spine and hips progressing from non-weight-bearing to weight-bearing (e.g., hip and back stretches lying down, progress to sitting and standing)

Functional Movement Training

Encourage relaxed movements and avoidance of guarded movements
Discourage breath-holding and propping with the hands during load transfer
Encourage patients to incorporate movement training into their usual daily activities (e.g., walking, bending, twisting) and strengthening and conditioning if relevant to the patient (e.g., squatting for someone who is involved in manual work)

Physical Activity

Aim for patients to undertake aerobic exercise for 20 to 30 minutes each day that does not excessively exacerbate pain (e.g., walking, cycling [leg or arm cycling] or swimming based on comfort and preference)
Explain to patients that they may need to exercise for a shorter duration initially, or exercise for short periods throughout the day to build exercise tolerance
Advise patients to increase activity gradually (e.g., 10% per week)

Balance and Coordination Impairment

The human postural system operates on the basis of integrated information from three independent sources: vestibular, visual, and somatosensory. It is conceivable that a derangement of any of these systems will influence the overall control of the postural system. Healthy persons have control of sufficient variability in motor learning and balance strategies, enabling adaptation to altered postural demands without running the risk of jeopardizing performance.[152,153] There is evidence that LBP patients may be prone to excessive postural sway, poor balance reactions, and altered strategies for balance.[154–159] Patients with LBP have been shown to display increased visual dependence, reduced hip and increased ankle strategy for postural control in quiet standing, and altered postural control in single limb stance[154–159] (**Evidence and Research 17-5**).

EVIDENCE and RESEARCH 17-5

Visual Dependence and Postural Control in LBP

A study by Lee et al.[160] evaluated standing stability in subjects with and without recurrent LBP during single limb stance for 25 seconds and visual condition (eyes open vs. eyes closed). Twenty-seven subjects without LBP and 15 subjects with LBP participated in the study. Participants with LBP were able to balance on their dominant leg for less time with their eyes closed compared to the healthy subjects (0.68 ± 0.30 for control vs. 0.37 ± 0.32 for LBP, $T = -3.23$, $P = 0.002$). This sensitive detection of imbalance with postural stability is important to understand compensatory mechanisms and for effective rehabilitation strategies in patients with LBP.

In addition, it has been shown that patients with LBP seem to adopt a body stiffening strategy when balance is challenged.[161] The question arises whether, and to what extent, mechanisms associated with pain, fear, and altered lumbosacral proprioceptive acuity alter postural control in anticipation of postural instability. This stiffening strategy (e.g., cocontraction of trunk muscles) when postural instability is anticipated could lead to more compressive forces on the spine.[162]

Authorities acknowledge the necessity of balance work in the rehabilitation of lumbopelvic patients.[163] Gym balls, wobble boards, slide boards, and foam rolls can be used to enhance proprioception and teach optimal balance strategies (e.g., use of intrinsic and superficial muscles as needed versus superficial only, improved use of hip strategy, decreased reliance on visual feedback). Aspects of proprioceptive training can be incorporated at any stage of rehabilitation, as illustrated by examples focusing on balance and coordination discussed in other sections of this chapter. After an activity is performed correctly on a stable surface, the patient can be positioned on a moving base of support, such as a gym ball (**Fig. 17-10**) or foam roll (**Fig. 17-11**) and progressed from double limb to single limb support. Any activity challenging balance and proprioception must be performed with confidence and without guarded, splinting, or overactive strategies, emphasizing correct body position and shaping toward a more nuanced strategy as balance control is achieved. Over time, the rate of movement is progressed while accuracy is maintained.

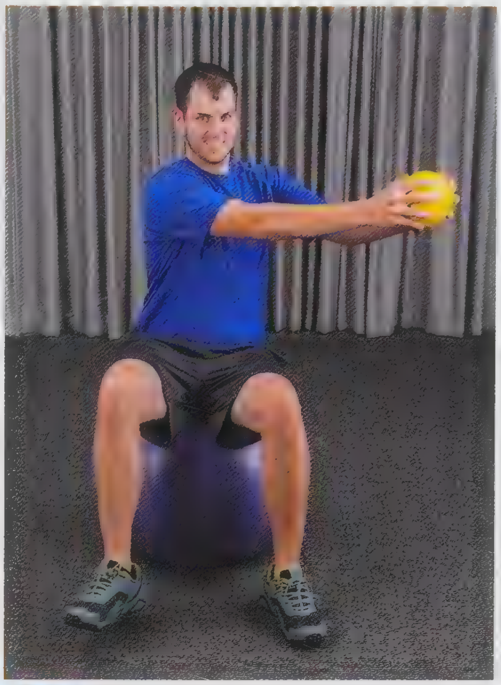


FIGURE 17-10 Sitting on a gym ball can add an element of difficulty to the stability phase of lumbopelvic exercise. Care must be taken to ensure quality of recruitment strategy as dominant strategies may emerge on the unstable surface.

FIGURE 17-11 Standing on two foam rolls is easier than standing on one foam roll. For the stability phase, the goal is to reach to the side through rotation of the feet and hips with the spine in neutral. For controlled mobility, the goal is to move the feet, hips, thoracic, and lumbar spine in a combined rotational movement pattern. However, movement should be emphasized at the feet, hips, and thoracic spine, with very little rotation occurring in the lumbar spine.

Muscle Performance Impairment

Treatment of general muscle performance impairments in the lumbopelvic region has limitations. Evidence suggests that muscular dysfunction in the presence of lumbopelvic syndromes does not so much affect the strength of the trunk musculature as it influences the patterns of trunk muscle recruitment.[164–167] Several electromyographic (EMG) studies have reported increased activation of the erector spinae muscle in study participants with LBP during tasks such as trunk flexion,[168–172] and the absence of relaxation of the erector spinae at the end of range of trunk flexion (the "flexion-relaxation" phenomenon) has been shown to be associated with reduced intervertebral motion.[169] In contrast to the increased activation of the superficial trunk muscles, activity of the intrinsic spinal muscles has been found to be either increased,[173,174] decreased,[175,176] similar,[175,177] or delayed[178,179] in patients with LBP. Similarly, activity of the deep abdominal muscle, transversus abdominis, has been found to be delayed in study participants with LBP.[50,129,180] Subtle shifts in the patterns of muscle recruitment result in some muscles being relatively underused in the force couple, whereas other muscles relatively dominate the force couple.[31] The cause and effect relationships of these subtle shifts in muscle recruitment patterns cannot be determined and should be thought of as part of a continuous cycle of altered recruitment strategies and movement patterns. In the presence of trunk muscle guarding and stiffness, which paradoxically increase spinal loading and pain,[71] performing relaxation of trunk muscles incorporated with graded movement training can be helpful to unload sensitized spinal structures and allow normal movements to occur.

Lack of muscle endurance has been shown to also be a prime impairment in muscle performance. Many investigators have reported diminished trunk muscle endurance and increased rates of muscular fatigue in patients with LBP compared with healthy individuals, even when strength measures testing results are within normal limits.[106,107,165,181] Sophisticated EMG testing using a technique called power spectrum analysis has identified that the LM is the back extensor most susceptible to endurance changes.[166,182] These studies indicate the need to provide an endurance training component in the course of a total rehabilitation program. No special exercise recommendations are needed, because the dosage can be modified for exercises prescribed for force or torque production to satisfy endurance goals (i.e., higher repetitions with lower loads).

Mechanisms such as muscle strain, pain, inflammation, neurologic pathology, or general deconditioning can contribute to muscle performance impairment. The clinician must consider the possible mechanisms contributing to the more dramatic as well as subtle changes in muscle recruitment patterns to develop the appropriate exercise intervention. After the underlying mechanism(s) are identified, precise exercise can be prescribed to activate, restore, or improve muscle control and performance of the trunk muscles. The following section describes exercises to establish control over specific trunk muscles. Subsequent sections investigate the various causes of reduced muscle performance around the lumbar spine and recommend activities and techniques to alleviate individual causes of muscle performance impairment.

Exercise for Motor Control

As already stated, research has established a link between lumbar dysfunction and altered muscle performance and neuromuscular control of the *intrinsic or deep trunk muscles* defined to include the TrA, LM, pelvic floor, and diaphragm.[164,183]

General strengthening programs for the trunk muscles may not adequately recruit or improve the muscle performance of the deep and often underused trunk muscles. Localized and specific exercise aimed at training neuromuscular control of the intrinsic spinal muscles may be critical to improving subtle patterns of muscle recruitment necessary for optimal segmental stability in the lumbar spine.[70,184,185] Similarly, specific exercises aimed at training neuromuscular control and muscle performance of the intrinsic spinal muscles plus the gluteus medius, gluteus maximus, biceps femoris, deep hip lateral rotators, and latissimus dorsi may be critical for optimal SIJ stability and load transference from the upper and lower quarter to the low back.[186,187] A pelvic floor contraction, in particular (see Chapter 18), is indicated for the chronic, hypermobile SIJ because of the shared muscle of the piriformis and obturator internus and the important supportive function of the pelvic floor to the pelvic girdle.[188]

Before presenting the exercise recommendations for the intrinsic spinal muscles, three additional concepts must be addressed:

1. Exercises chosen should promote optimal length–tension properties of the trunk and pelvic girdle muscles. The affected muscles should be trained at the length desired for function. Too often, the lumbar spinal muscles are strengthened in the lengthened range because of use of a Valsalva maneuver, resulting in abdominal distension or "pooching," lumbar flexion, and bearing down on the pelvic floor (see **Fig. 17-12**). A disadvantage to strengthening the muscles in a lengthened range is the contribution this may have toward altered length–tension properties. The lumbar spinal muscles need to be of the right length to support the spine and pelvis in good static alignment and have the correct length–tension properties to continue to support the spine and pelvis during dynamic activities.
2. A second important principle is specificity of training or the principle of specific adaptation to imposed demands (SAID principle). For example, although a sit-up is a functional activity, it is not the primary function of all the abdominal muscles for BADLs and IADLs. It has been proposed that the intrinsic spinal muscles are linked with the control of stability of the spine against the perturbation produced by movement of the limbs.[50] The primary role for the deep trunk muscles is to provide static stability via isometric contraction to the trunk during movements of the extremities. In addition, they also offer dynamic stability during trunk movements. It is important to realize that all the trunk muscles play a role in static and dynamic control of the trunk dependent on the demand placed on the spine and the level of skill involved in performing the activity.
3. A third principle governs exercise progression. The stages of motor control (i.e., mobility, stability, controlled mobility, and skill) can be used to progress lumbopelvic exercise. Mobility and stability usually occur together in the lumbopelvic region. Stability is often a problem at the dysfunctional segmental level, and mobility is more likely to be a problem at an adjacent

A B

FIGURE 17-12 **(A)** Use of the abdominal muscles in a lengthened range. Note protrusion of the umbilicus. **(B)** Use of the oblique abdominal muscles and transversus abdominis (TrA) in the short range.

lumbar level or in some associated region (e.g., hip, thoracic spine, shoulder girdle). To be most effective, simultaneous reconciliation of mobility and stability impairments is desired. When developing a program focusing on stability, the chosen direction of force must be based on the directions in which the spine is most susceptible to motion and the directions most correlated with symptom reproduction.[31,188,189] After adequate mobility and stability are achieved, the patient is progressed to controlled mobility (BADLs) and then to skill-level activities (IADLs). According to a study by Richardson and Jull,[57] patients who followed a graded program of exercise to improve the muscle performance and neuromuscular control of the intrinsic spinal muscles experienced pain resolution within 4 weeks, with only a 29% recurrence rate at 9 months. These results were compared with a control group of patients with LBP who exercised aerobically by jogging and swimming. They too were pain-free at 4 weeks, but they had a LBP recurrence rate of 79% at 9 months. With certain subgroups of patients, specificity seems to be the key to the proper prescription of the exercises that correspond with improved neuromuscular control and muscle performance of the deep trunk muscles. This treatment approach demands a high level of skill by the instructor in teaching the exercise and a high level of patient adherence and attention to detail. Continual reassessment of muscle recruitment capabilities and muscle performance is necessary to progress or modify the exercise for optimal results.

Patient-related instruction is the first step to establish awareness over the individual intrinsic spinal muscles. **Display 17-6** contains specific instruction for the clinician as to how to train the intrinsic spinal muscles. **Patient-Related Instruction 17-1** describes in patient terms, techniques to activate the intrinsic spinal muscles.

Self-Management 17-1 describes a series of exercises in the supine position to progressively challenge the intrinsic and global spinal muscles. Beyond level I, most individuals will require recruitment of global muscles for stabilization in addition to the recruitment of the intrinsic muscles. The exercise is progressed from level I to level V through a combination of progressively longer lever arms and increased loads. The direction of forces imposed on the spine also must be considered in advancing the

DISPLAY 17-6

How to Teach the Components of the Intrinsic Spinal Muscle Group Synergy

- The clinician must first determine the presence or absence of the intrinsic spinal muscles synergy by palpating the TrA, LM, and external palpation of the pelvic floor if necessary (see Chapter 18). Although it is not necessary to facilitate the intrinsic spinal muscles in this manner, often the easiest component of the intrinsic spinal muscles to activate is the pelvic floor (see Chapter 18 and Patient-Related Instruction 17-1). After the patient has contracted the pelvic floor, the therapist can palpate other components of the intrinsic spinal muscles.
- The **TrA** can be palpated medially and deep to the ASIS. Contraction of the TrA should feel like taut fascia under the fingertips, whereas contraction of the IO will push the fingertips out superficially. Toning down the force of contraction will assist in isolating the TrA. Another indication that the TrA has contracted is that the waist will pull inward laterally like the function of a girdle, and the umbilicus will be gently pulled in toward the spine. The umbilicus pulled upward toward the ribs coupled with rib cage depression indicates dominance of the RA and is a common mistake.
- The **LM** can be palpated best at the L5 level just medial and deep to the spinous process. If the LM is not contracting, the therapist can provide an explanation to the patient as to the function of this muscle with respect to sacral nutation, lumbar extension, and stabilization against rotational forces. Visually, show the patient models and pictures of the region and LM muscles. Cue for tactile input by palpating directly over the LM at the affected level. Key to isolation of the LM is to facilitate a submaximal isometric contraction. Patients often have initial difficulty in facilitating a LM contraction in a home exercise program. This is particularly true for patients with a chronic condition and for postoperative patients. Manual techniques can be used to help facilitate recruitment in the early stages of neuromuscular training. Figure A illustrates a manual technique for facilitating recruitment of LM musculature. Another technique is to use isometric hip lateral rotation (see Patient-Related Instruction 17-1). After a consistent

(continued)

DISPLAY 17-6

How to Teach the Components of the Intrinsic Spinal Muscle Group Synergy (*continued*)

LM contraction can be elicited, ask the patient to perform a body check and determine whether focusing on contraction of the LM facilitated a pelvic floor contraction. The clinician can palpate the TrA to determine whether it has contracted in synergy with the LM and pelvic floor. The clinician can ask the patient to vary the initial muscle activation focus from the pelvic floor, to the LM, to the TrA to ensure the synergy is intact.

- Contraction of the intrinsic spinal muscles should occur in conjunction with good breathing habits. Ask the patient to perform a deep diaphragmatic breath and assess the quality of the inhalation and exhalation technique. If the quality is poor, teach the patient diaphragmatic breathing as discussed in Chapter 24. Next, ask the patient to take a deep diaphragmatic breath with a relaxed, not forced, exhalation. Before the next breath, ask the patient to slowly and gently contract the intrinsic spinal muscles synergy, then resume normal relaxed breathing. After relaxed breathing can be performed while sustaining an intrinsic spinal muscles contraction, the intrinsic spinal muscles supine progression (see Self-Management 17-1) and intrinsic spinal muscles series (Self-Management 17-2) can be prescribed.

FIGURE A Sidelying manually resisted lumbar multifidus exercise. Restoration of lumbar multifidus activity may need to begin by facilitating the muscle at the specific level of spinal pathology with a manual technique. Low-load rotary resistance is applied to the affected segment in a sidelying position as if testing for passive physiologic intervertebral movement. The patient is encouraged to maintain submaximal contraction against the therapist's resistance into rotation. The therapist palpates the segmental level to ensure multifidus activity. EMG reveals that the multifidus is active in rotation both ipsilateral and contralateral as a stabilizer.[190] The primary role of the multifidus is to oppose the flexion moment associated with rotation.

Patient-Related Instruction 17-1

How to Activate Your Intrinsic Spinal Muscles

What are the Intrinsic Spinal Muscles?

The intrinsic spinal muscles refers to a group of deep muscles that, under normal circumstances, work together to provide stability to the lower back and pelvis. In normal function, they should contract automatically and simultaneously before any upper extremity, lower extremity, or trunk movement—in effect, before any movement you make. The intrinsic spinal muscles include

- The diaphragm—your primary breathing muscle
- The pelvic floor—attached to the bony ring of the pelvis from the tailbone to the pubic bone
- The lumbar multifidus—the deepest layer of the back muscles
- The TrA—the deepest layer of the abdominal muscles

How Do You Activate Them?

This section describes intrinsic spinal muscle awareness activities. These activities must be mastered before using the intrinsic spinal muscles with more advanced self-management activities and activities of daily living. NOTE: Your physical therapist will work with you individually to identify the best strategy to initiate your intrinsic spinal muscles.

- To contract the pelvic floor:
  Think of slowly and gently pulling the tip of your tailbone toward your pubic bone. Try not to contract the rectal portion of your pelvic floor, but rather more of the portion closer to your pubic bone. To see if you are using the correct muscles, the next time that you urinate, let out half the volume of your bladder and then stop the flow of urine with the least amount of effort possible. Be aware of which muscles you are using. *Note*: This *test* is not to be used as a daily exercise. It is simply a method for you to identify which muscles make up the pelvic floor. Another image is to think about an elastic cord anchored between your feet and extending up toward your umbilicus. Think about pulling the cord tight from the anchor point upward toward your umbilicus. Monitor your seat and inner thigh muscles to be sure you are relaxed in these muscle groups.
- To contract the lumbar multifidus
  Think of initiating a *very tiny* tilt of the sacrum (moving the tailbone away from your body as if to arch your back). The contraction should be isometric (the muscle contracts but the joint does not move). Another image is to think about an elastic cord running between your "dimples" in your low back. Think about tightening the cord between your dimples. This may help you to feel the contraction of the lumbar multifidii.
  Another method to begin to feel your lumbar multifidus is to lie on the floor with your knees bent and your heel pressing into the leg of a table (pictured). Press your heel *gently* (about 10% effort) into the leg of the table. Think about contracting your "dimple" muscle as you perform the push. Hold for 10 seconds. Repeat four times each leg.
- To contract the TrA
  Slowly and gently pull your lower abdomen inward. Imagine trying to "zip up" a slightly tight pair of pants. You can feel the tension in the muscle under a finger placed 1 in inward from

Patient-Related Instruction 17-1 (*continued*)

the front pelvic bones. You should feel a tensing of the deep muscle, not a bulging of the more superficial muscles. Another image is to think about an elastic cord running between the two prominent pelvic bones (called the *ASIS*). Think about tightening the cord between these two bones. This may help you to isolate your TrA from the other abdominal muscles. Another option is to try humming. Hum at a low level, and palpate 1 in inward from your pelvic bones. You should feel the deep muscles tense, but the superficial muscles should stay relaxed.

- To activate the intrinsic spinal muscles synergy
  Your physical therapist will help you to identify which intrinsic spinal muscle best activates the entire intrinsic spinal muscle group. Next, take a deep diaphragmatic breath, allowing your ribs to expand to the front, sides, and back. Allow the air to exhale naturally. Before you take another breath, *slowly and gently* contract your intrinsic spinal muscles. Next, resume normal breathing while maintaining contraction of your intrinsic spinal muscles. Your physical therapist will instruct you how to proceed from this step.

- Positions to activate your intrinsic spinal muscles:

___ back lying	___ stomach lying
___ sidelying	___ quadruped
___ sitting	___ standing
___ squatting	___ walking

SELF-MANAGEMENT 17-1
Supine Intrinsic Spinal Muscle Progression

Purpose: A back lying activity to strengthen and improve muscle control over your deep trunk muscles including your LM, TrA, and pelvic floor. Use of progressively more difficult leg movements challenges your intrinsic spinal muscles. Higher levels will require use of more superficial muscles, but the intrinsic spinal muscles should still be activated as the local stabilization strategy. You can think of this progression as strengthening from the "inside out."

Starting Position: Lie on your back on a firm surface, such as the floor, with knees bent, feet flat on the floor, and shoes off. To feel the TrA, place your fingertips deep to the inside of your front pelvic bones (your physical therapist will show you the exact location). Refer to the Patient-Related Instruction sheet that teaches how to contract each muscle of the intrinsic spinal muscles. Take a deep diaphragmatic breath in (your physical therapist will teach you the correct technique for diaphragmatic breathing). Allow the exhalation to occur naturally; do not force the exhalation. Before you take your next breath, activate your intrinsic spinal muscles. Resume normal breathing. After normal breathing has been established, you can begin the prescribed level of this exercise.

TIP:

- The abdominal muscles must be pulled in, not ***pooched out*** or distended. The pelvic floor must be pulled up, not pushed downward. These errors in strategy often occur as increased strain is placed on the abdominal and pelvic floor muscles from the progressively difficult leg movements.
- The lumbar spine must remain in a neutral position with a ***slight*** forward curve—just enough to fit your hand between your back and the floor—and not move into further forward curve or excessively flat. If needed, you may use a small hand towel rolled under the small of your back to provide feedback as to the position of your spine.

Movement Technique: Your physical therapist will check off the level(s) you are to perform with the appropriate dosage.

Level I: While keeping your intrinsic spinal muscles activated, *slowly* slide one leg down to a straight position followed by sliding the other leg down so that both are in a straight position. If your back is arched, you may need to limit your heel slide so that your pelvis is not pulled out of a neutral position. Next, slide one leg up the table to a flexed hip and knee position. After you have completed this movement, slide the same leg back to a straight position. Repeat with the opposite limb.

TIP: The pelvis must remain in neutral and not rotate. The spine must remain in neutral and not flatten, arch, or rotate. To keep your spine and pelvis stable you must be sure to keep your intrinsic spinal muscles activated, especially during the initiation of the heel slide because this is the moment when the neutral position is often lost.

Dosage:

Sets/Repetitions: ______________________

Frequency: ______________________

(*continued*)

SELF-MANAGEMENT 17-1

Supine Intrinsic Spinal Muscle Progression (*continued*)

Level II: Assume the start position. Lift one leg off the floor until your hip is at a 90-degree angle with the floor. Next, slide the other leg down to a fully extended position while keeping the opposite leg elevated off the floor. Slide the leg back to the same position as the nonmoving limb. Repeat with the other leg.

TIP: As soon as you are unable to stabilize the pelvis and lumbar spine with your intrinsic spinal muscles, stop and rest for a minute before continuing. If your hip flexors (front thigh muscles) are short, you will not be able to fully extend your leg without moving your spine or pelvis out of neutral. In this case, stop sliding your leg when you notice your spine or pelvis moving from the neutral position. Eventually, your hip flexor muscles will lengthen as your abdominal muscles shorten and become stronger.

Dosage:

Sets/Repetitions: ______________________________

Frequency: ______________________________

Level III: Repeat level II, but instead of sliding your leg down and back, glide your leg down and back. The nonmoving leg should remain in a flexed position off the floor.

TIP: It is easy to transition from a flat abdomen to a pooched abdomen and from keeping the pelvic floor pulled upward to pushing it downward at this level. Keep the intrinsic spinal muscles activated and continue to breathe.

Dosage:

Sets/Repetitions: ______________________________

Frequency: ______________________________

Level IV: Begin from the starting position, and lift both legs off the floor at the same time to the 90-degree position. Return to the start position by lowering both legs at the same time. Slide both legs simultaneously to the fully extended position, and slide both legs back to the start position.

Dosage:

Sets/Repetitions: ______________________________

Frequency: ______________________________

Level V: Repeat level IV, but glide both legs down and back to the start position.

Dosage:

Sets/repetitions ______________________________

Frequency ______________________________

exercise, and levels may be interchanged depending on which direction of force the patient has most difficulty controlling.

It is important that the exercise is not progressed to the next level unless the prescribed number of repetitions of the previous level can be achieved *and* the following criteria have been met:

- The lumbar spine should minimally deviate from the initial starting position, which should be in a neutral spine position (**Table 17-6**).
- The trunk muscles should be functioning at optimal lengths (i.e., not lengthened).
- The RA should not be dominating the synergy.
- Valsalva maneuver is discouraged.

Self-Management 17-2 challenges the intrinsic spinal muscles in a variety of positions and motor control levels. As the exercises become more difficult, superficial muscles will contract concurrently with the intrinsic spinal

TABLE 17-6

Neutral and Functional Spine Positions

SPINE POSITION	DEFINITION	CLINICAL JUDGMENT OF POSITION
Neutral	Lumbar spine in slight extension. Anterior superior iliac spine and pubic symphysis in the same vertical plane[a]	In supine, enough lumbar extension curve that the clinician can palpate the lumbar spinous processes, but not so much lumbar extension so as to pass hand through to the other side
Functional spine	Position of greatest stability, least stress, fewest symptoms for an individual for any given activity	Varies with pathology, activity, and symptoms

[a]Maitland GD. Vertebral Manipulation. 4th Ed. London: Butterworth, 1977.

SELF-MANAGEMENT 17-2
Intrinsic Spinal Muscle Series

Purpose: The purpose of this series of activities is to progressively recruit your intrinsic spinal muscles, aided by your more superficial trunk muscles as needed, in a variety of positions. Be sure to activate your intrinsic spinal muscles prior to and during these various activities to strengthen "from the inside out." Your physical therapist will check off the positions you are able to perform with good technique and will teach you appropriate variations and progressions of these activities.

Back Lying: You can perform the back lying intrinsic spinal muscle progression in this position. Refer to the back lying intrinsic spinal muscle progression handout.

Sidelying:

Start Position: Lie on your side with your hips and knees bent about 45 degrees. Place one or two pillows between your knees. You may need to place a small towel under your waist.

Movement Technique: Slowly rotate your hip so that your kneecap rotates slightly upward. Do not allow your pelvis to move.

TIP: You can advance this activity to a straighter hip position and add a lifting movement with your thigh. Your physical therapist will teach you this progression and provide you with a more detailed handout.

Dosage:

Repetitions: ______________________________

Frequency: ______________________________

Stomach Lying:

Start Position: Lie on your stomach with a pillow positioned vertically under your chest and hips. Bend your elbows and rest your hands on the back of your head.

Movement Technique: Lift your elbows only about 1/2 in off the surface. Hold the position for 5 to 10 seconds. Return your elbows to the start position.

TIP: You can advance this exercise by changing your arm positions and movements or by adding leg movements. Your physical therapist will teach you the appropriate progression and provide you with a more detailed handout.

Dosage:

Repetitions: ______________________________

Frequency: ______________________________

Quadruped:

Start Position: Assume a position on your hands and knees, centering your hips over your knees and your shoulders over your hands. Rotate your pelvis so that your hips are at a 90-degree angle with your thigh, spine straight, and head in line with the rest of your spine.

TIP: Do not round your spine upward, drop your head, or arch your low back excessively.

Movement Technique: Lift one arm off the table top surface. It is not important to lift the arm fully overhead. Return your hand to the supporting surface.

TIP: Do not let your spine and pelvis move from the start position when lifting your hand. Your physical therapist will teach you how to advance this exercise with variations in the start position or by adding arm and leg movements together.

Dosage:

Repetitions: ______________________________

Frequency: ______________________________

Sitting:

Start Position: Sit on a chair with a straight seat pan and straight back. Hips and pelvis should be at a right angle with the seat pan. Shoulders should be centered over hips.

Movement Technique: Slowly straighten one leg as far as possible without letting your spine or pelvis move out of the start position. Return to the start position and repeat with the other leg.

TIP: Do not let your spine or pelvis move backward (slump) or rotate. Your physical therapist can advance this exercise with combined arm and leg movements.

Dosage:

Repetitions: ______________________________

Frequency: ______________________________

Activities of Daily Living: Your physical therapist will teach you how to engage your intrinsic spinal muscles with various movements used in your daily activities such as squatting, stair stepping, lifting, reaching, or walking.

muscles. Strengthening should continue to occur "from the inside out."

Another exercise focusing on the ability of the intrinsic spinal muscles to stabilize the spine and pelvis is illustrated in **Self-Management 17-3**. This exercise challenges the ability of the intrinsic spinal muscles to stabilize against extension and rotation torques. The introduction of rotational torques requires the synergy of abdominal obliques to control the rotational torques. For example, if the patient is having difficulty controlling right pelvic rotation with a right hip abduction/extension/lateral rotation movement, the patient is cued to recruit the left external oblique and right internal oblique to control the rotation.

An increased measure of difficulty can be introduced to any of these exercises by using half or full foam rolls or gym balls. An unstable surface is believed to facilitate recruitment of the deep trunk muscles and stimulate the proprioceptors and balance reactions that are necessary for function.[154,191–194] Care must be taken to introduce this variation when the patient is capable of using subtle recruitment patterns and does not use excessive superficial muscle cocontraction to balance on the roll or ball.

As shown in the deep trunk muscle progressions, exercises emphasizing stability can be progressed to sitting or standing. In sitting, extremity movements can be used in much the same way as in supine positions to challenge the spine to stabilize against various directional forces, with the emphasis on using the entire lumbopelvic stabilizing system in a synergistic manner. For example, sitting while raising the arms in the sagittal plane can challenge the spine to stabilize against sagittal forces, and changing the movement to a unilateral arm raise or to a diagonal direction challenges the spine to stabilize against a transverse plane force. Sitting on a gym ball (Fig. 17-10) making the base of support unstable can further challenge sitting. The patient is encouraged to preset the intrinsic prior to beginning arm or leg movements. Stabilization progressions can also be developed in standing. Standing on a half or full foam roll can further challenge a standing progression (Fig. 17-11).

After neuromuscular control and adequate muscle performance are established, higher forces are required than can be supplied by the extremities alone. Dumbbells, weighted balls, and ankle weights can be used to progress the previously described exercises. Pulleys or elastic tubing can also be used to increase the force requirements of the trunk musculature to stabilize the spine. For example, the patient can be challenged to maintain trunk stability with an isometric contraction while pulling the weight up or down (**Fig. 17-13A**), side to side, or in a rotary motion. The emphasis initially is on dynamic motion at the hips (Fig. 17-13B), while avoiding motion through the trunk (i.e., stability level of stages of motor control). This exercise requires recruitment of the intrinsic as well as the more superficial trunk muscles and latissimus dorsi, gluteus maximus, gluteus medius, HSs, adductors, and hip rotators. All of these muscles are important in stabilization of the lumbar spine and pelvic girdle through the posterior, anterior, and oblique muscular systems. The load is increased as tolerated, and the speed is maintained at a low level.

Preparation for high-level functional return requires more advanced strength training that incorporates spine motion as part of the total movement pattern (i.e., controlled mobility and skill stages of motor control). Programs of this nature may include spine motions involving concentric and eccentric work with variable resistance in all planes (**Fig. 17-14**). At this stage, the various isokinetic machines (e.g., MedX, MET [Medical Exercise Therapy] rotation trainer) and any pulley apparatus or elastic resistance can be useful. The chosen movement pattern should be tailored to address the patient's activity limitations and participation restrictions.

One precaution to strength training involving spinal motion is in the presence of true articular instability. Rotation is often not well tolerated by those with a true articular instability of the lumbar spine or SIJ, particularly when the pelvis is fixed, as when sitting. Patients with true articular instability should avoid motion in the affected region and should train strictly in isometric modes. Vocational counseling or recreational modification may be necessary for those with true articular instability. In cases where lumbopelvic joint dysfunction fails to respond to physical therapy modes of stabilization, a trial of prolotherapy may be considered.

SELF-MANAGEMENT 17-3
Bent-Knee Fall-Out

Purpose: To train you to move your thigh independently of your pelvis, lengthen your inner thigh muscles, strengthen and shorten weak and overstretched abdominal muscles, and train your intrinsic spinal muscles to stabilize against rotational forces

Starting Position: Back lying with one leg straight and the other hip and knee bent with the foot flat on the floor. Place your hands on your pelvis as indicated by your physical therapist to monitor pelvic motion. Your physical therapist may ask you to place ____ pillows under the outside of the bent knee to let the knee fall into something.

TIP: Before beginning the movement, engage your intrinsic spinal muscles. Be sure to keep it engaged throughout the entire movement and continue to breathe in a relaxed manner.

Movement Technique: Let the bent knee fall out to the side. Do not allow motion to occur in the pelvis. Relax the inner thigh muscles completely before returning to the start position.

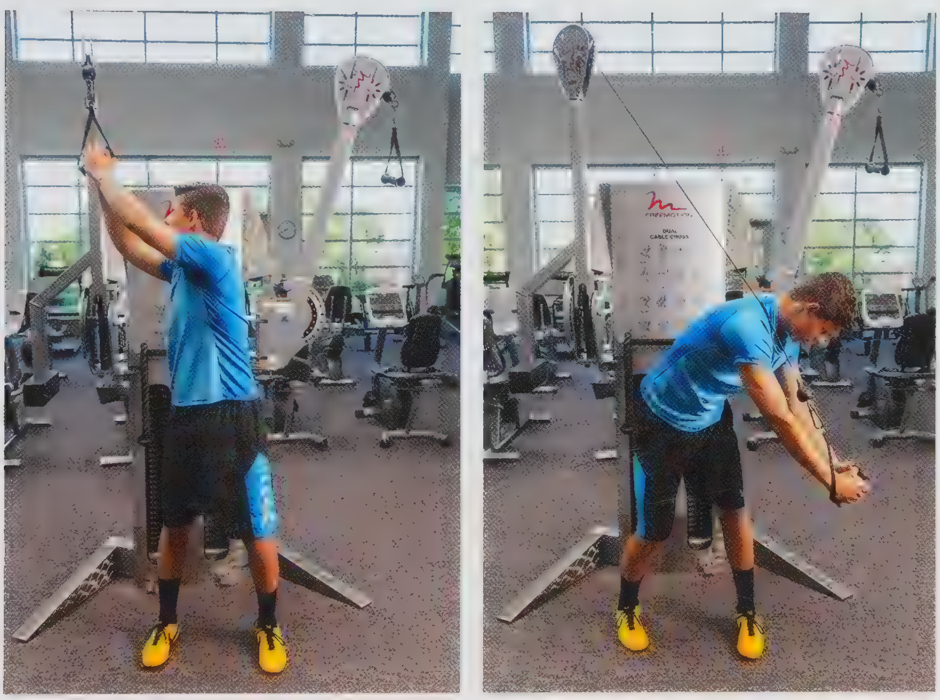
Dosage:

Repetitions: ______________________

Frequency: ______________________

A B

FIGURE 17-13 Tubing or pulleys can be used to add isometric resistance to create an upright stability activity. The goal is to maintain the spine in neutral through isometric contractions of the trunk musculature while the upper quarter, trunk, or lower quarter is moving in sagittal or transverse planes. In this example, the primary motion is occurring at the hips in the **(A)** sagittal or **(B)** transverse plane while the trunk remains in neutral alignment via isometric contractions of the intrinsic spinal muscles and more superficial trunk muscles.



A B

FIGURE 17-14 A progression from Figure 17-13 is controlled mobility. Instead of holding the trunk in neutral alignment, the lumbar spine is incorporated into combined movement patterns. Controlled mobility activities can be performed about separate planes of movement (e.g., sagittal, transverse, frontal plane). This figure demonstrates spine motion across all planes of motion. **(A)** start position and **(B)** end position. Caution must be practiced when moving in multiple complex planes of movement. Resistance can be applied through pulleys, elastic tubing, or weighted balls. The patient can perform these activities on an unstable surface such as foam rolls or high-density foam squares.

Dorman and co-workers observed in vitro that injecting chemical irritants into ligamentous tissue incites collagen proliferation.[195] Theoretically, scarring and tightening of the ligaments results in stabilization of the joint. Present studies provide no evidence that prolotherapy injections alone have a beneficial role in the treatment of CLBP. However, repeated ligament injections, irrespective of the solution used, may give prolonged partial relief of pain and disability as part of a multimodal treatment program, including exercise.[196] If injury to specific structures, such as ligaments or fascia, can be related to a specific clinical presentation and subsequent loss of function associated with pain, a case could be made for the use of prolotherapy.

As with all resistive exercise, after the muscle performance has reached a functional level, functional activities must be added to the program. However, it is unnecessary to wait until the end of the rehabilitation program to train functional activities. These should be considered from the beginning in designing the plan of care. For example, a minimal expectation for a patient in acute pain is to perform hip and knee flexion (see Self-Management 17-1, Level I) and bent-knee fall-outs (see Self-Management 17-3) in a supine position without pain. These duplicate movements which are necessary for pain-free bed mobility.

The definition of a successful functional outcome varies. Success for one person may be to perform light housework; for another, success may mean resuming heavy lifting in a job, playing a racket sport, or running a marathon. The ability to return to desired functional activities, regardless of the level, requires neuromuscular skill to control motion of the trunk and pelvic girdle in relation to the other extremities. Exercises addressing force or torque generation of the trunk muscles should be part of a comprehensive rehabilitation program. To achieve the neuromuscular skills necessary to return to activity at any level, functional exercises must be practiced with precise movement and recruitment patterns and for many repetitions frequently throughout the day. The exercises used to progress to a functional outcome are based on the postures and movement patterns unique to the patient. As such, no two functional retraining programs should be the same. Examples of functional activities are provided in the "Posture and Movement Impairment" section.

Neurologic Impairment and Pathology Mechanical (e.g., compression, traction) and biochemical (e.g., inflammatory response) factors arising from lumbopelvic dysfunction can result in nerve root pathology. For example, a herniated nucleus pulposus (HNP) at the L5–S1 level can cause mechanical and biochemical irritation to the L5 nerve root and medial branch of the dorsal rami, resulting in weakness in the gluteus medius and same-level LM, respectively.[197] The underlying pathology or impairment causing the mechanical or biochemical irritation must be treated, if possible, to affect the efferent input into the corresponding musculature. Exercise to improve force or torque capability of the affected musculature without treating the underlying neurologic dysfunction will prove futile. Nonetheless, exercise may be a large part of the solution. For example, excessive mobility at a segmental level can lead to degenerative disk disease,[198] which can result in nerve root compression and reduce efferent input into the associated musculature. Exercises to improve the stability of the offending segment coupled with exercises to improve the mobility of other segments or regions (e.g., thoracic spine rotation, hip joint flexion) can reduce the mechanical stress on the nerve root, thereby contributing to restoration of neurologic input into the affected musculature. Appropriate strengthening exercises for the affected musculature (see **Display 17-7**) can be more effective after the neurologic compromise is resolved.

Another neurologic cause of impaired muscle performance is nerve injury resulting in muscle paresis or paralysis, which can occur as a complication of surgery or from a traction injury to the nerve. LM segmental atrophy at the surgical site has been reported in the CLBP population after surgical intervention.[198,199] It is thought to be the result of iatrogenic lesions of the dorsal rami and innervation failure of the low back muscles after surgery. This finding is highlighted as a possible cause of "postoperative failed back syndrome" and is supported by histologic evidence.[198,199] Other investigators have reported denervation of segmental paraspinal musculature in patients with the radiologic diagnosis of segmental hypermobility.[200] These changes were thought to result from traction injury of the posterior primary rami segmentally supplying the muscle at the hypermobile segment. The ability for exercise to reverse the effects of denervation is related to the neurophysiologic recovery of the damaged nerve. Nonetheless, sustained mechanical stress from segmental instability delays or inhibits healing, and exercise targeted toward increasing segmental stability can reduce mechanical stress on the segment and augment healing. If nerve regeneration occurs, specific exercises focused on improving force or torque generation are necessary to "reeducate" the previously denervated muscle.[200] Specific exercise recommendations will be discussed subsequently.

Muscle Strain Muscle strain can result from a variety of mechanisms:

- Trauma (e.g., spinal extensors and LM after a motor vehicle accident)
- Overuse (e.g., one diagonal EO and IO muscles in a competitive rowing team member)
- Gradual continuous stretch (e.g., EOs in a swayback or lordotic posture)

Strain to lumbopelvic musculature, particularly if caused by trauma, is difficult to diagnose, because it often occurs with injury to other tissues in the motion segment. If a strain is suspected, the exercise and dosage depend on the severity of the strain, the stage of healing, and the mechanism of injury. Severe strains in early stages of recovery and chronic strains with long-term disuse must start with low-intensity isometric exercises. Strains resulting from chronic stretch must be supported in a short range and exercised with low initial loads with a focus on generating tension in the short range. For example, in the case of an EO strain resulting from marked lordosis and anterior pelvic tilt, use of an abdominal binder combined with low-load exercises in a neutral spine and pelvis position may be indicated in the early stages of recovery (see Patient-Related Instruction 17-1 and Self-Managements 17-1 and 17-2).

If the strain is the result of overuse, ultimate recovery must involve improving the force or torque production and recruitment patterns of the underused synergist(s). For example, strain to one diagonal oblique abdominal muscle is a common injury among members on a rowing team who only row either port or starboard. It is caused by repetitive flexion and unilateral rotation. Changing the movement pattern to greater flexion and rotation occurring at the hips, and improving the force and torque capability of the posterior spinal muscle group (to minimize the flexion component during unilateral rotation) and opposite oblique abdominal muscle group, may be indicated.

Rarely does a patient progress from a trunk muscle strain in the expected time frame, primarily because of frequent reinjury of the muscle. Reinjury is most likely a result of poor protection of the injured area during postures and movement patterns the patient is unaware he or she is performing. It is the responsibility of the therapist to educate the patient to avoid postures and movement patterns most likely contributing to delayed healing and to use improved postures and movement patterns to promote the healing process.

General Disuse and Deconditioning General disuse and deconditioning of the trunk and pelvic girdle muscles can result from the previously described causes. However, the trunk and pelvic girdle muscles also are susceptible to deconditioning as a result of general decreased activity level. Trunk and pelvic girdle deconditioning may be a leading cause of lumbopelvic

DISPLAY 17-7
Resisted Exercises for the Lumbopelvic System

Stability Activities for the Anterior Aspect

- Intrinsic spinal muscle activation (see Patient-Related Instruction 17-1)
- Leg slides (see Self-Management 17-1)
- Prone knee bend (see Self-Management 17-5)
- Hip and knee flexion, hip abduction, and lateral rotation (see Self-Management 17-3)

Stability Activities for the Posterior Aspect

- Intrinsic spinal muscle activation (see Patient-Related Instruction 17-1)
- Manual lumbar multifidus facilitation (see Fig. A in Display 17-5)
- Sidelying small-range hip abduction
- Prone small-range hip extension (see Self-Management 19-1 in Chapter 19)
- Prone neutral spine isometric

Stability Activities for Lumbopelvic Synergy

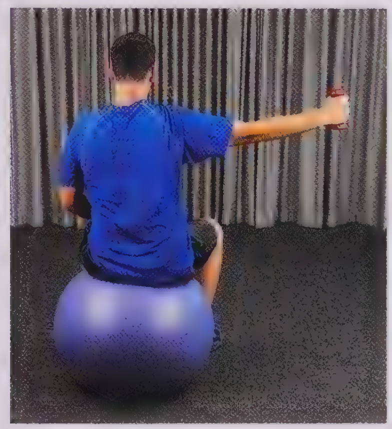
- Intrinsic spinal muscle activation (see Patient-Related Instruction 17-1)
- Sitting upper extremity abduction (**Fig. A**), flexion (**Fig. B**), rotation (not pictured)
- Quadruped arm lift (**Fig. C**)
- Intrinsic Spinal Muscle Series: Self-Management 17-2

Controlled Mobility Activities for Lumbopelvic Synergy

- Trunk curl sit-up (see Self-Management 17-4)
- Trunk sagittal and transverse plane motion in standing (see Fig. 17-14)

Skill Activity for Lumbopelvic Synergy

- Monitor performance of recreational or occupational skills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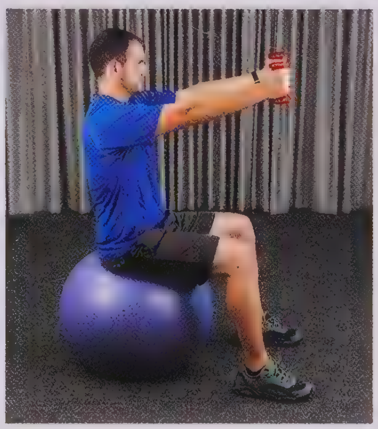
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syndromes and therefore are critical areas to address in prevention. Individuals with general deconditioning require a careful examination so that a graded conditioning program is focused on the specific muscles in need of strengthening and that the program is initiated at the appropriate level of difficulty. The dilemma with most trunk-strengthening exercises performed to improve fitness (e.g., bent-knee sit-ups, crunches, Roman chair hyperextensions, abdominal or back strengthening machines) is that the exercise is often performed at a higher level than that at which the muscles can safely and precisely execute the movement. When one synergist of a group is relatively weak, the other synergists often produce the necessary force or torque required to perform the desired movement, thereby reinforcing muscle imbalance and increasing the risk of injury to the lumbopelvic region.

It is beyond the scope of this text to analyze all the common fitness exercises used to strengthen the trunk muscles. Because the ability to curl up to a sit-up should be considered a normal ADL and because various forms of the sit-up are still commonly performed, a concise analysis of this exercise is provided.

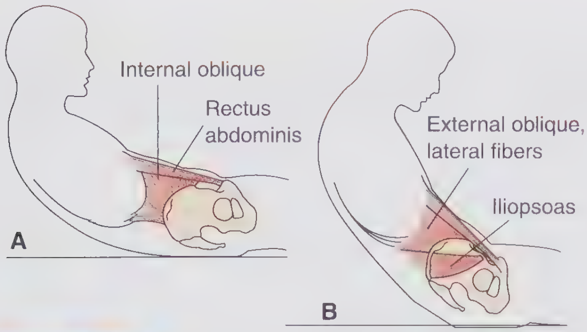


FIGURE 17-15 The sit-up can be considered a two-phase activity. **(A)** The first phase is the trunk curl. Trunk flexion is slowly initiated by raising the head and shoulders, with the pelvis tilting posteriorly simultaneously. **(B)** As the trunk is raised in flexion on the thighs, the hip flexors exert a strong force to tilt the pelvis anteriorly, the external oblique (EO) maintains the spine in flexion and the pelvis in posterior rotation. (Adapted from Kendall FP, McCreary EK, Provance PG. Muscles Testing and Function. 4th Ed. Baltimore, MD: Williams & Wilkins, 1993.)

The sit-up can be considered as two distinct phases of one movement: trunk flexion followed by hip flexion (**Fig. 17-15**). The RA and IO produce the trunk flexion phase, as indicated by rib cage depression (RA) and rib angle widening (IO), and the hip flexors produce the hip-flexion phase.[101] The role of the EO is to offset the anterior force on the pelvis and lumbar spine exerted by the hip flexor muscles.[101]

Although hip flexors may exhibit some weakness associated with postural problems (e.g., weak hip flexors in the swayback posture), it rarely interferes with performing the hip-flexion phase of the sit-up. The problem in accurately performing a straight leg sit-up is usually weakness of the abdominal muscles, causing the lumbar spine to be vulnerable to the extension forces exerted by the hip flexor muscles lifting a longer lever arm.

Instruction in proper execution of the sit-up requires a complex level of analysis and decision-making considering the performance of the abdominal muscles in relation to the hip flexor muscles and structural factors. **Self-Management 17-4** offers a detailed description of the sit-up. It is important to

SELF-MANAGEMENT 17-4
Sit-Up

Purpose: To strengthen the abdominal muscles and hip flexor muscles necessary to sit up from a supine position

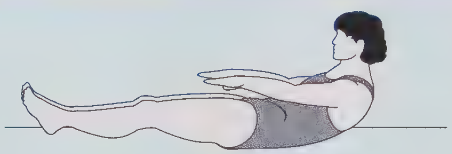
Starting Position: Back lying with hips and knees straight. Your physical therapist will determine if you are to begin this exercise in a supine position with hips and knees straight or with pillows under your knees. Your physical therapist will also determine if you will require fixation of your feet during the sit-up phase of this exercise.

TIP: To perform this exercise with proper technique, follow the tips listed:

- Start with an intrinsic spinal muscle contraction and hold this contraction throughout the entire sit-up and return to the start movement.
- Curl your trunk to the same spine level with the selected arm position.
- Maintain lumbar flexion and posterior pelvic tilt during the hip flexion phase.
- If you require fixation for your feet, do not use the fixation until the sit-up phase.
- If you did not require fixation for level I, you should not require fixation at any level of the exercise. Premature lifting of your feet can be an indication of abdominal fatigue.

Movement Technique:

Level I: With your arms in front of your body, bring your chin to your chest, and slowly curl your trunk as you come to a full sitting position. Slowly reverse the curl and resume the start position.

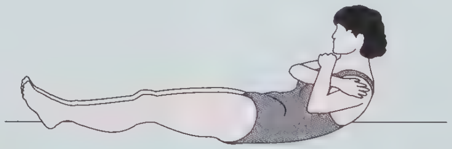


Dosage:

Sets/Repetitions: ____________

Frequency: ____________

Level II: Perform as in level I, but place your arms folded across your chest.

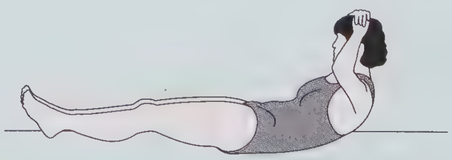


Dosage:

Sets/Repetitions: ____________

Frequency: ____________

Level III: Perform as in level I, but place your hands on top of your head with your elbows open.



Dosage:

Sets/Repetitions: ____________

Frequency: ____________

teach the client to complete the trunk-curl phase before the sit-up phase for proper execution of this exercise.

The lower extremities constitute about one-third of the body weight.[201] This means that the force exerted by the trunk in the supine position is greater than that of the lower extremities, and the feet need to be held down during the hip-flexion phase. However, if the spine flexes sufficiently as the trunk raises and the center of mass moves downward toward the hips, the trunk can be raised in flexion without having the feet held down. Most adolescents and women can perform the sit-up without having their feet held down because of a combination of body proportion (e.g., upper body less mass relative to lower body) and segmental trunk flexion lowering the center of mass. In contrast, many men may need to have some added force applied (usually very little) at the point where the trunk curl is completed and the hip flexion begins because mass of the upper body is greater than that of the lower body. This may also be true for women with a stiff trunk because of the inability to segmentally flex the spine, which creates a longer lever arm and may require the feet to be held down during hip flexion. If it is necessary to stabilize the feet during the hip-flexion phase, the feet should be held down *only during the hip-flexion phase* to ensure full trunk flexion before the hip-flexion phase begins. If the feet are held down prematurely or throughout the sit-up, the hip flexors are given fixation, and the trunk can be raised by hip flexion instead of trunk flexion.

Elevation of the feet during the sit-up can indicate abdominal muscle fatigue, as the abdominal muscles are no longer producing enough torque to flex the trunk through the specified arc of motion. Therefore, the hip flexors act earlier in the range to raise the trunk, with the feet rising as a result.

The bent-knee sit-up has long been advocated as a means of minimizing or eliminating the action of the hip flexors, placing them "on slack" during the sit-up. This idea is false and misleading. The abdominal muscles do not cross the hip joint and can therefore only flex the trunk. Regardless of hip position, the sit-up is a strong hip flexor exercise; the difference is the arc of hip joint motion through which the hip flexors act (i.e., hips extended: 0 to 80 degrees flexion; hips flexed: 50 to 125 degrees flexion). Because the hip joint moves to completion of hip flexion ROM with the hips and knees flexed, high repetitions of this type of sit-up may be more conducive to the development of short hip flexors than the sit-up with the hips extended.

Although normal flexibility of the back is desired, excessive flexibility is not. A contraindication to performing a bent-knee sit-up is excessive flexibility of the lumbar spine. With the hips extended, the center of mass is slightly anterior to the first or second sacral segment. With the hips and knees bent, the center of mass moves cranially. The lower extremities exert less force in counterbalancing the trunk during the sit-up with the hips and knees flexed than with the hips extended. To sit up from the bent-knee position, the feet must be held down, or the trunk must flex excessively to move the center of mass downward. As the curl progresses, the center of mass moves distally toward the hip joint. In the hip-extended position, by the time the hip-flexion phase arrives, the center of mass has moved toward the hips, which encourages the hips (not the lumbar spine) to flex during the sit-up phase. With the hips flexed, the center of mass may not reach the axis of motion of the hips by the hip-flexion phase, thereby imposing a flexion moment on the lumbar spine versus the hip joints. The persons most in danger of being adversely affected by repeated bent-knee sit-ups are children and young adolescents because of their tendency toward excessive flexibility. Adults with LBP associated with excessive flexion flexibility of the low back may also be adversely affected by this exercise.

A precaution to performing a straight-leg sit-up is short hip flexors. In the supine position with the legs straight, a person with short hip flexors lies in anterior pelvic tilt and lumbar extension. The danger with performing the sit-up from this position is that the multijoint hip flexors (i.e., tensor fascia lata [TFL] and rectus femoris) pull the pelvis into more anterior pelvic tilt and subsequently the spine into further extension during the hip-flexion phase. The bent-knee position releases the downward pull of the short hip flexors, allowing the pelvis to tilt posteriorly and the lumbar spine to relatively flex. The hips and knees should be bent only as much as needed to allow the pelvis to reach neutral in the supine position. This position should be maintained passively by using a large enough roll or pillow under the knees. Prescribing bent-knee sit-ups (even in a partially bent-knee position) to individuals with short hip flexors is not the final solution, and this position should not be used indefinitely. Short hip flexors often accompany lengthened EO muscles because of the anterior pelvic tilt posture induced by the short hip flexors. The bent-knee sit-up neither addresses the short hip flexors nor the lengthened EOs. Consequently, it is important to perform exercises to stretch the short hip flexors (see **Self-Management 17-5**), to strengthen and shorten the EO muscles (see Self-Management 17-1), and to attend to undesirable postural habits (e.g., avoiding excessive anterior pelvic tilt and lumbar lordosis).

A contraindication to either bent-knee or straight leg sit-up techniques is concern about compressive loading of the spine. Lumbar compressive loads >3,000 N were predicted for both sit-up techniques.[202] In the presence of an HNP, for example, the issue of using straight-leg or bent-knee sit-ups is not as important as the issue of whether or not to prescribe sit-ups at all.

A trend in abdominal strengthening is a trunk curl or "crunch" performed without the hip-flexion phase. Performance of only the trunk-curl phase should be safe and effective for strengthening the abdominal muscles. There is less intradiskal pressure in performing the trunk curl than in a full sit-up.[203] However, the trunk curl focuses primarily on producing torque for movement rather than force or torque for stabilization of lumbar segments. This preferentially recruits the RA and IO over the EO. Moreover, the trunk curl is contraindicated for any person with a thoracic kyphosis because of the stress thoracic flexion exerts on the kyphosis. Alternative exercises should be suggested for persons with poor lumbar stabilization and thoracic kyphosis (see Self-Managements 17-1 and 17-2).

If the trunk curl is chosen, the therapist should determine the position in which the patient should start—a small towel roll under the knees, a wedge-shaped pillow under the head and shoulder, or a pillow under the knees. Before any trunk movement, an intrinsic spinal muscle contraction should be initiated (see Patient-Related Instruction 17-1). With the arms extended forward, the patient should flex the chin toward the chest and continue to curl the upper trunk as far as the spine can flex (see Self-Management 17-4). If the subject cannot perform the curl to completion of his or her spine flexion because of abdominal weakness, a wedge-shaped pillow can be placed behind the

SELF-MANAGEMENT 17-5
Prone Knee Bend

Purpose: To lengthen the hip flexors and quadriceps, improve the strength of the intrinsic spinal muscles, and train the pelvis and spine to remain still during knee bending movements

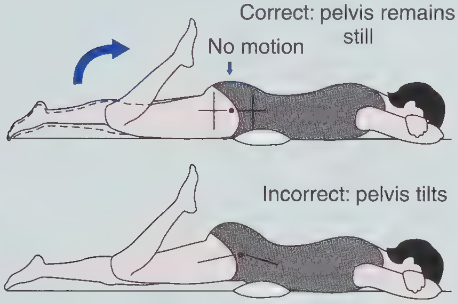
Starting Position: Facelying with both lower limbs straight and knees together.

Options: You may need _______ pillows under your hips, as indicated by your physical therapist.

You may need to position your thigh out to the side.

Movement Technique: Before moving your legs, engage your intrinsic spinal muscles. Maintain this contraction as you bend one knee as far as possible *without movement in the pelvis or spine*

Options: Bend both knees at the same time while keeping knees and ankles together.



Dosage:

Repetitions: ________________________________

Frequency: ________________________________

head and shoulders to limit the range and decrease the effect of gravity. As abdominal muscle strength improves, smaller pillows can be used. If the hip flexors are short, temporary use of a pillow under the knees can decrease the pull of the hip flexors on the spine and allow the individual to lie in supine with the pelvis and spine in neutral. **Table 17-7** summarizes features related to the prescription of the sit-up and its variations.

Range of Motion, Muscle Length, and Joint Mobility

Clinical decisions regarding exercise prescription for ROM, muscle length, and joint mobility must be considered in relation to other regions of the spine, upper quarter, and lower quarter.

Hypermobility

Diagnosis of hypermobility and true articular instability can be made from careful clinical examination.[119,141] The examiner should also seek to discover the impairments contributing to the hypermobility or articular instability.[31] Four factors can be responsible for the development of a hypermobile segment: trauma (e.g., motor vehicle accident resulting in an acceleration injury), pathology (e.g., rheumatoid arthritis, degenerative joint changes), structural impairment (spondylolisthesis, HNP, asymmetric trophic changes in the ZJ), or chronic repetitive movement patterns. With repetitive movement, hypermobility can develop within the lumbopelvic region in response to a relatively less mobile segment or region. Theoretically, in a multijoint system, any given movement follows the segments providing the least resistance, resulting in abnormal or excessive movement of segments with the least amount of stiffness.[31] With repeated movements over time, the least stiff segments increase in mobility, and the more stiff segments decrease in mobility.

Sahrmann has termed the site of abnormal or excessive motion *the site of relative stiffness or flexibility*.[31] The term *relative* is key to this concept. For example, the fifth lumbar vertebra, because of its biomechanical and anatomic properties, is more adapted to produce rotation than any other lumbar segment. It is therefore *relatively* more flexible in the direction

TABLE 17-7

Summary of Indications, Contraindications, and Precautions in Prescribing Sit-Ups and Sit-Up Variations

EXERCISE	INDICATIONS	CONTRAINDICATION AND PRECAUTIONS
Bent-knee sit-up	Lordosis	Short hip flexors, excessive trunk flexion range of motion, thoracic kyphosis
Temporary use of pillows under knees for sit-up	Short hip flexors	
Straight leg sit-up	At least 3+/5 strength of all abdominal muscles and hip flexors	Acute or subacute disk pathology
Trunk curl (only)	Weak external oblique, acute or subacute disk pathology	Thoracic kyphosis
Temporary use of wedge under spine	<3/5 in lower fibers of abdominals, stiff lumbar region (restricted in flexion)	

of rotation. This becomes a clinical problem or impairment only if the segmental motion becomes excessive due to relative stiffness elsewhere along the kinetic chain. For example, playing golf involves a significant amount of total-body rotation. If the hips or feet are relatively stiff in rotation, the spine may incur excessive rotational stress. If the thoracic spine or upper lumbar segments are stiff in rotation, this pattern may impose excessive rotation on the L5 segment.

The cause and effect relationship of relative flexibility can be addressed through a comprehensive program of improving mobility at the relatively more stiff segments or regions and improving stiffness at the relatively more mobile segment. Stiffness should be increased at the site of relative flexibility by improving neuromuscular control, muscle performance (i.e., hypertrophic changes), and length–tension relationships of the stabilizing muscles (see the "Muscle Performance Impairment" section). According to a study by Shirley et al.,[204] voluntary submaximal contractions as low as 10% maximum voluntary contraction (MVC) demonstrated an increase in lumbar stiffness. This conclusion points to the importance of motor control and simply teaching the patient to activate the spinal muscles at low levels to increase segmental stability.

Exercises to reduce hypermobility at a segmental level or within the pelvis can be progressed according to traditional stages of motor control: mobility, stability, controlled mobility, and skill. The stage of mobility can be thought of as improving mobility at relatively stiff or hypomobile segment(s) or region(s) in the specific direction(s) desired to reduce the stress at the associated hypermobile segment. Activities and techniques to improve mobility are presented in the "Hypomobility" section.

The stage of stability can be thought of as improving motor control, muscle performance (particularly hypertrophic changes), and length–tension properties of the affected muscles. Specific activities and techniques chosen to promote stiffness and stability should be based on the direction the segment is susceptible to motion. The patient must be educated to avoid habitual postures that place a lengthening stress on the muscle (e.g., avoid standing in a swayback in the presence of lengthened EO). In some cases, immobilization in the short range (e.g., use of an abdominal binder or taping) may be necessary to facilitate adaptive shortening. To stimulate hypertrophic changes that lead to increased muscle stiffness, prescribe exercises for specific muscles dosage levels for hypertrophy (i.e., 10 to 12 repetition max sets).

Controlled mobility focuses on the ability of the lumbopelvic region to move dynamically in all three planes with appropriate distribution of movement throughout the lumbar region, the thoracic spine, the SIJ, and the extremities. Skill is reached when the patterns of muscle activation become automatic and internalized by the patient during functional activities. Display 17-7 provides recommendations for exercises to develop stability through the stages of motor control.

To be most effective in reducing hypermobility with exercise, the therapist should educate each patient to use appropriate spine positions during all exercises and activities. There is no particular lumbopelvic functional position that is best for all patients and for all activities. Although the standard is the neutral position (see Table 17-6), it may not be achieved by all patients and for all activities, in which case the functional position of the spine should be used. The functional position (see Table 17-6) varies with physiologic status and stresses from BADLs and IADLs. For example, to avert exacerbation of symptoms, patients with spinal stenosis must avoid extension. The functional position may vary with the patient's activity. For example, flexion should be avoided during heavy lifting from the floor to the waist, whereas end-range extension should be avoided during lifting from waist level to overhead. Functional spinal posture may also vary with the patient's behavior of symptoms. The more severe, irritable, and acute the condition, the more limited the functional position of the spine becomes to avoid symptoms.

Hypomobility

To be most effective, activities or techniques to reduce hypermobility must occur simultaneously with activities or techniques to increase hypomobility in related regions. Many activities or techniques can be used to increase mobility, such as manual techniques (e.g., articular joint mobilization, muscle energy techniques, soft-tissue mobilization); passive self-stretch or self-mobilization; or active assisted, active, and resisted exercise.

There are multiple justifications for the use of manual therapy including (see Chapter 7):

- Psychologic effects as a result of patient–therapist interaction[205]
- Mechanical effect (e.g., altering positional relationships or mobilizing joints through stretching or rupturing restrictive structures)[206]
- Neurophysiologic effect (e.g., activation of the gate control mechanism, reflexogenic decrease of muscle hypertonicity)[206]

Research does not support the use of rotatory manual techniques for reduction of herniations in contained or uncontained disks.[207–209] These techniques seem contraindicated in diskogenic dysfunctions because they cause tensile strain to annular fibers which further weaken nuclear containment.[210] Research also does not support the rationale that manual therapy can affect the positional relationship in the SIJ and thus decrease complaints.[140] Neurophysiologic mechanisms may offer a better explanation of the effects of manual therapy. Clinical outcome studies demonstrate better results with manual therapy techniques when patients with NSLBP are classified using clinical guideline indices.[211]

Passive intervention in the form of manual therapy or manual exercise without some form of follow-up active exercise is discouraged. One potential hazard in providing purely passive intervention is that the patient may not participate *actively* in the rehabilitation process. Whenever possible, active participation in the form of patient-related education and self-management exercise is encouraged.

Active assisted ROM, active ROM, proprioceptive neuromuscular facilitation techniques (see Chapter 13), and passive stretching can also be used to increase mobility (see Chapter 7). This discussion focuses on self-management exercises, emphasizing passive and active stretching.

Passive stretching may be necessary, particularly for muscle groups with adaptive shortness. Careful muscle length testing determines which trunk and pelvic girdle muscles require stretching. Superficial trunk muscles, such as the RA, quadratus lumborum, and lumbar erector spinae, and multijoint hip muscles, such as TFL/iliotibial band, HSs (semitendinosus or semimembranosus [medial HSs], biceps femoris [lateral HSs]), hip adductors, and rectus femoris, are susceptible to adaptive shortening.

Care must be taken when stretching muscles crossing the hip joint in individuals with lumbopelvic dysfunction, because the SIJ or lumbar spine often becomes the site of relative flexibility when the hip becomes hypomobile. Appropriate stabilization at the pelvis while the distal attachment moves is essential. Otherwise, the spine or SIJ becomes the path of least resistance and therefore easily moves before the feeling of a stretch.

An example of proper stabilization for a diarthrodial muscle with attachments on the pelvis is the supine passive HS stretch. The HSs may be passively stretched in supine with one hip flexed and the ipsilateral knee extended (to the point of mild HS tension) and the foot against a wall while the contralateral hip and knee are extended. The lumbopelvic region is stabilized by appropriate recruitment of the intrinsic spinal muscles and by the surface supporting the patient. The length of the HSs determines the distance from the wall and angle of SLR. Certain criteria are used for proper stabilization to facilitate the optimal stretch (see **Building Block 17-1**).

BUILDING BLOCK 17-1

With regard to supine passive HS stretch:

1. Provide specific criteria for positioning for the:
   - Contralateral limb
   - Spine and pelvis
   - Ipsilateral limb
2. How could you isolate medial versus lateral HSs?
3. Based on your knowledge of the dosage for stretching, prescribe specific duration and repetitions for an effective stretch.

Neuromeningeal Hypomobility

Loss of mobility of the nervous system can occur as a result of congenital disorders, trauma, surgical complications, or degenerative changes.[120,133,212] There are two types of neuromeningeal hypomobility: the tethered cord syndrome and the nerve root and dural movement dysfunction. The tethered cord syndrome forms a contraindication to physical therapy intervention; however, nerve root and dural movement dysfunction can respond quite well to neural mobilization techniques.[120] Before intervention, neuromeningeal mobility should be assessed and its influence determined. Specific exercises may be prescribed that are designed to improve mobility of the neural system (see **Self-Management 17-6**). The related anatomy, physiology, and application principles must be well understood for the effective and safe use of this type of treatment. This topic is worthy of more extensive coverage. Detailed information is provided by Butler.[120]

Pain

LBP is the most common type of pain reported by adults in physician offices.[213] The well-meaning clinician desires to identify and explain the source of pain to a patient. Of frustration to the clinician is the difficulty associated with identifying the pathoanatomic cause for most cases of LBP due to the complex interaction of peripheral and central mechanisms responsible for the pain experience. The physiologic and psychologic impact that lumbopelvic pain has on the person can create profound participation restriction. The experience of musculoskeletal origin pain is a complex process involving both the peripheral nervous system and the central nervous system and is beyond the scope of this chapter. The reader is referred to Chapter 10 and additional reading on the topic.[214–216] This section addresses the treatment of pain based solely on body function and structures.

There is growing evidence that factors such as sleep disturbance, sustained high stress levels, depressed mood, and anxiety are strong predictors of persistent LBP.[217] This highlights the role that cognitive/affective subsystem components such as lifestyle and negative emotional factors play in sensitizing spinal structures.[217] This may reflect clinically as a patient presenting with acute LBP, reporting high levels of pain, distress, and muscle guarding associated with a "minor" mechanical trigger. Identifying this pattern in the acute phase may prevent the slide into CLBP. It is also important to note that negative beliefs about LBP are predictive of pain intensity, disability levels, and work absenteeism.[218] Unfortunately, many beliefs such as a negative future outlook, believing that "hurt equals harm" and that "movements that hurt should be avoided" because of fear of pain gain their origins from health care practitioners.[219,220] What we say to our patients matters. Inadvertent comments from a well-meaning practitioner can affect the long-term recovery of a patient experiencing pain, highlighting the critical role of communication in the acute care of people with LBP (see **Patient-Related Instruction 17-2**).

There is also evidence that, in the absence of a clear traumatic injury, pain behaviors, such as limping, protective muscle guarding, and grimacing, are more reflective of catastrophic thinking (e.g., "my back is damaged," "I am never going to get better" and "I am going to end up in a wheel chair"), fear and distress.[221] These behaviors can result in abnormal loading of sensitized spinal structures, feeding a vicious cycle of pain. They are also linked to poor coping skills, such as avoidance and excessive rest, and leave the person feeling helpless and disabled. In contrast, people who have positive beliefs about LBP and its future consequences are less disabled.[218]

Treatment of the physiologic musculoskeletal component of pain can include a variety of interventions, ranging from pharmaceutical interventions (oral medications or injections) to physical therapy, to surgery—applied individually or in any combination. The choice of intervention must be tailored to each case, ideally with input from all involved practitioners. This section discusses therapeutic exercise as one type of intervention for the treatment of musculoskeletal lumbopelvic pain. Although the exercises suggested in this section were chosen to demonstrate activities or techniques to treat different underlying causes of pain, many are used to treat associated impairments, such as those of mobility, muscle performance, posture, and motor control. Consequently, they may be referred to in other sections of this chapter, illustrating the complex interaction of impairments and the diversity and versatility of the exercises. To make informed decisions about the exercises chosen to treat pain, the clinician should understand the physiologic impact that pain has on the structures of the lumbopelvic region. There is evidence of segmental changes within the deep low back muscles in the presence of LBP.[51,200,216,222–225] Atrophy has been found at the corresponding level of symptoms in the LM.[51,226] Histologic changes have been found in type I fibers of the LM in patients with herniated intervertebral discs (IVDs) and CLBP.[223,227–230]

SELF-MANAGEMENT 17-6
Neuromeningeal Mobilization

Purpose: To improve the mobility of your sciatic nerve and its branches into the calf and foot and to reduce the pain coming from a loss of mobility in the sciatic nerve

Assessment: Before beginning this exercise, you must first assess the status of your neural mobility.

While seated, slump in your low back and pelvis as far as possible.

Bring your chin toward your chest.

Flex your foot as far as possible.

Slowly extend the knee on the side of symptoms as far as possible.

Stop at the onset or worsening of symptoms.

Notice the angle of your knee. You will recheck this angle after performing the exercise. You should be able to extend your knee further if you are successful with mobilizing your nerve.

If the angle is less, you have exacerbated your nerve and should repeat the series, reducing the range of motion of each movement in the series. Recheck the knee angle. It should be back to the original assessment position or may be improved.

Starting Position: Slump in your low back, and roll your pelvis back as far as possible. *Slightly* flex your neck to take the stress off the forward head position the slumped posture placed your head in.

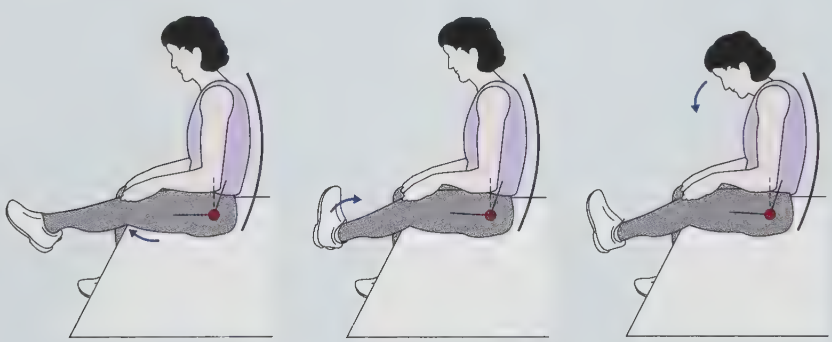
Movement Technique: Repeat each activity up to 15 times.

Knee Mobilization: Keeping your ankle relaxed, extend your knee until you feel *mild* tension behind your knee. Relax back to the start position.

Ankle Mobilization: Extend your knee about three-fourths of the distance you found during the assessment. Flex and extend your ankle.

Neck Mobilization: Extend your knee three-fourths of the distance you found during the assessment. Flex your ankle toward your head about three-fourths of the distance of its full range of motion. Actively flex your chin toward your chest and release to the start position.

Reassess after the first cycle. If you have been successful as described under the assessment, repeat the cycle ________ times.



Knee mobilization   Ankle mobilization   Neck mobilization

Patient-Related Instruction 17-2

Messages that can Harm People with NSLBP

Promote Beliefs About Structural Damage/Dysfunction

- "You have degeneration/arthritis/disk bulge/disk disease/a slipped disk"
- "Your back is damaged"
- "You have the back of a 70-year-old"
- "It's wear and tear"

Promote Fear Beyond Acute Phase

- "You have to be careful/take it easy from now on"
- "Your back is weak"
- "You should avoid bending/lifting"

Promote a Negative Future Outlook

- "Your back wears out as you get older"
- "This will be here for the rest of your life"
- "I wouldn't be surprised if you end up in a wheelchair"

Hurt Equals Harm

- "Stop if you feel any pain"
- "Let pain guide you"

(continued)

Patient-Related Instruction 17-2 (*continued*)

Messages that can Reduce Pain in People with NSLBP

Promote a Biopsychosocial Approach to Pain

- "Back pain does not mean your back is damaged—it means it is sensitized"
- "Your back can be sensitized by awkward movements and postures, muscle tension, inactivity, lack of sleep, stress, worry, and low mood"
- "Most back pain is linked to minor sprains that can be very painful"
- "Sleeping well, exercise, a healthy diet and cutting down on your smoking will help your back as well"
- "The brain acts as an amplifier—the more you worry and think about your pain the worse it gets"
- "Pain with movement does not mean you are doing harm"

Promote Resilience

- "Your back is one of the strongest structures of the body"
- "It's very rare to do permanent damage to your back"

Encourage Normal Activity and Movement

- "Relaxed movement will help your back pain settle"
- "Your back gets stronger with movement"
- "Protecting your back and avoiding movement can make you worse"
- "It is safe to exercise and work with back pain—you may just have to modify what you do until the sensitivity is reduced"

Address Concerns About Imaging Results and Pain

- "Your scan changes are normal, like gray hair"
- "The pain does not mean you are doing damage—your back is sensitive"
- "Movements will be painful at first—like an ankle sprain—but they will get better with time and as you get active"

Encourage Self-Management

- "Let's work out a plan to help you help yourself"
- "Getting back to work as you're able, even part-time at first, will help you recover"
- "Gradually increase your activity levels based on time rather than pain levels"

These changes may result from pain-provoked, low-tension muscle contraction, which is not strong enough to stimulate type II fibers.[52] Others have hypothesized that the atrophy is consistent with pain-induced disuse.[224] Although the physiologic changes are not well understood, they do occur and contribute to a decline in muscle performance and neuromuscular control, particularly in the LM.

Most structures in the lumbar spine can be a source of pain at some time under the right circumstances, making it difficult or impossible to diagnose a specific pathoanatomic cause of pain. The nerve root, disk, annulus, facet joint, and muscle seem to be the most acceptable candidates for sources of pain.[231] The mechanisms of pain production are described as a combination of mechanical and chemical irritation of the nociceptive receptors within the tissues. It is not clear whether mechanical stresses lead to chemical irritation, which sensitizes the tissue, or chemical irritation makes tissue more sensitive to mechanical stress. The two mechanisms most likely coexist in the vast majority of cases.

In the spinal canal, the HNP is a strong candidate for the cause of inflammation and irritation of nerve roots and nerve endings. Because of the juxtaposition of disk and nerve roots in the spinal canal, sciatica (i.e., pain radiating from the low back into the buttock, posterior thigh, and leg) is likely to rise from compression of the dorsal root ganglion and inflamed nerve roots. When a painful condition is set in the peripheral tissue, the consequent barrage of noxious signals into the spinal cord can sensitize somatosensory neurons in the dorsal horn. These sensitized neurons can contribute to a condition of CLBP.[133]

The physical therapist is most interested in the mechanical cause of pain as it relates to movement. A systematic physical examination can reveal postures, stabilization, and movement strategies that contribute to the onset of pain, worsen existing pain, or conversely, reduce or abolish pain.[189,232]

One philosophical approach to treating mechanical causes of pain related to posture or movement is to teach the patient to modify postures or movements that aggravate pain.[31,189,232,233] Based upon examination findings, the therapist instructs the patient in strategies to modify aggravating movements and postures and treats the aggravating physiologic impairments (e.g., ROM, joint mobility, muscle performance, neuromuscular control). This approach is believed to intervene mechanically by avoiding aggravating postures and movements, therefore allowing the painful structures to "rest" which will decrease the inflammatory process. For example, in the patient who reports worsening of pain during forward bending, the lumbar-pelvic relationship is faulty, with excessive motion in the low back relative to the hips.[234] If the pain is reduced or abolished when the patient is instructed to bend with a greater contribution of movement from the hips and less movement from the low back, this information can be used to devise an exercise intervention. Examples of exercises to include in such a program are listed in **Display 17-8.**

In many cases, reducing the mechanical stress on the affected structures by improving mobility in adjacent regions, improving stability in the affected region, and making associated changes in posture and movement patterns are sufficient steps to resolve the episode of pain without need for other interventions. In other instances, short-term use of complementary interventions (e.g., joint mobilization or manipulation, traction, physical agents, pharmaceutical intervention, psychologic counseling) by the physical therapist or other practitioners involved in the case may be necessary to treat additional mechanical, chemical, or psychologic contributions to pain. It is important for the clinician to be mindful of what is said during this period regarding the underlying causes of pain and the steps necessary to reduce pain (see Patient-Related Instruction 17-2).

McKenzie developed another therapeutic exercise approach for the treatment of pain.[235,236] A simplified example of this approach is the use of movements that reduce or abolish symptoms. Self-reports of postures related to pain, observation of posture, and

DISPLAY 17-8

Exercises to Improve Hip Flexion Mobility and Decrease Lumbar Flexion Mobility

- Exercises to improve hip flexion mobility
  - Hand-knee rocking (see Self-Management 19-7 in Chapter 19)
  - Supine hip flexion without lumbar flexion or rotation (**Fig. A**)
- Exercises to reduce lumbar flexion mobility
  - Seated knee extension (see Self-Management 19-8 in Chapter 19)
  - Standing hip flexion (**Fig. B**)
  - Instruction to alter posture and movement patterns
  - Corrected sitting posture (see Patient-Related Instruction 18-4 in Chapter 18)
  - Improved lumbar-pelvic movement (see Patient-Related Instruction 17-3)

A

B

uniplanar movements (e.g., flexion, extension, lateral flexion) are used to assess the effect of posture and movement on symptoms. During the examination, each movement is rated according to terms used to describe a change in status (e.g., improve, worsen, status quo). After the movement, or repeated movements, the patient is asked to compare his or her symptoms with the baseline.

The concepts of *peripheralization* (i.e., pain or paresthesia that moves distally away from the spine) and *centralization* (i.e., pain or paresthesia that is abolished or moves from the periphery toward the lumbar spine) are used to determine which movements should be used in self-treatment. For example, if repeated forward bending peripheralizes symptoms and extension centralizes symptoms, extension-related exercises would be used in self-management to modulate symptoms (see **Self-Management 17-7**). This approach to the treatment of acute LBP has been effective in restoring function,[236] particularly if used in conjunction with a treatment-based classification approach to low back syndrome.[237] In a retrospective study of 87 patients with leg and LBP, Donnelson et al.[238] found that all patients with excellent outcomes of McKenzie-based diagnosis and treatment showed centralization during the initial evaluation.

McKenzie's conceptual model for treatment of diskogenic dysfunction theorizes that when the annulus is intact, it will force the NP to move posteriorly during flexion and anteriorly during extension.[6,77] Other rationale includes effects related to activating gate control mechanisms, neural tissue relaxation, decreasing mechanical stimulation of nerve roots and other nociceptive tissues, and disk hydration.[133,239-243]

Positional techniques can also be used to modulate pain. For example, a patient can be taught to use positional traction if the goal is to separate joint surfaces to expedite relief of pain (**Fig. 17-16**). The theory behind positional traction is similar to that for other types of traction (see "Traction" in a later section of this chapter) in that the technique is used to affect the mechanical causes of pain.[244]

Self-mobilization can be prescribed to correct articular dysfunction, particularly that which relates to the SIJ. For example, a patient who presents with recurrent iliosacral dysfunction (e.g., anterior innominate rotation) should be able to self-treat the articular dysfunction rather than relying solely on the therapist to restore articular function.[245] An example of a prescriptive articular exercise is illustrated in **Self-Management 17-8**. For this type of technique to be successful, the patient must learn to evaluate his or her dysfunction and to perform the appropriate technique with precision only until correction is achieved. It also must be emphasized to the patient that these techniques are not considered part of the regular exercise regimen; they should be used only for articular dysfunction that contributes to the patient's symptoms. Although pain is the most common symptom, limited ROM, stiffness, paresthesias, and weakness are also symptoms related to articular dysfunction, and should be used as indications for this treatment technique. A relative contraindication for this technique is a hypermobile hip joint. Repeated use of this technique in the presence of a hypermobile hip may cause further increases in hip laxity and subsequent pain. **Self-Management 17-9** can be used if the specific dysfunction is a sacral torsion in which the sacrum is rotated causing a unilateral counter-nutation. This technique activates both piriformis and LM to restore sacral nutation. From a sequencing standpoint, a technique to correct an articular dysfunction should be performed before any other exercise. Once articular alignment is restored, the patient should perform intrinsic stabilization exercises.

For patients with nonspecific CLBP, there is compelling evidence that active rehabilitation that is directed toward return to normal activity and work can reduce absence from work more than traditional care.[246] Interventions such as physical exercise, application of operant-conditioning behavioral principles, and promotion of improved functioning and safe return to work despite pain are recommended.

In an acute onset of LBP, inflammation often dominates the clinical picture, and attempts at altering mechanical causes may not substantially decrease pain. The clinician must treat inflammation with the appropriate adjunctive modalities (e.g., cryotherapy, electrotherapy), protective measures (e.g., corset,

SELF-MANAGEMENT 17-7
Prone Press-Up Progression

Purpose: To improve the mobility of your low back into backward bending, stretch the front trunk muscles, move your leg pain toward your back or abolish it completely, and/or progressively relieve the pressure on your lumbar disk

TIP: Your physical therapist may ask you to perform special exercises to reduce any shift you exhibit in your spine before the execution of this exercise.

Starting Position: Face lying with legs straight.

Movement Technique: Your physical therapist will inform you of the levels of this exercise you are to perform and the duration of time you should spend at each level.

TIP: You should ***not*** progress to the next level if your pain does not move toward your spine. Occasionally, your LBP may increase in intensity. This is normal and should return to baseline quickly.

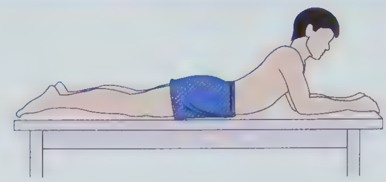
Level I: Remain on your stomach with your hands supporting your forehead.

Dosage:

Repetitions: ______________________________

Frequency: ______________________________

Level II: Prop up onto your forearms. Exhale and relax the muscles in your back.



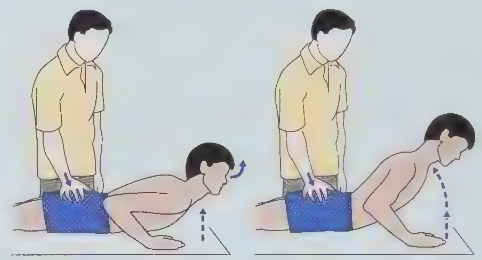
Dosage:

Duration: ______________________________

Sets/Repetitions: ______________________________

Frequency: ______________________________

Level III: Place your hands next to your shoulders. Press your upper trunk upward with your arms through the prescribed range of motion. Be sure the muscles in your back are fully relaxed.



Dosage:

Range of motion: ______________________________

Sets/Repetitions: ______________________________

Frequency: ______________________________

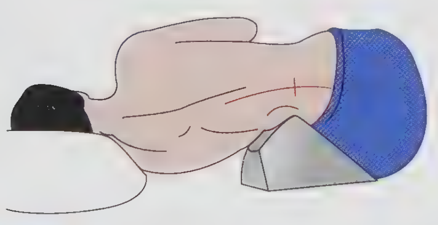


FIGURE 17-16 Positional traction. The use of a foam wedge allows maximal lateral flexion at a desired segmental level because of its sharp apex and ability to accommodate to the bony pelvis. The wedge easily can be made at a business that specializes in the manufacturing or design of foam products. The recommended density is CD-80. The preferred dimensions are 0 × 8 × 8 × 18 in (small) and 0 × 10 × 10 × 18 in (large).

SIJ belt), and controlled rest, but strict bed rest should be avoided (see Chapter 7). Moreover, the patient's physician should be alerted so that, if necessary, appropriate pharmacologic agents may be prescribed or modified.

Exercise is not contraindicated when an inflammatory response dominates the clinical picture. Although the primary goal is to reduce the inflammatory process, exercises encouraging controlled rest are prescribed to enable the patient to perform basic movements without aggravating pain. To move without inducing an increase in baseline pain, motion must be prevented at the affected lumbar spine segment or SIJ. Patient education is critical to teach the patient what postures and movements to avoid to reduce mechanical stress. Exercise may involve low-intensity isometric recruitment of the stabilizing muscles of the lumbar spine and SIJs with simultaneous small-range movements of the extremities. Altering the length of lever arms, limiting the ROM, and adjusting the position of the exercise to a gravity-lessened position are examples of altering the exercise to reduce the stress on the inflamed segments. Prophylactic ROM exercises for associated regions and neuromeningeal mobility exercises[120] (see Self-Management 17-6) also may be used to prevent unnecessary loss of movement.

As the acute pain subsides and functional movement improves, more advanced exercises may be introduced, focusing on impairments in muscle performance, ROM, muscle extensibility, joint mobility, and balance. Transition to more advanced stages of care is rarely simple; if a dosage stresses any given subsystem of the movement system beyond its tolerance, the result will be an increase in pain and inflammation. Therefore, exercise gradation should err on the conservative side to avoid exacerbation of symptoms.

SELF-MANAGEMENT 17-8
Self-Mobilization for an Anterior Innominate Dysfunction

Purpose: To normalize the position and motion of your pelvis

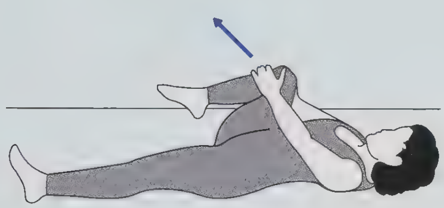
Starting Position: Back lying on a firm surface.

Movement Technique: Keep your ___ hip and knee straight. Pull your ___ knee toward your chest until you feel a mild barrier. Gently squeeze your ___ gluteal muscles against an unyielding force exerted by your hands keeping your knee to your chest. Hold your contraction for 8 to 10 seconds. On relaxation, flex your hip and rotate your pelvis posteriorly until you feel a new barrier. Repeat this process three to four times.

Dosage:

Repetitions: ______________________________

Frequency: ______________________________



SELF-MANAGEMENT 17-9
Self-Management for a Sacral Dysfunction

Purpose: To restore normal position and movement of your sacrum

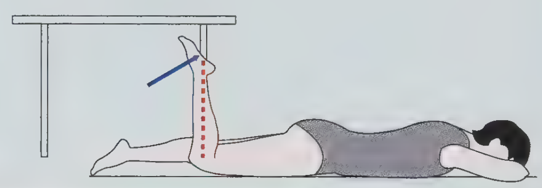
Starting Position: Lie on your stomach on the floor with your legs on either side of a table leg or door. Bend your ___ knee to 90 degrees and position your heel against the table leg or door.

Movement Technique: First, activate your pelvic floor muscles, transverse abdominis, and LM. *Gently* (about 10% maximum pressure) press your heel into the table leg or door. *Use your deep hip muscles (not your thigh muscles). Hold the contraction for 10 seconds.*

Dosage:

Repetitions: ______________________________

Frequency: ______________________________



Patients should be educated about when to modify or stop exercise in light of increased symptoms (e.g., numbness, paresthesia, pain) beyond acceptable time frames (e.g., if symptoms are increased for more than 24 hours). Continuing to exercise duration these situations can be counterproductive to progress. Educating the patient to respond to their body's response to exercise and to modify exercises appropriately (e.g., decrease lever arms, work in gravity-lessened position, decrease repetitions, decrease frequency, longer rest periods) can prevent excessive stress on healing tissues. Conversely, fear-avoidance behaviors should be circumvented with encouragement that pain does not always mean harm and carefully prescribed exercise will induce healing and adaptation.

The muscular changes that occurred as a result of lumbopelvic pain (e.g., muscle performance capabilities, cross-sectional area, neuromuscular control) may not improve naturally after the pain has ceased and the patient resumes functional activities.[179] Specific localized exercises as described in this chapter can restore the ideal lumbopelvic muscle control and performance (see **Building Block 17-2**).

An earlier section (see "Myology" and "Muscle Performance Impairment") discussed the role of the TrA, LM, and pelvic floor in the stabilization of the lumbopelvic region. Specific stabilization exercises aimed at improving motor control and muscle performance of the intrinsic spinal muscles appear effective in reversing atrophic changes in the LM muscles in patients with acute LBP[179] and may reduce recurrence rates

BUILDING BLOCK 17-2

1. A clinical example may provide insight into the complex relationships between pain and the development of hypermobility in the lumbopelvic region. A 45-year-old male presents with LBP. He has a flat back, a slight pelvic shift in standing, and increased foot pronation and foot abduction on the right. During the examination, the physical therapist notices that the pelvis and lumbar spine rotate during the initiation of active hip flexion in the supine position and that this movement provokes LBP. When the patient is properly cued to recruit the intrinsic spinal muscles, pelvis and spine rotation is reduced, and symptoms are eliminated. Other tests throughout the examination confirm that the L5–S1 segmental level is the site of relative flexibility in the direction of flexion and rotation. The examination should determine all contributing physiologic impairments. What examination findings would you expect in relation to key muscle testing, motor control over intrinsic spine muscles, and muscle flexibility?
2. To develop a program to improve the stability at the site of relative flexibility, each of the correlating impairments must be addressed. The program emphasizes achieving local spinal control over flexion and rotation stresses, improving quality of body movement, and training kinesthetic awareness to control spinal postures and movements in the direction associated with symptoms. Given this case study, develop an exercise program that addresses all relevant impairments. Provide at least one exercise progression or functional transition for each exercise. Be sure to include dosage information.

after the first episode of acute LBP.[113] In a subgroup of patients with structural abnormalities predisposing them to segmental instability, specific stabilization exercises reduced long-term pain and disability levels when compared with general exercise.[247]

Posture and Movement Impairment

Effective education in the area of posture and movement is essential to recover from and prevent recurrence of lumbopelvic syndromes. Education regarding posture and movement should be initiated at the first visit. By the end of the initial examination, the clinician should have identified aggravating postures and movements[248] and instructed the patient in recommendations regarding sitting, standing, and recumbent postures. Basic movement patterns, such as bed mobility (see **Patient-Related Instruction 17-3**), sit to stand, and bending (see **Patient-Related Instruction 17-4**) and lifting maneuvers can be taught to the patient. The specific postures and movement patterns should reflect the patient's impairments, activity limitations, and participation restrictions. For example, a person with a diagnosed HNP at L4 may have different sitting recommendations than a person with spinal stenosis. The former is advised to avoid sustained end-range flexion, while the latter is advised to avoid sustained, end-range extension. The bottom line is that patients need to understand why, not just what to do, to facilitate empowerment and commitment to change.[249,250] They must play an active role in their treatment to obtain optimum benefit.[251–254]

In addition to education regarding posture and movement during ADLs, the clinician must consider specific posture and movement patterns for each prescribed exercise to be most effective. For example, allowing a patient with disk pathology to sit or move in lumbar flexion during a sitting HS stretch not only reduces the

Patient-Related Instruction 17-3

Bed Mobility

To reduce the stress on your low back, your physical therapist may ask you to get out of bed in a specific manner. The following instructions pertain to safe bed mobility.

- Activate your intrinsic spinal muscles and slide one foot at a time up the bed until your knees are flexed and your feet are flat on the bed. Be sure to prevent your back from arching or rotating by using your intrinsic spinal muscles.
- If you are not close to the side of the bed, you must bridge and slide until you are close to the side of the bed. Be sure to keep your intrinsic spinal muscles activated while bridging and sliding.
- Roll your body as one unit until you are lying on your side. Do not lead with your upper body or pelvis because this will result in a rotational stress on your spine that is detrimental to the healing process.
- Gently let your feet slide off the bed while simultaneously pushing yourself into the upright position with your hands.
- *TIP*: Be sure to maintain an intrinsic spinal muscle contraction during all components of this maneuver. You should be able to perform this skill without increase in symptoms. Talk to your physical therapist if you are unable to transfer from back lying to sitting without increased symptoms.

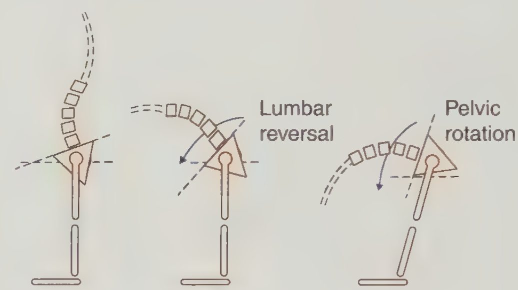
Patient-Related Instruction 17-4

Lumbar-Pelvic Movement

When you bend forward to pick up a light object, such as a shirt or a pencil, you can practice moving with the appropriate relationship between your low back and pelvis. The following are key points to keep in mind while bending forward:

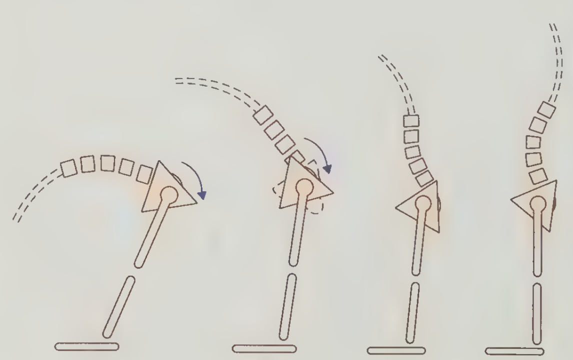
Bending Forward (Figs. A to C)

- Leading with your head, slowly curl your spine as you bend forward.
- Think about relaxing at each vertebral segment.
- Try to keep your knees straight and minimize the backward shift of your hips.
- After you have reached the level of your low back in your forward bend, try to rotate your pelvis.
- Do not flex your low back further after your pelvis has stopped rotating.
- If you need to bend more to reach the desired distance, bend your hips and knees instead of flexing your low back beyond the rotation of your pelvis.
- At the end of the forward bend, relax your low back.



Return from Forward Bend (Figs. D to G)

- Lead with your hips and pelvis by contracting your gluteal muscles.
- Your low back should only extend after your pelvis has achieved its neutral position.
- At the end of the range, you may need to pull in with your abdominal muscles to achieve your neutral pelvic position.



Adapted from Calliet R. Low Back Pain. 3rd Ed. Philadelphia, PA: FA Davis, 1981.

BUILDING BLOCK 17-3

The following are examples of movement patterns used in ADLs that require education and training in proper performance:

1. Simple bed mobility and sit-to-stand transfers
2. Small bends and squatting maneuvers
3. Gait (**Fig. A**) and stair stepping (**Fig. B**)
4. Occupational activities, such as lifting mechanics
5. Recreational activities, such as baseball (**Fig. C**)

Teach a partner safe patterns of movement during bed mobility, sit-to-stand transfers, small knee bends, and squatting maneuvers. Teach a partner how to lift from floor to waist, then from waist to shoulder height. Consider what region of the body you would teach a baseball pitcher to emphasize in movement during a pitch.

A B C

effectiveness of the stretch, but also places additional stress on the disk. The posture of the spine and pelvis throughout the exercise must be emphasized. Attention to posture and movement during *all* exercises prescribed enhances their effectiveness. This requires a high level of supervision by the physical therapist. Research has shown that higher levels of supervision are associated with better outcomes with individuals with CLBP.[255]

The ultimate goal of each individual seeking treatment is to achieve a desired functional outcome. This involves skill in total-body posture and movement patterns that use optimal dynamic stabilization and recruitment strategies. To achieve this, the individual must pay close attention to precision of movement during specific functional exercises (e.g., heel slides to improve bed mobility skills), during BADLs (e.g., squatting maneuvers), and during IADLs (e.g., playing golf). The clinician should instruct the patient in proper stabilization and movement strategies using the foundation of neuromuscular control, muscle performance, mobility, and proprioception that the impairment-based exercises have provided.

Aspects of posture and movement retraining can be incorporated into any stage of rehabilitation. Training begins by breaking complex movements into a number of simple components. For example, an introductory postural strategy may be to teach the individual to sit properly in an ergonomic chair. Later, the patient may be progressed to sitting in a standard chair or on a soft surface such as a gym ball.

The more advanced the movement pattern, the more the task needs to be broken into simplified components to ensure that the proper amount of movement and stabilization occur in the desired segments. After skill is achieved at each simplified component, the components are linked together to form the complete activity sequence. Teaching skill in movement requires high levels of motivation and adherence from the patient and in-depth knowledge of concepts of motor learning and movement analysis by the clinician. Chapter 9 further addresses exercise prescription for the treatment of posture and movement impairments (see **Building Block 17-3**).

Specific exercises may be linked together in a circuit-training format. The circuit may include a variety of manual handling procedures, such as single- and double-handed lifts with a variety of different shapes and weights, pushing and pulling activities, and reaching high and low levels. In addition, almost any piece of equipment, whether designed for a specific exercise, sport, or work activity, can be utilized for movement retraining. Exercises should be adapted to meet the demands of the patient's work and recreation. The clinician must be careful not to progress the patient faster than he or she can learn to control motion with the optimal strategies. Diligence displayed by the patient and clinician is rewarded with fewer setbacks and higher gains in functional return (see **Building Block 17-4** and **Case Study 17-1**).

BUILDING BLOCK 17-4

Develop a sport-specific circuit for a soccer player with LBP. Bias your cues based upon sensitivity toward flexion postures/movements; and then with extension postures/movements.

CASE STUDY 17-1

HISTORY

The patient was a 54-year-old female with a 10+ year history of LBP. The pain had an insidious onset, but has gotten worse in the past year. Pain intensity, using a numeric pain rating scale, is 5/10 on average and 7/10 at worst. Standing, lifting, and walking more than 20 minutes made symptoms worse; sitting and lying with a pillow under the knees alleviates the pain. She estimates her sleep is disrupted about 30% to 40% of the time. Associated symptoms included an intermittent ache along the paraspinal musculature and a throbbing pain radiating into the buttock and posterior thigh. The patient reported having no saddle paresthesia, change in bowel and bladder function, or generalized weakness or incoordination of her lower extremities.

Other medical history included an appendectomy, tonsillectomy, hysterectomy, hypertension, hypercholesterolemia, and depression. Her depressive symptoms were being treated with bupropion hydrochloride. Other current medications included lisinopril and hydrochlorothiazide for hypertension, metoclopramide for gastroesophageal reflux, and lamotrigine for stabilizing mood. The patient's work activities included lifting and carrying boxes of files and sitting at a computer. Her hobbies included gardening. The patient's goals were to garden and perform all work duties with a pain level of 4/10.

EXAMINATION

At intake, the patient's Oswestry Low Back Disability Questionnaire (ODQ) score was 18/50, her Beck Depression Index (BDI) was 8/63, indicating minimal depressive symptoms; and her Fear-Avoidance Belief Questionnaire (FABQ) work subscale score was 38/42, indicating high fear-avoidance behavior concerning work activities. However, her FABQ physical activity subscale score was 10/24, indicating minimal fear-avoidance behavior concerning physical activity outside of work.

Her posture included increased thoracic kyphosis and lumbar lordosis with anterior pelvic tilt and iliac crest asymmetry with right ilium high. During the stance phase of gait, it was observed that her lumbar spine moves excessively into extension and rotation instead of the stance hip moving into extension. Patellar reflexes were 1+ bilaterally, and Achilles reflexes could not be elicited. Dermatomal function was normal, but there was a slight reduction in anterior tibialis force production on the right. Standing lumbar active range of motion revealed non-reversal of lumbar extension, but no pain during flexion. Slight pain was elicited upon return from flexion. Passive range of motion during a right SLR, as measured with bubble inclinometry, was 52 degrees, with reproduction of right gluteal pain, but sensitizing using dorsiflexion was negative. Left SLR was positive at 60 degrees for familiar back pain, and sensitizing with dorsiflexion was also negative. Muscle length testing in the Thomas test position with the knee flexed revealed right hip extension lacking 18 degrees and left hip extension lacking 15 degrees. Manual muscle tests of the hip revealed right gluteus medius muscle strength was 3/5, left 3+/5, and gluteus maximus muscle strength was 3+/5 bilateral. Abdominal performance testing, which was conducted as described by Sahrmann, showed inability to perform level 1 correctly. Palpation assessment of transverse abdominis and LM demonstrated poor activation with verbal cueing. Passive intervertebral testing revealed guarding with posterior/anterior pressure at L4/L5 and a positional fault in extension and rotation.

EVALUATION

Based on the initial examination data, the mediators influencing the patient's chronic LBP were categorized using the WHO-ICF model (see **Case Table 17-1**). It is hypothesized that the listed impairments contribute to the relative flexibility of the lumbar spine in the direction susceptible to motion (DSM) of extension and rotation include poor muscle performance of the intrinsic spinal muscles combined with short hip flexors.

INTERVENTION

The patient was educated on her physical therapist's diagnosis, prognosis, and plan of care. She was seen for 10 visits over 12 weeks. Patient education, specific exercise for associated impairments, and graded exercise were used to address her avoidance of physical activity, especially at work. Specifically, she was educated during the initial visit that pain did not signal harm, but that by moving with improved patterns of movement and using improved posture habits, it would be possible for her to perform more work-related duties and leisure activities with less pain. It was explained, however, that she needed to maintain a consistent activity pace, and to stay as active as tolerable. This was reinforced during discussions in subsequent visits.

Two examples of exercises to address specific impairments in motor control and muscle performance are listed below.

Self-Management 17-1 demonstrates an exercise progression targeting the impairments in the intrinsic spinal muscles simultaneous with lengthening the hip flexors. While the intrinsic spinal muscles contract in the short range, the hip flexor muscles elongate. If the patient allows the hip flexors to pull the pelvis and spine out of alignment, the exercise becomes detrimental to altering the site of relative flexibility. The patient can be taught to control the specific spine stabilization strategy with targeted muscle activation patterns.

In conjunction with this exercise, the patient can work on the same relationship in other positions, such as prone (see Self-Management 17-5). The lumbopelvic region is stabilized through appropriate intrinsic spinal muscle recruitment, and the knee is flexed to the point of mild tension and before the loss of lumbopelvic stabilization. Emphasis is placed on relaxation of the rectus femoris and TFL simultaneously with stabilization of the spine against the extension force imposed by the short hip flexors. Eventually, the patient can progress to the closed chain and the walk stance progression (see Self-Management 19-2) with emphasis on controlling lumbopelvic position in relation to the extending hip. These active movements prepare the patient for the ultimate goal of stabilizing the lumbar spine during standing tasks and during the stance phase of gait. The therapist will most likely need to guide the patient in the proper stabilizing strategies during gait.

CASE STUDY 17-1 (continued)

OUTCOME

At 12 weeks, the patient reported that she was able to bend and carry charts at work for a full day without increased pain. She regularly sat and stood at work for 30 minutes without pain. Her worst pain was reported as 3/10. Her ODQ score was 6/50. Hip flexion combined with knee flexion in the Thomas test position was 6 degrees on the left and 10 degrees on the right. Abdominal strength was graded as level 2 and she could demonstrate activation control over transverse abdominis and LM at L4 and L5 levels. The patient cancelled a follow-up appointment at 14 weeks and subsequently was contacted by telephone. Final questionnaires revealed an ODQ score of 2/50, a BDI of 4/63, an FABQ work subscale score of 0/42, and an FABQ physical activity subscale score of 0/24. Pain intensity, as measured with a numeric pain rating scale, was 2/10 at worst. The patient stated that she was "much improved."

CASE TABLE 17-1 The World Health Organization's International Classification of Functioning, Disability and Health (WHO-ICF) Model Applied to the Evaluation of Patient with CLBP

	BODY STRUCTURES AND FUNCTIONS	ACTIVITIES	PARTICIPATION
Patient's perspective	Pain in back and back of thigh	Standing	Unable to garden
		Lifting	Decreased work tolerance
		Walking 20 min	Interrupted sleep
Physical therapist's perspective	Reduced muscle power functions (b730)	Lifting and carrying objects (d430)	Remunerative employment (d850)
	Reduced mobility of joint functions (b710)	Maintaining body positions (d410)	Recreation and leisure (d920)
	Gait pattern functions (b770)		
	Neuromusculoskeletal and movement-related functions, other specified (b798)		

CONTEXTUAL FACTORS

Personal

Temperament and personality functions: fear-avoidance behavior for physical activities and perceived ability to function in work activities and leisure activities.

Environmental

- Products and technology for employment (e135)
- Labor and employment, systems, and policies (e590)

THERAPEUTIC EXERCISE INTERVENTION FOR COMMON DIAGNOSES

The following section discusses three of the most common diagnoses of the lumbopelvic region. Although SIJ syndrome is not discussed, it should be evaluated and treated combining concepts related to both the lumbopelvic region and hip joint (see Chapter 19). The reader is challenged to develop a comprehensive lumbo-pelvic-hip therapeutic exercise prescription for each individual SIJ syndrome patient encountered.

Lumbar Disk Herniation

Disk degeneration involves structural disruption and cell-mediated changes in composition. Traditionally, disk degeneration has been linked to mechanical loading. The importance of mechanical factors has been emphasized by experiments on cadaver spines with both a severe single event as well as relentless loading.[256–260] Failure of the disk is more common in the areas with the heaviest mechanical stresses, such as the lower lumbar region. It has been suggested that mechanical factors produce endplate damage, the antecedent to disk degeneration[261] (**Evidence and Research 17-6**).

EVIDENCE and RESEARCH 17-6

Degeneration Versus Aging Changes to the Spine

Conventional theory would imply that degeneration and aging are very similar processes, albeit occurring at different rates. Resnick and Niwayama[262] emphasized the differentiating features of two degenerative processes involving the intervertebral disk.[263] These include *spondylosis deformans*, which affects essentially the annulus fibrosus and adjacent apophyses, and *intervertebral osteochondrosis*, which affects mainly the nucleus pulposus and the vertebral body endplates. Studies suggest that spondylosis deformans is the consequence of normal aging, whereas intervertebral osteochondrosis results from a clearly pathologic, though not necessarily symptomatic, process.[260–268] Anterior and lateral marginal vertebral body osteophytes have been found in 100% of skeletons of individuals over 40 years of age, and therefore are consequences of normal aging, whereas posterior osteophytes have been found in only a minority of skeletons of individuals over 80 years, and therefore are not inevitable consequences of aging.[264] Endplate erosions with osteosclerosis and chronic reactive bone marrow changes also appear to be pathologic.

Nutritional[269,270] and genetic[271,272] factors may also play a role in the cascade of disk degeneration, albeit to variable degrees in different individuals. The presence of degenerative change is by no means an indicator of symptoms, and there is a very high prevalence in asymptomatic individuals.[273] The etiology of pain as the symptom of degenerative disease is complex and appears to be a combination of mechanical deformation and the presence of inflammatory mediators. Regardless of the etiology of disk degeneration, by the age of 50 years, 85% to 95% of adults show evidence of degenerative disk disease at autopsy[274] with the peak incidence of herniated lumbar disks in adults between the ages of 30 and 55 years.[275]

The underlying mechanism of internal disk disruption is theorized as follows[261]: The damaged endplate deforms more when under load,[276] allowing more space for the hydrated nucleus pulposus, or allowing some nucleus tissue to pass through it. The nucleus therefore experiences a reduction in pressure,[277] which is similar in amount to the reduction seen in degenerated disks.[278,279] The decompressed disk bulges more and loses height.[280] This process is intensified by water loss after sustained loading.[281] Less of the applied compressive force is resisted by the decompressed nucleus, so more must be resisted by the surrounding annulus (and apophyseal joints). High stress gradients in the annulus then force the inner lamellae inward toward the decompressed nucleus[282] and the outer lamellae outward. The buckling of the lamellae is encouraged by the accompanying loss in disk height. The effects are greater in older disks because their tissues are less hydrated, and therefore less able to deform sufficiently to reduce steep stress gradients. Nucleus pulposus material can move into the disrupted annulus during repetitive loading, but bulk extrusion of nucleus pulposus from the disk can be achieved (in vitro) only if the motion segment is heavily loaded in flexion or hyperflexion.[257,259,283] With a disk protrusion, the NP does not herniate from the disk; it is confined by the annular fibers. This may be the typical "back sprain" that results from bending, lifting, and frequent twisting. It often gives a person LBP with little or no pain radiation into the legs. The pain is usually relieved quite rapidly with rest or curtailment of most bending or lifting activities for several days. Patients are usually fairly comfortable when on their feet, but when they change from a lying to a sitting position or from sitting to standing, the pain can be acute and disable them from fully standing. The probable cause of the pain is the flexion or torsion forces imposed on the disk during these movements. These episodes, if not treated appropriately, can recur and become more frequent as time progresses. Eventually, they can lead to the more disabling disk herniation.

If the annular tear progresses to full annular disruption, a HNP results. Penetration of the nuclear material into peripheral areas that are highly sensitive to mechanical and chemical stimulation may be the source of the disabling pain felt in disk herniation. Clinically, disk herniation can be divided into the following subsets:

- HNP without neurologic deficit
- HNP with nerve root irritation
- HNP with nerve root compression

HNP without neurologic deficit has signs and symptoms similar to those of an annular tear but is slower to recover and imparts slightly more disability. No encroachment on the nerve root has occurred with this condition. HNP with nerve root irritation has signs and symptoms, including sciatica, paresthesias, and positive SLR, but no neurologic deficit is diagnosed. HNP with nerve root compression has signs of nerve root irritation plus neuroconductivity changes. A massive midline disk herniation may cause spinal cord or cauda equina compression, requiring immediate surgical referral. Fortunately, the cauda equina syndrome occurs in only 1% to 2% of all LDHs that result in surgery.[284]

Regular physical activity appears to reduce or increase the risks of disk degeneration, depending on how severe the degenerative changes are.[261] This complication probably is caused by the ability of skeletal tissues to strengthen with regular moderate exercise[285] but to experience (fatigue) failure if the loading is too severe[286] (**Evidence and Research 17-7**).

EVIDENCE and RESEARCH 17-7

Physical Stress Theory and Disk Degeneration

"Adaptive remodeling" in response to controlled exercise explains why professional tennis players have 30% more bone in their racquet arm,[287] and why physically active individuals have extremely strong vertebrae[288,289] and disks.[290] Conversely, a lack of exercise leads to tissue weakening, and this may explain why some sedentary occupations increase the risk of disk prolapse.[291] The weakened spinal tissues would be vulnerable to accidental injury during slips and falls. Physical stress theory proposed by Mueller[292] summarizes the importance of optimal stress to tissues to sustain health (see **Fig. 17-17**).

Examination and Evaluation Findings

Sciatica is a symptom of nerve root irritation and is a form of neuropathic pain (NeP). Sciatica is defined as a sharp or burning pain radiating down the posterior or lateral aspect of the leg, usually to the foot or ankle, often associated with numbness or paresthesia. Coughing, sneezing, or the Valsalva maneuver often aggravates the pain. Sciatica caused by disk herniation is worsened by prolonged sitting and improved by walking, lying supine, lying prone, or sitting in a reclined position.[293] The absence of sciatica makes a clinically important LDH unlikely.[90,91,275,293,294] The estimated incidence of disk herniation in a patient without sciatica is 1 in 1,000.[11]

The International Association for the Study of Pain has defined NeP as "pain caused by a lesion or disease of the somatosensory system."[295–298] It has been estimated that 2% to 4% of the general population have some form of NeP with substantially higher rates in those with CLBP.[299–303] Importantly, the presence of NeP has been linked with poor recovery along with higher health care costs and lower quality of life.[297,298,304,305]

Neurodynamic tests are a series of multijoint movements of the limbs and/or trunk that produce mechanical and physiologic events in the nervous system and can detect NeP.[122,306,307] One of these mechanical events is an increase in tension in the nerve being tested.[308–312] The SLR test is the most commonly used neurodynamic test for the lower extremity. In the supine SLR test, tension is transmitted to the nerve roots after the leg is raised beyond 30 degrees, but after 70 degrees, further movement of the nerve is negligible.[312] A typical SLR sign is one that reproduces the patient's sciatica between 30 and 60 degrees of elevation.[275,313] The lower the angle producing a positive result, the more specific the test becomes, and the larger is the disk protrusion found at surgery.[314,315] The SLR test demonstrated 100% specificity in patients clinically diagnosed with NeP.[316] In addition, the rate of NeP was more than 14-fold higher in

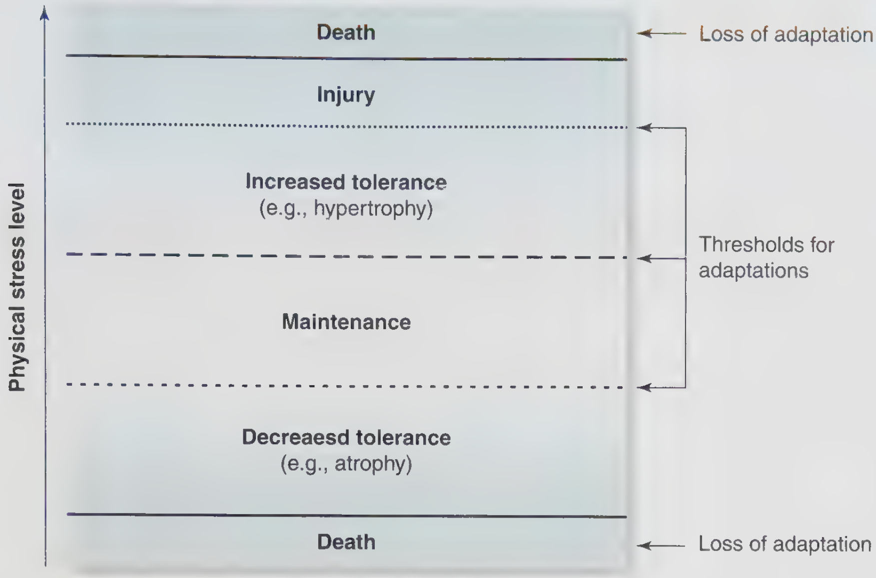


FIGURE 17-17 Effect of physical stress on tissue adaptation. Biological tissues exhibit five adaptive responses to physical stress. Each response is predicted to occur within a defined range along a continuum of stress levels. Specific thresholds define the upper and lower stress levels for each characteristic tissue response. The relative relationship between these thresholds is fairly consistent between people, whereas the absolute values for thresholds vary greatly.

those with a positive SLR test.[317,318] Care must be taken to differentiate HS tension from sciatica. Sensitizing techniques (e.g., neck flexion, ankle dorsiflexion) can be used to determine whether the pain experienced is originating from HS tension or nerve irritation. Straight-leg raising is most appropriate for testing the lower lumbar nerve roots (L5 and S1), where most disk herniations occur.[275] Irritation of higher lumbar roots is tested with femoral nerve stretch. The femoral nerve stretch, which is passive knee flexion, can be performed in prone with the spine in a neutral position. Alternately, the spine can be biased into flexion with the test performed in sidelying.

The slump test is another neurodynamic test which differs from the SLR test in that it incorporates spinal flexion and can therefore potentially generate greater overall neural tension and detect NeP in patients with more mild symptoms. The slump test also incorporates knee extension as a sensitizing maneuver which can be used to modulate the mechanical strain on the nervous system,[122] thereby confirming nervous tissue as the source of symptoms during the test. Accepting that neurodynamic tests increase tension in nerves and that NeP is associated with lowered mechanical thresholds, it would be expected that a positive outcome on a neurodynamic test would be highly associated with NeP. A variation of the slump test accurately identified patients with upper/mid lumbar nerve root compression[328] (**Evidence and Research 17-8**).

About 98% of clinically important LDHs occur at the L4–L5 or L5–S1 intervertebral level,[314,315,320] causing neurologic impairments in the motor and sensory regions of the L5 and S1 nerve roots. The most common neurologic impairments are weakness of the ankle and great toe dorsiflexors (L5) or ankle and foot plantar flexors (S1), diminished ankle reflexes (S1), and sensory loss in the feet (L5 and S1).[314,315,320] In a patient with sciatica and suspected disk herniation, the neurologic examination can be concentrated on these functions. Among patients with LBP alone (no sciatica or neurologic symptoms), the prevalence of neurologic impairments is so low that extensive neurologic evaluation is usually unnecessary.[121]

EVIDENCE and RESEARCH 17-8

Sensitivity and Specificity of the Slump Test

A 2015 study investigated the ability of a neurodynamic test to independently detect NeP in individuals with low to moderate levels of CLBP.[319] The neurosensory examination designated 11 of the 21 participants with LBP/sciatica as having NeP. The slump test displayed high sensitivity (0.91), moderate specificity (0.70), a positive likelihood ratio of 3.03, and a negative likelihood ratio of 0.13. Adding the criterion of pain below the knee significantly increased specificity to 1.00 (positive likelihood ratio = 11.9). Pain quality descriptors did not improve diagnostic accuracy. The authors concluded that the slump test was highly sensitive in identifying NeP within the study sample. Adding a pain location criterion improved specificity. Combining the diagnostic outcomes was very effective in identifying all those without NeP and half of those with NeP. Limitations arising from the small and narrow spectrum of participants with LBP/sciatica sampled within the study prevent application of the findings to a wider population.

Higher lumbar nerve roots account for only about 2% of LDHs.[314,315,320] They are suspected when numbness or pain involves the anterior thigh more prominently than the calf. Testing includes patellar tendon reflexes, femoral nerve neurodynamic testing, and assessment of quadriceps strength, and psoas strength.[275,315,320] Quadriceps weakness is virtually always associated with impairment in the patellar tendon reflex.[321]

The most consistent finding with a low lumbar midline disk herniation, called *cauda equina syndrome*, is urinary retention.[11,96,321–324] Unilateral or bilateral sciatica, sensory and motor deficits, sexual dysfunction (i.e., decreased sensation during intercourse, decreased penile sensation, and erectile dysfunction), and abnormal SLR also are common examination findings.[96,323,324] The most common sensory deficit (i.e., hyperesthesia or anesthesia) occurs over the buttocks, posterosuperior thighs, and perineal regions.[96,322,324] Finally, decreased anal sphincter tone can be a neurologic sequelae of cauda equina syndrome.[96] Kostuik et al.[96] warn that a central disk lesion, especially at the L5–S1 disk, can pose a diagnostic challenge because it affects only the lower sacral roots and causes no motor or reflex changes in the legs.

As has already been presented, radiological imaging for LBP, in the absence of red flags, progressive neurologic deficits or traumatic injury, is not warranted and may in fact be detrimental. The Quebec Task Force on Spinal Disorders suggests that early roentgenography is necessary only under the following conditions:

- Neurologic deficits
- Patient older than 50 or younger than 20 years of age
- Fever
- Trauma
- Signs of neoplasm[325]

Magnetic resonance imaging and CT can be used even more selectively, usually for surgical planning.[11] The finding of herniated disks and spinal stenosis in many asymptomatic individuals[326,327] indicates that imaging results alone can be misleading. There is strong evidence that unwarranted imaging makes patients worse; MRI scans for nontraumatic LBP lead to poorer health outcomes, greater disability and work absenteeism due to the pathologizing of the problem.[328]

Treatment

For the small group of patients (5%) who present with LBP due to disk herniation and associated radicular pain with or without neurologic deficit, the natural history is very good. Prospective studies demonstrate high recovery rates (over 80%) and reduction of the herniation in most of these patients at 12 months of follow-up when managed conservatively. Only in people with progressive neurologic changes and cauda equina symptoms is a surgical opinion immediately warranted. There is no "cookbook" approach toward the exercise management of LBP, even if a specific structural diagnosis, such as HNP with nerve root irritation, is offered. Determining which interventions to use depends on the pathoanatomic process, the identified impairments, and the patient disability profile, including the desired "return to" activities and participations. The following concepts of care for specific stages of disk herniation can guide patient management.

Acute Stage In the acute stages of any injury, the immediate goals are often to relieve pain and to reduce or halt the inflammatory process so that the healing process can occur unimpeded. Investigations into the biochemistry of disk degeneration and herniation indicate that intraspinal inflammation is a major cause of radicular pain.[329] A neurotoxic, inflammatory mediator phospholipase is contained within the disk nucleus and is released after annular injury. Early intervention and patient adherence to the recommendations addressing pain and inflammation in the case of HNP are essential for achieving a rapid recovery and for preventing chronic pain and disability.

Along with physical therapy intervention, the patient's physician usually prescribes steroidal or nonsteroidal anti-inflammatory medications and may suggest epidural steroid injection. Corticosteroids have powerful anti-inflammatory effects. The use of epidural steroid injection, performed by experienced physicians who have shown competence in the technical aspects of this procedure, has produced favorable outcomes, particularly if used in conjunction with physical therapy[330] (**Evidence and Research 17-9**).

EVIDENCE and RESEARCH 17-9

Evidence for Use of Epidural Steroid Injections in Conjunction with Physical Therapy

Intervertebral disk herniation, spinal stenosis, intervertebral disk degeneration without disk herniation, and post lumbar surgery syndrome are the most common diagnoses of chronic persistent low back and lower extremity symptoms, resulting in significant economic, societal, and health care impact. Epidural injections are one of the most commonly performed interventions in the United States in managing CLBP. However, the evidence is highly variable among different techniques utilized as well as for the conditions treated.

The available literature on epidural injections with or without steroids in managing various types of CLBP with or without lower extremity pain was reviewed and methodically analyzed.[331] The primary outcome measure was pain relief (short-term relief = up to 6 months and long-term >6 months). Secondary outcome measures of improvement in functional status, psychologic status, return to work, and reduction in opioid intake were utilized. There was good evidence for short- and long-term relief of chronic pain secondary to disk herniation or radiculitis with local anesthetic and steroids and fair relief with local anesthetic only. Further, this systematic review also provided indicated evidence of fair for caudal epidural injections in managing chronic axial or diskogenic pain, spinal stenosis, and post surgery syndrome.

While attempting to halt the inflammatory process, the primary role of the physical therapist may be to promote the concept of "controlled rest." This intervention may take the form of posture and activity modification (i.e., avoidance of flexed postures, sitting, and bending or lifting activities), pacing activity and rest, positions for pain relief, and most importantly, guiding the patient through this phase to avoid developing fear-avoidance behaviors. It is important to teach the patient to temporarily avoid flexed and asymmetric postures, flexion and rotation movements (especially under load), and sitting (which elevates disk pressures) to enhance healing and prevent reinjury. The clinician also can teach the patient how to use cryotherapy at home to control inflammation and reduce pain levels. Traction can be a useful adjunctive modality in the acute phase. Similar to the recommendations of Delitto et al.,[238] the most common examination criterion cited by clinicians as an indication for traction is the presence of signs of nerve root compression[332] (see the "Adjunctive Interventions" section).

Exercise can play a vital role in the treatment of pain and inflammation. For example, careful prescription of exercises based on the McKenzie diagnostic classification system may be useful in the early treatment of disk-related signs and symptoms (see Examination and Evaluation: Range of Motion, Muscle Length, and Joint Mobility and Therapeutic Exercise Intervention for Common Physiologic Impairments: Pain and Self-Management 17-7).[133,236,333]

As with any mechanically induced injury, the underlying causes of muscle or soft-tissue injury must be avoided. In the acute phase of disk herniation, due to altered movement patterns from the pain, it is often difficult to determine the postures and movements associated with the development of segmental dysfunction (see **Building Block 17-5**).

BUILDING BLOCK 17-5

In the acute phase of managing a herniated disk, it is useful to teach the patient basic bed mobility movements. Name two exercises you have learned in this chapter that would help a patient move in bed with less pain.

In the acute phase of disk herniation, the patient is often susceptible to the effects of immobilization as a result of the protective nature of this phase of care. Treatment to maintain or improve mobility of adjacent segments within the lumbar spine and thoracic spine and the extensibility of lower extremity muscles is vital for reducing stress on the injured segment and reducing the negative effects of immobilization that may play a role in recurrence of the condition. For example, joint mobilization of the thoracic spine and segments above and below the affected segmental level, along with soft-tissue mobilization of the erector spinae group, can maintain joint mobility during the acute phase. Piriformis spasm is a common secondary effect of lower LDH. Soft-tissue mobilization and passive stretching to this muscle can decrease pain associated with the spasm (see **Building Block 17-6**).

BUILDING BLOCK 17-6

Devise a safe stretch to the piriformis that will not place torsional stress on the sacrum or lumbar spine.

Treatment to maintain or improve mobility in the neural tissues also is critical in the acute stages. Decreased neuromeningeal mobility is a common sequel of HNP and can affect muscle performance and lumbopelvic mobility. Neuromeningeal mobility should be assessed and, if indicated, specific exercises to improve mobility of the neural system may be prescribed (see Self-Management 17-6). Initially, tolerance is usually very low, and neuromeningeal mobility exercises must be performed with caution, usually in recumbent positions to prevent exacerbating symptoms. Neuromeningeal mobility exercises performed during the acute stage may prevent chronic complications from increased neural tension. The related anatomy, physiology, and application principles must be well understood for the effective and safe use of this type of treatment. This topic is worthy of more extensive coverage; further guidance in prescribing these exercises has been provided by Butler.[122]

The clinician should encourage the patient to maintain some activity level, such as swimming or walking, during the acute stage. Swimming can be employed with the use of a kick board to minimize unwanted spinal motion while promoting aerobic fitness and lower extremity motion. Walking with a corset, wearing good shock-absorbing shoes, and walking on a soft surface (e.g., gravel) may reduce disk pressure enough to tolerate the stress of walking. In addition to the benefits of movement, the benefits of low-level aerobic exercise are gained.

Subacute and Chronic Stages After the acute pain has subsided and the patient has more freedom of movement, the treatment should focus on altering postures and movements and the associated impairments that produce symptoms. The ultimate goal is the return to the highest possible level of function with the safest and most desirable postures and movement patterns possible.

Review the sections on treatment of impairments to understand the concept of exercise intervention for mobility, muscle performance, balance, coordination, posture, and movement impairments and the progression through traditional stages of motor control. This information provides the basis for developing a progressive program of intervention for a patient with disk pathology beyond the acute stages of care.

Patient education is the most important intervention to protect against developing chronic disability. The patient must be taught self-management techniques to gain control over the pathology and remain less reliant on the health care system for ongoing treatment. The clinician must teach the patient to temporarily manage acute exacerbations with cryotherapy, positional techniques, or repeated shift correction and extension movements.[133] Instruction in body mechanics, ergonomics, and ongoing fitness activities is equally important in preventing recurrence. Evaluation of the home and work environment, work-station ergonomics, and the development of fitness programs are preventive strategies the clinician should implement. Perhaps the most important outcome of patient education is the sense of confidence gained by the realization that back problems can be managed while the patient continues to function and lead a productive life.

Spinal Stenosis

Spinal stenosis is defined as an abnormal narrowing of the spinal canal (central) or the intervertebral foramen (lateral or foraminal).[334] Central stenosis can result from osteophyte enlargement of the inferior articular process or vertebral bodies, congenitally decreased anteroposterior or mediolateral diameters of the spinal canal, hypertrophy of the ligamentum flavum, spondylolisthesis, or neoplasm that impinges on the cauda equina. Lateral or foraminal stenosis is typically caused by subluxation of the facets as a result of disk narrowing. Extension and rotation positional faults of the segment produce further narrowing. Symptoms are usually segmental because of entrapment of the nerve root.

Examination and Evaluation Findings

The characteristic history of persons with spinal stenosis is that of neurogenic claudication (i.e., pain in the legs) and, occasionally, neurologic deficits that occur after walking. In contrast to arterial ischemic claudication, neurogenic claudication can occur on standing (without ambulation), may increase with cough or sneeze, is associated with normal arterial pulses,[335] and is relieved by flexion of the lumbar spine. One often-used test to discriminate between ischemic and neurogenic claudication is stationary biking.[336] The patient is positioned in lumbar flexion and asked to pedal. This test will likely reproduce symptoms if the source is ischemic claudication, whereas with the spine positioned in flexion, neurogenic claudication is less likely.

Increased pain on spine extension is typical of stenosis. Although flexion is usually painful with herniated disks, it can be a position of relief for patients with spinal stenosis. Patients feel more comfortable walking in a stooped position, cycling, walking behind a shopping cart or lawn mower, or walking up an incline or stairs, rather than walking on a flat surface, down an incline, or downstairs.[337,338]

Treatment

Recently, the published surgical literature is sending a message to look for new strategies in the field of rehabilitation and conservative treatments before considering decompressive, instrumented surgery, or minimally invasive techniques that are presently offered.[339] This is great news for physical therapists who can provide much insight and rehabilitative skill into conservative treatment of spinal stenosis. Treatment of spinal stenosis is based on symptoms related to postures and movements. If the patient has mild symptoms that fluctuate with mechanical, postural, and movement changes, he or she can be accommodated with appropriate patient-related education, exercise, external lumbar support, (i.e., corset), and nonsteroidal anti-inflammatory medication. Although nonoperative measures cannot reverse a true anatomic impairment, they can accommodate it by increasing the foraminal or spinal canal diameter.

Exercise should focus on physiologic impairments that may contribute to foraminal or spinal canal narrowing:

- Poor muscle performance from the intrinsic spinal muscles (TrA, LM, diaphragm, and pelvic floor) resulting in insufficient support to the lumbar spine
- Short hip flexors, hypertrophied erector spinae, and long EO contributing to anterior pelvic tilt and lumbar lordosis
- Thoracic kyphosis with overstretched and weak thoracic erector spinae accompanying lumbar lordosis
- Asymmetry of pelvic girdle and lower extremity muscle length and strength resulting in lumbar scoliosis and lateral foraminal narrowing

Canal or foraminal narrowing is typically associated with spine extension, combined extension and rotation, or anterior translation. Postures associated with relative extension (i.e., kyphosis and lordosis), combined extension and rotation (i.e., kyphosis and lordosis and functional/structural limb length discrepancy), or anterior translation (i.e., swayback) should be avoided, and the patient should be instructed in postural correction to remedy these postural habits.

The clinician should teach the patient to avoid movement patterns that require repeated extension, rotation, or shearing and to develop control over these forces when unavoidable (see **Building Block 17-7**).

BUILDING BLOCK 17-7

Name at least three ADLs that require movement into extension that you will examine and retrain if faulty or too provocative for your patient's current status.

Limited ambulation is a frequent functional limitation among patients with spinal stenosis. Harness-supported treadmill ambulation or use of a walker, crutches, or a cane for patients with leg pain brought on by walking can be used as a progressive return to walking without symptoms. The amount of unloaded force can be progressed until unloading force is no longer required to relieve pain during ambulation.[340]

Patients should be instructed in recreational activities that do not produce symptoms. Exercise biased toward flexion should be encouraged, such as walking on a treadmill with a slight incline, cycling, or walking while pushing a stroller. Exercise biased toward extension should be discouraged, such as walking on a flat surface, walking downhill, or swimming.

Spondylolysis and Spondylolisthesis

Spondylolysis, a bilateral defect in the pars interarticularis, occurs in 58% of adults.[341] Approximately 50% of those never progress to any degree of spondylolisthesis, a condition of forward subluxation of the body of one vertebrae on the vertebrae below it.[341] Spondylolisthesis is not limited to any specific segment of the spine, but is most often seen at L4/L5 or L5/S1.[342] Defects or impairment of any of the supporting structures can lead to subluxation of the superior segment on the inferior segment. Spondylolisthesis has been classified[343] by cause into five types:

1. Type I, isthmic: A defect in the pars interarticularis may be caused by a fracture or by an elongation of the pars without separation.
2. Type II, congenital: The posterior elements are anatomically inadequate because of developmental deficiency. This occurs rarely.
3. Type III, degenerative: The facets or the supporting ligaments undergo degenerative changes, allowing listhesis. There is no pars defect, and the condition worsens with age.
4. Type IV, elongated pedicle: The length of the neural arch elongates to allow listhesis. This is essentially an isthmic type. Traction forces are apparently contributory.
5. Type V, destructive disease: Metastatic disease, tuberculosis, or other bone disease may change the structure of the supporting tissues. This is rare.

Examination and Evaluation Findings

The patient may complain of backache, gluteal pain, lower limb pain or paresthesias, hyperesthesia, muscle weakness, intermittent claudication, or bladder and rectal disturbances. The physical examination may reveal that symptoms worsen on return from forward bending that is accompanied by lumbar extension. If the patient is cued to lead with the gluteal musculature and recruit the intrinsic spinal muscles, symptoms are reduced. The clinical diagnosis is suspected if this finding is accompanied by inspection and palpation of the spine in which a depression at the listhesis level is noticed. Percussion over the segment may elicit pain. Radiologic confirmation can be made by an oblique view of the lumbosacral region. A roentgenogram can diagnose spondylolysis or spondylolisthesis and the degree of subluxation, which can be graded.

Treatment

In general, treatment of spondylolysis or spondylolisthesis is nonsurgical.[344] Surgical treatment of this condition varies depending on patient age, degree of slip, presence of neurologic findings, and degree of deformity. Pediatric and adolescent patients with a low-grade slip that is asymptomatic only need observation. Nonsurgical treatment includes bracing, exercise, and nonsteroidal anti-inflammatory medications. In children and adolescents, immobilization in a thoracolumbosacral brace, activity modification, and exercise expedite healing of the defect.[343,345] It may be advisable to avoid contact sports and sports that require lumbar hyperextension, such as gymnastics, in patients with a Grade II slip (**Evidence and Research 17-10**).

EVIDENCE and RESEARCH 17-10

Surgical Versus Conservative Management of High-Grade Slips in Spondylolisthesis

Symptomatic high-grade isthmic spondylolisthesis in children and adolescents has an unfavorable natural history with high risk of progression and low likelihood of symptomatic relief. Conservative treatment is generally not recommended in symptomatic patients who constitute the majority of patients with high-grade slips in this age group[346-347] Pizzutillo et al.[346] found that only 1 of 11 symptomatic patients treated conservatively had significant pain relief at long-term follow-up. Asymptomatic patients can be treated with observation, and if symptoms do develop, surgery is considered. Some authors[348] have recommended surgical treatment for these patients regardless of symptoms because of the high risk of progression.[347] However, Harris and Weinstein[349] reported that 10 out of their 11 patients with high-grade slips who were treated nonoperatively remained active and required only minor modifications in activity. At a mean of 18-year follow-up, only one patient had significant symptoms, and all patients led an active life. Five patients had one or more neurologic findings, but none were incontinent. Adults with high-grade slips have often reached a stable position and typically do not experience progression. Autofusion or ankylosis of the slipped level can occur. Some of these patients are asymptomatic or minimally symptomatic and can be successfully treated with physical therapy and selective nerve root injections if radicular symptoms are present. If conservative treatment fails, surgery is recommended in adult patients with high-grade slips with back pain and/or radicular symptoms.[349]

Exercise, posture and movement retraining, and activity modification are the cornerstones of the rehabilitation program. As for the patient with spinal stenosis, lumbar extension and shearing forces should be avoided. Exercises focused on resolving the impairments associated with extension or shearing forces should be prescribed, and strong emphasis should be placed on intrinsic spinal muscle control and strengthening, and posture and movement retraining. **Figure 17-18** is a good position to activate the intrinsic spinal muscles without the anterior force from the hip flexors (Self-Management 17-1). Self-Management 17-2 provides examples of initial exercises to stimulate the stability necessary for recovery from

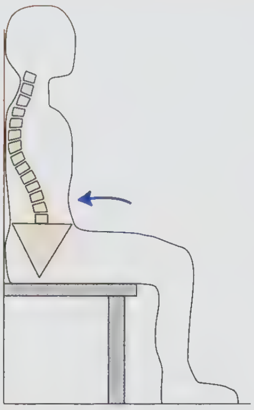


FIGURE 17-18 Sitting posterior pelvic tilt. This activity can be used by individuals with lordosis, anterior pelvic tilt, weak and overstretched abdominal muscles (particularly external oblique [EO] and transversus abdominis [TrA]), and short hip flexors. The supine intrinsic spinal muscle progression is often contraindicated for this type of patient due to the anterior translation force exerted by the iliopsoas and anterior pelvic tilt force exerted by the TFL and rectus femoris. The patient sits with her back against a wall and is instructed to pull the umbilicus toward the spine to reduce the lordosis. Sitting takes the stretch off the hip flexors, and the pelvis should be able to move posteriorly with greater ease than in standing with the hip flexors on relative stretch. Use of a gluteal contraction over an abdominal contraction is discouraged. This exercise can be progressed to standing in slight hip and knee flexion (to release tension on the hip flexors) and then to standing upright once the abdominal muscles are strong enough and the hip flexor muscles are of sufficient length to attain a neutral pelvic position. The advantage of this exercise is that it can be performed frequently throughout the day.

spondylolisthesis. If a brace is used in conjunction with physical therapy, the physical therapist should communicate with the physician regarding the prescribed immobilization period and weaning program. Most often, the patient can continue to participate in certain sports during the immobilization period and is encouraged to do so. However, contact or collision sports should be avoided. In addition, activity modifications may be warranted. For example, volleyball requires a great deal of extension movements and shearing forces when hitting. An athlete may avoid hitting during practice and focus more so on serving and defense. If movement patterns cannot be modified enough to reduce symptoms during these activities, the patient may need to be counseled to seek another form of recreation or athletic endeavor.

KEY POINTS

- A thorough understanding of the anatomy and biomechanics of the lumbopelvic region is prerequisite to appropriate therapeutic exercise prescription for this region.
- Exercise must be based on a thoughtful and systematic examination process identifying the physiologic and psychologic impairments most closely related to the individual's activity limitations and participation restrictions.
- Therapeutic exercise intervention for common physiologic impairments must be coordinated to address associated

impairments and prioritized to address those most closely related to activity limitations and participation restrictions.

- Exercise management of common pathoanatomic diagnoses must not follow a "cookbook" approach, but rather be highly prescriptive and relate to the patient's unique impairments, activity limitations, and participation restrictions.

CRITICAL THINKING QUESTIONS

1. Prioritize postures from the most to the least stressful on the lumbar spine.
2. Describe the principles for the use of optimal body mechanics during lifting.
3. Describe the biomechanical differences between the bent-knee and straight-leg sit-up. What would be the best abdominal exercise for an individual with a HNP? Spinal stenosis or spondylolisthesis? How would you modify the sit-up for a person with a kyphosis/lordosis posture type?
4. How can exercise impact chemical sources of nociception?
5. What postures place the EO in a lengthened position, making it susceptible to strain resulting from overstretch?
6. Given the following activities: flexion phase of forward bending, sidelying hip abduction, and seated rotation. Describe the optimal site and direction of relative flexibility during these movements. (Hint: during the return from forward bending, the optimal site of *relative* flexibility is the hip in the direction of extension versus the lumbar spine in the direction of extension.)
7. What is the conceptual basis for treatment of a relative flexibility or stiffness problem?
8. Define the anatomic injury that occurs with disk prolapse and the three subsets of disk herniation.
9. Define the three clinical categories of signs and symptoms associated with HNP.
10. Define the broad category of spinal stenosis and the two types of stenosis.
11. Discuss the difference between spondylolysis and spondylolisthesis.
12. What spine position and movement should a person with stenosis avoid? Same question with respect to spondylolisthesis?
13. What intrinsic muscle group would you target in a patient with stenosis or spondylolisthesis? (Hint: you want to avoid forces that produce extension or anterior translation on the lumbar spine.)
14. Discuss the musculature involved in force closure of the SIJ.
15. Refer to Case Study No. 5 in Unit 7.
    a. Based on her history and physical examination findings, what is the likely medical diagnosis for this patient?
    b. What are the faulty posture and movement patterns associated with the onset of her symptoms?
    c. What are the correlating physiologic impairments? List them under the headings used in this chapter (e.g., mobility, muscle performance).
    d. Develop an exercise program addressing all pertinent impairments related to her activity limitations and participation restrictions.
    e. Be sure to include patient-related instruction tips.

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CHAPTER

18 The Pelvic Floor

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Pelvic floor dysfunction refers to dysfunction of the entire pelvis including impairments of the gynecologic, urinary, and gastrointestinal systems, as well as neuromusculoskeletal impairments. Physical therapists are often involved in the rehabilitation of patients with the following diagnoses:

- Urinary incontinence (UI)
- Fecal incontinence
- Pelvic organ prolapse
- Urinary retention
- Pelvic pain
- Painful penetration

The *PFMs* refers collectively to a group of skeletal muscles under voluntary control that span from the pubic bone to the coccyx. PFM rehabilitation utilizes the same training techniques as other skeletal muscles in the body and can prevent or reverse pelvic floor dysfunction[1] (**Evidence and Research 18-1** and **18-2**).

EVIDENCE and RESEARCH 18-1

A recent study investigated the prevalence of stress urinary incontinence (SUI) in a sample of 408 subjects age 30 to 50, attending a public well women clinic. SUI was reported in 37.5% of the women and 30.7% of those women reported impaired quality of life. In addition, 52.9% of the women with SUI believed that this was "inevitable with age"; 13.7% thought there was no treatment available.[2]

In a retrospective study of 778 women with pelvic floor dysfunction, including UI, defecatory dysfunction, and pelvic pain, 80% of the patients reported improvement in symptoms upon completion of five pelvic floor rehabilitation sessions.[3]

Fan et al.[4] investigated the effect of pelvic floor muscle (PFM) training on symptoms of UI and quality of life. The authors reported that 65% of the subjects had improvement in symptoms of incontinence and quality of life.

EVIDENCE and RESEARCH 18-2

Clinical audit in the United Kingdom showed that 79% of patients receiving PFM training improved sufficiently to avoid urological surgery.[5]

This chapter introduces students to the following concepts:

- Anatomy and kinesiology of the PFMs
- Physiology of micturition
- Screening for pelvic floor dysfunction
- Examination of the PFMs
- Management of common physiologic impairments of the PFM
- Relationship of the PFM to other body regions, particularly the lumbo-pelvic-hip complex (see Chapters 17 and 19)
- Clinical application through case studies

This chapter provides screening and examination tools that do not require internal vaginal evaluation or surface electromyography (EMG) of the pelvic floor and explains how to teach pelvic floor exercises (PFEs). These exercises, commonly referred to as Kegel (pronounced "kagel") exercises, strengthen the PFMs and specifically address impaired muscle performance. Arnold Kegel was an obstetrician who pioneered PFM strengthening in the 1940s.[6]

Postgraduate study is recommended for therapists interested in the specialized practice of pelvic floor rehabilitation. A complete evaluation of this area often requires intravaginal or intrarectal palpation and surface EMG evaluation, which are usually not considered entry-level skills.

REVIEW OF ANATOMY AND KINESIOLOGY

This section outlines the terminology used by most clinicians for structures of the pelvic floor.[7,8] Because most patients with PFM dysfunction are female, female anatomy is discussed in this chapter, but the pelvic diaphragm layers and intrapelvic hip rotators are essentially the same in both sexes.

Skeletal Muscles

Currently, the term "pelvic floor" refers to all the structures of the lower pelvis including the boney pelvis, viscera, fascia and ligaments, and PFMs. The skeletal muscles of the pelvic floor (**Fig. 18-1**) are specifically called "pelvic floor muscles"[7] and can be divided into four layers, from superficial to deep: (a) the anal sphincter, (b) superficial genital muscles, (c) perineal membrane, and (d) the pelvic diaphragm.[8]

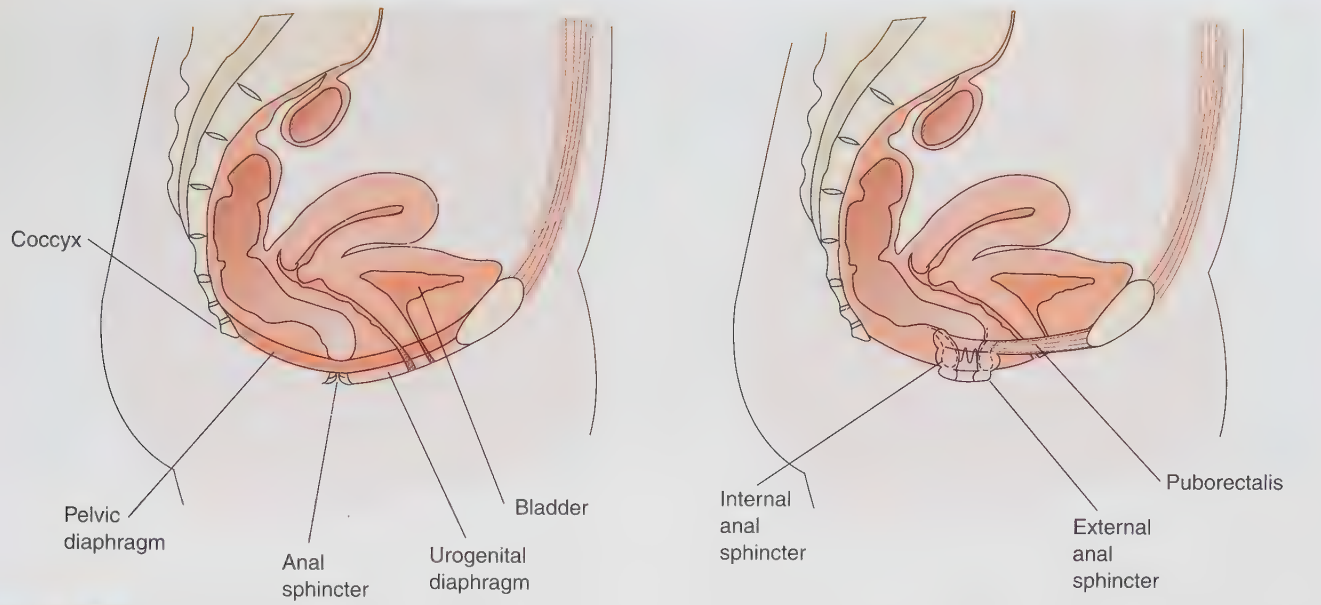


FIGURE 18-1 PFM layers.

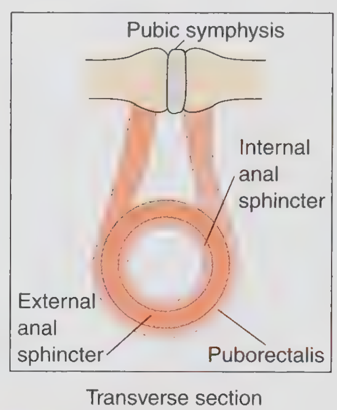


FIGURE 18-2 Anal sphincter.

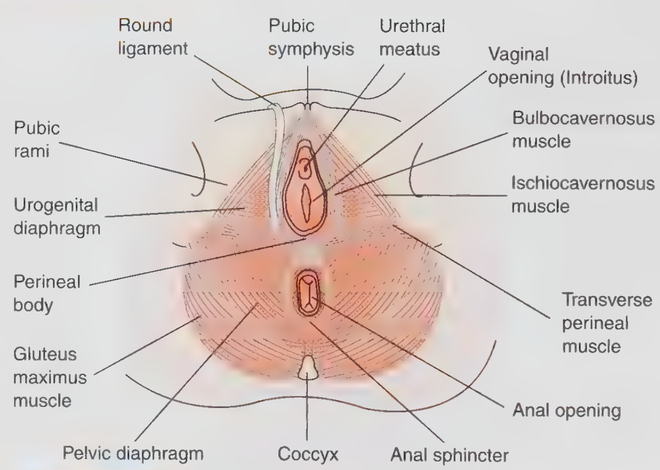


FIGURE 18-3 Female PFMs—inferior view.

The *anal sphincter* (**Fig. 18-2**):

- Most superficial skeletal muscle
- Includes internal anal sphincter (i.e., smooth muscle) and external anal sphincter (i.e., skeletal muscle)
- Internal and external anal sphincters fuse superiorly with the puborectalis (pelvic diaphragm muscle)
- Function is to provide fecal continence
- Innervated by S4 and the inferior branch of the pudendal nerve.

The *superficial genital muscles* (**Fig. 18-3** and **Table 18-1**[9–12]):

- Aid in sexual function of the pelvic floor
- Muscles include the bulbocavernosus, ischiocavernosus, superficial transverse perineal

The perineal membrane (**Fig. 18-4** and Table 18-1[9–12]):

- Part of the continence mechanism
- Muscles include the urethrovaginal sphincter, compressor urethrae (formerly known together as the deep transverse perineal), sphincter urethrae

Pelvic Diaphragm Muscles

The pelvic diaphragm (**Fig. 18-5**) contains the largest skeletal muscle group in the pelvic floor, the levator ani muscles. The four muscles of the levator ani are the coccygeus, iliococcygeus, puborectalis, and pubococcygeus (**Table 18-2**). These muscles function as a group to provide the following:

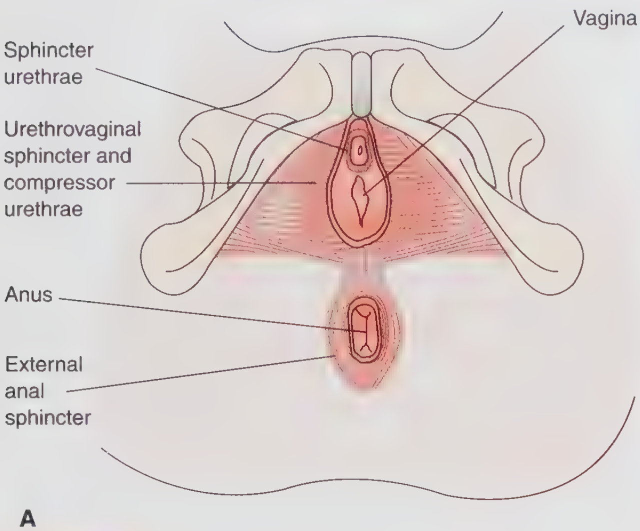
- Support pelvic viscera
- Maintain continence
- Postural stabilization
- Sexual function

The pelvic diaphragm muscles are approximately 70% slow-twitch muscle fibers (type 1) and 30% fast-twitch muscle fibers (type 2).[10] Both types of muscle fibers have specific functions in the pelvic floor, and therefore, a complete exercise program should train both types of muscle fibers. Impairments of the PFM can occur in a single layer or throughout the entire skeletal muscle layers. The PFMs contract as a unit to achieve various functions. Sensation in the region is limited and may be decreased with

TABLE 18-1

Muscles of the Female Urogenital Triangle

MUSCLE	ORIGIN	INSERTION	INNERVATION	FUNCTION
Superficial Perineal				
Bulbocavernosus	Corpus cavernosum of the clitoris	Perineal body	Perineal branch of pudendal S2–S4	Clitoral erection
Ischiocavernosus	Ischial tuberosity and pubic rami	Crus of the clitoris	Perineal branch of pudendal S2–S4	Clitoral erection
Superficial transverse	Ischial tuberosity	Central perineal tendon	Perineal branch of pudendal S2–S4	Stabilizes perineal body
Perineal Membrane				
Urethrovaginal sphincter	Vaginal wall	Urethra	Perineal branch of pudendal S2–S4	Compression of urethra
Sphincter urethra	Upper two-thirds of urethra	Trigone ring	Perineal branch of pudendal S2–S4	Compression of urethra
Compressor urethra	Ischiopubic rami	Urethra	Perineal branch of pudendal S2–S4	Compression of urethra



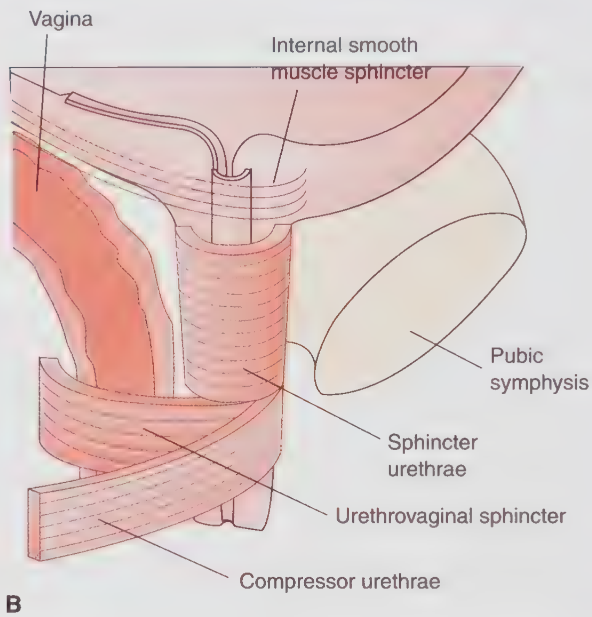


FIGURE 18-4 Female urogenital diaphragm—**(A)** inferior view, **(B)** side view. (From Schussler B, Laycock J, Norton P, et al, eds. Pelvic Floor Re-education Principles and Practice. New York, NY: Springer-Verlag, 1994.)

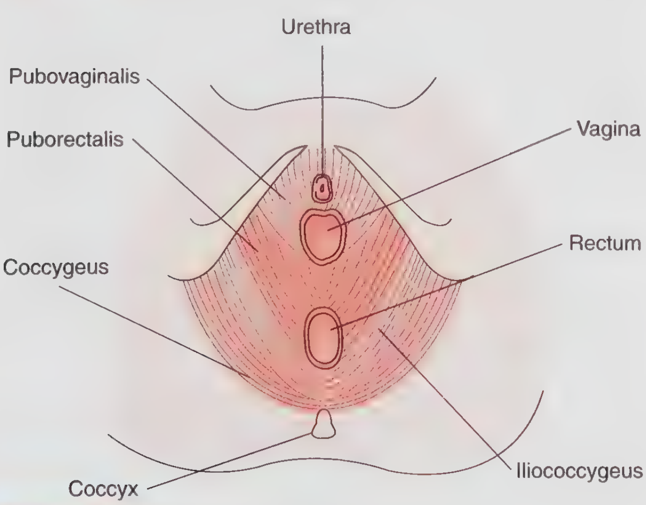


FIGURE 18-5 Female pelvic diaphragm—superior view.

surgery or childbirth making awareness of PFM contraction difficult. The PFM has extensive fascia throughout the muscle layers (see Table 18-2).

There is a very close anatomic relationship between the PFM and some hip muscles (**Fig. 18-6**).[13,14] The inferior border of the piriformis is close to the superior border of the coccygeus muscle, and the levator ani muscles attach to an extension of the obturator internus fascia (i.e., the arcus tendinous levator ani) (**Fig 18-7**). Clinically, it appears that impairments in length, strength, endurance, and patterns of recruitment of the piriformis and obturator internus muscles can contribute to PFM impairments and vice versa.[15]

The adductor muscle group also may contribute to PFM pain syndromes and overactive bladder. Adductor fascia at the pubic rami is in close proximity to the superficial perineal muscle fascia. The psoas minor and major muscles, iliacus, and quadratus lumborum are key muscles to treat in lumbopelvic dysfunctions including PFM pain syndromes.

TABLE 18-2

Levator Ani Muscles

MUSCLE	ORIGIN	INSERTION	INNERVATION	FUNCTION
Coccygeus	Spine of the ischium	Anterior portion of the coccyx and S4	Ventral rami, S4, and S5	Flex the coccyx
Pubococcygeus	Posterior os pubis	Perineal body, vaginal walls	Inferior rectal branch of the pudendal nerve, S2–S4, and ventral rami, S2–S4	Support of the pelvic viscera Compression of the vagina
Puborectalis	Pubic bone, arcus tendineus	Anterior coccyx, lateral rectum	Inferior rectal branch of the pudendal nerve, S2–S4, and ventral rami, S2–S4	Support of the pelvic viscera Compression of the rectum
Iliococcygeus	Pubic rami, arcus tendineus	Coccyx	Inferior rectal branch of the pudendal nerve, S2–S4, and ventral rami, S2–S4	Support of the pelvic viscera

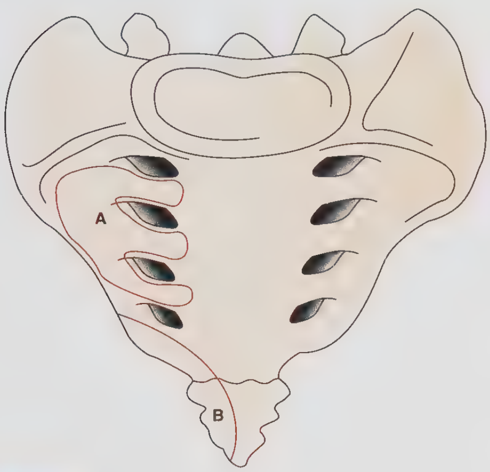


FIGURE 18-6 The anterior sacrum. Origin of the piriformis **(A)** and coccygeus **(B)**.

Pelvic Floor Function

Organ Support Function

The PFMs provide support to the pelvic organs against the forces of gravity and increased intra-abdominal pressure (e.g., laugh, cough, sneeze, vomit, lift, strain). This supportive function is primarily performed by the tonic, slow-twitch muscle fibers of the PFMs to maintain a minimal resting tone. Wei stated that normal pelvic organ support is achieved by ligamentous support from above, PFMs function from below, and the structural geometry achieved by normal function of both.[8] Recovery of organ support requires attention to restoring PFM function (i.e., PFM rehabilitation) firstly and in some cases restoring ligament support (i.e., surgery).[16] Women with pelvic organ prolapse, or protrusion of the pelvic organs, more often have defects in the levator ani and generate less vaginal closure force than women with good organ support.[17]

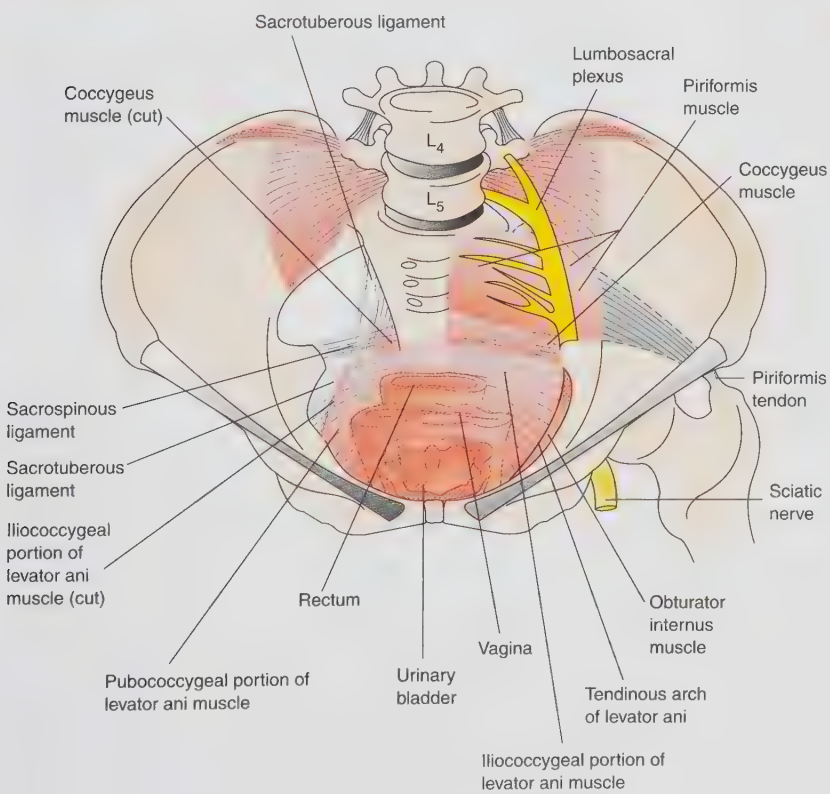


FIGURE 18-7 Piriformis and pelvic area—superior view.

Trunk Support Function

The PFM, transversus abdominis, deep multifidi, and diaphragm work together to enhance trunk stability.[18–21] There is cocontraction of the PFM and transversus abdominis muscles. The PFMs contract before movement to assist the abdominals in stabilizing the trunk.[22] Current research results support the role of the PFM in orthopedic conditions. It is essential that all physical therapists understand the role of the PFM, symptoms, and possible treatments (**Evidence and Research 18-3**).

EVIDENCE and RESEARCH 18-3

Many studies have documented bladder dysfunction in association with low back pain (LBP).[23] One study showed 78% of 200 women reporting to a physical therapy (PT) clinic with a chief complaint of LBP had UI.[24] Smith et al.[25] have documented decreased balance ability in women with SUI (a condition related to PFM weakness) compared to continent women.

Stuge et al.[26] documented an automatic PFM contraction with active straight leg raise in patients with pelvic girdle pain and in controls. This automatic PFM contraction was reduced by 62% to 66% when manual compression to the pelvis was provided.

Sphincteric Function

The PFMs provide closure of the urethra and rectum for continence. During normal function, quick closure of the orifices is provided by the phasic, fast-twitch fibers. Closure during rest (i.e., static resting tone) is provided by the slow-twitch muscle fibers. Continence is preserved when the pressure in the urethra (provided by several structures including the PFMs) is higher than the pressure in the bladder. Loss of sphincteric function may lead to incontinence. The medical literature commonly points out that incontinence is a symptom and not a disease; based on the terminology used in this book, incontinence results from impairments not a pathologic condition. Intervention should be aimed at the impairments that contribute to the syndrome of incontinence.

Sexual Function

The vagina has very few sensory nerve fibers.[27] The PFMs provide proprioceptive sensation that contributes to sexual appreciation. Hypertrophied PFMs create a smaller vagina and more friction against the penis during intercourse. This results in the stimulation of more nerve endings and provides pleasurable sensation during intercourse. Strong PFM contractions occur during orgasm. Patients with weak PFMs often cannot achieve orgasms.[27] In men, the PFMs assist in achieving and maintaining an erection.[28,29]

Physiology of Micturition

Micturition refers to the physiologic process of urination and involves a complex set of somatic and autonomic reflexes. An explanation of micturition is provided in **Display 18-1**. This information is included, so the therapist can explain the basics of normal bladder function to the patient and assist with basic bladder retraining.

Urine is produced steadily at about 15 drops per minute. Bladder filling is constant and urine production increases in the presence of bladder irritants. As the bladder fills, it passively expands until approximately 150 mL of fluid is collected. Stretch receptors in the bladder then signal the brain that it may be necessary to get to the bathroom soon. This is called the first sensation to void. The detrusor muscle (i.e., muscle of the bladder) remains quiet, and the PFMs maintain normal resting tone. Filling continues until 200 to 300 mL, when a stronger sensation of urgency is felt from increased activation of stretch receptors. The detrusor and PFMs remain unchanged. A strong urge to void usually occurs at 400 to 550 mL.[12,30] The brain eventually directs the person to a toilet and the person voids. The PFMs relax, the detrusor contracts, and urine flows out.[31] The PFMs return to resting tone when the urine flow stops. Normative values vary, but most practitioners consider it normal to have 5 to 50 mL of urine left in the bladder after a normal urination. It is neither necessary nor desirable to increase intra-abdominal pressure (i.e., bear down) at any time during urination.[11]

DISPLAY 18-1
Micturition Facts

- The bladder's job is to store urine and empty fully at the appropriate time and place.
- It is necessary to allow normal filling of the bladder for normal bladder function. Voiding "just in case" may contribute to urinary dysfunction.
  - Normal voiding frequency in a 24-hour period with normal fluid intake:
  - 6 to 8 times
  - >8 times is called *urinary frequency*
- Normal day time voiding interval: 2 to 5 hours
- Normal nocturnal voiding frequency (after the patient has gone to bed for the evening):
  - 0 to 1, children and adults <65 years
  - 1 to 2, adults >65 years
  - Normal volume for urination: 8 to 10 oz
- Recommended fluid intake per day: 6 to 8 oz glasses. Decreasing fluids does not decrease incontinence and may make urgency worse because concentrated urine is a bladder irritant.[32]
- Many fluids or substances are bladder irritants, causing urgency and increasing urine production:
  - Caffeine (e.g., coffee, tea, cola, medications, chocolate)
  - Alcohol
  - Carbonated beverages
  - Nicotine
  - Artificial sweeteners
  - Acid-containing foods (citrus, tomatoes, coffee, soda)
  - Some over-the-counter and prescription medications

Eliminating or limiting bladder irritants decreases symptoms of urgency and urge incontinence.

- Hovering over the toilet may result in incomplete emptying of the bladder due to increased PFM tone and decreased urine output.
- Toileting recommendations for women:
  - Wipe from front to back to ensures that fecal matter is not introduced into the urethra and decreasing the incidence of infection

Dysfunctions of micturition are complex. The screening questionnaire in Display 18-5 can help identify patients with dysfunctions of micturition who may need further medical intervention and who should be referred to the physician.

IMPAIRMENTS OF BODY STRUCTURES

Many factors contribute to normal function of the PFMs. Some of these factors cannot be changed by PT interventions. The two major causes of structural impairments are birth injury and neurologic dysfunction.

Birth Injury

Vaginal delivery may result in tears, overstretching, or crush injury of the PFMs (i.e., between the baby's head and the pubic rami) or may cause complete or partial denervation of unilateral or bilateral pudendal nerves (i.e., stretch injury or avulsion of the nerve) (**Evidence and Research 18-4**).

EVIDENCE and RESEARCH 18-4

Dollan et al.[33] found 80% of vaginal deliveries showed evidence of pudendal nerve reinnervation indicating trauma to the nerve. This occurrence was associated with longer pushing and larger babies.

Mild and moderate injuries can be effectively treated with behavioral interventions (see the "Impaired Muscle Performance" section). However, severe trauma may result in severe muscle damage (usually unilateral) and decreased sensory or motor innervation sufficient to render the muscle ineffective. This type of trauma occurs in a very small percentage of births. However, most women with vaginal deliveries sustain only minor, temporary dysfunctions and recover fully. To maximize birth recovery, all women of childbearing age should receive accurate preventative education on PFM health.[34]

Delivery Factors That May Contribute to PFM Injury[35–37]

■ Pushing phase >2 hours	■ Larger size of the baby's head
■ Forceps-assisted delivery	■ Medical interventions
■ Woman's position—supine	■ Medications administered
■ Use of episiotomy	■ Very fast deliveries

Neurologic Dysfunction

Many central and peripheral nervous system (PNS) dysfunctions affect PFM and bladder function.[38] PNS conditions, such as disk herniation and spinal cord injury, may result in sensory or motor denervation of the PFMs. Diabetes may result in sensory or motor denervation of the PFMs and autonomic neuropathy with disruption of bladder function. The pelvic plexus includes many small nerves that are often not visible during surgery. These nerves are not located in a consistent pattern in all patients. Radical pelvic operations, such as total hysterectomy[39] and radical prostatectomy,[40] may result in inadvertent disruption of the sensory and motor nerves to the bladder and PFMs. Patients may be able to strengthen the remaining innervated muscles to achieve full supportive and sphincteric function. Central nervous system (CNS) diseases such as cerebrovascular accidents,[41] multiple sclerosis,[42] and Parkinson disease may affect cognitive control of the bladder and PFMs. These conditions may also affect the patient's ability to get to the toilet or to recognize the toilet and may affect the patient's social awareness of continence. In these patients, UI is associated with eventual functional dependence and poor survival.[43] Maintaining functional independence should include treatment of PFM dysfunction and continence.

IMPAIRMENTS OF MENTAL FUNCTIONS

Motivation

PFM strengthening requires motivation and persistence. Improvement in muscle function with PFM therapy can be quick and dramatic, but it is more often slow and gradual. Some patients do not have enough motivation to complete therapy and find it easier to wear incontinence pads. Incontinence affects patients' lives differently. Some patients are devastated and severely limited by a small amount of urine leaking two or three times per week. Other patients view large leaks two or three times per day as a mild inconvenience. The perceived severity of the condition helps determine motivation. Ask the patient, "On a scale of 0 to 10, how severely does your condition affect your life (0 = no effect; 10 = severely limiting)." Therapists must strongly encourage patients throughout the therapy to maintain motivation. Depression and poor motivation may limit a patient's progress with pelvic muscle exercise (PME) (**Evidence and Research 18-5**).

EVIDENCE and RESEARCH 18-5

Adherence to PFM exercise programs has been shown to be predictive of positive outcomes.[44–46] Several factors limiting full participation in PFM exercises have been identified. These include lack of time and motivation, inconvenience, poor social support, and cultural beliefs.[47]

A prospective observational study investigated the effect of depression and anxiety on the success of PFM training in 108 subjects with pelvic floor dysfunction. The results revealed that subjects with no or mild depression or anxiety "benefited most" from PFM training.[48]

Vella et al.[49] investigated the effect of self-motivation on the success of PFM training for UI. The authors found that three of the five domains (positive attitude for treatment, frustration of living with incontinence, desire for treatment) of the Incontinence Treatment Motivation Questionnaire correlated significantly with outcome.

Sexual Abuse

All therapists should be aware of symptoms of sexual abuse (**Display 18-2**) and should have some exposure to techniques to facilitate rehabilitation of these patients (**Display 18-3**). It is especially important to be sensitive to these issues when treating PFM dysfunction and pelvic pain (see **Building Block 18-1**). Therapists are encouraged to seek additional information on sexual abuse survivors (see the "Recommended Reading" section) (**Evidence and Research 18-6**).

DISPLAY 18-2

Symptoms of Sexual Abuse

- Low self-esteem, feelings of loss of control
- Poor body awareness, often not trusting their own physical or emotional feelings
- Difficulty with anger and violence
- Difficulty with sexuality and intimacy; may avoid sex completely or compulsively seek sex
- Denies and forgets instructions or appointments
- Self-mutilating or addictive behaviors
- Controlling of environment, treatment, or your time
- Multiple personalities
- Dissociation (i.e., avoidance of eye contact, distant look), an unconscious defense mechanism to separate the mind from the body and protect the mind from impending trauma; may occur during the treatment sessions

DISPLAY 18-3

Guidelines for Therapy with Known or Suspected Sexual Abuse Survivors57

- Give the patient control over as much as you can in the environment and in therapy.
- Offer names of community support services and psychologists skilled in the treatment of sexual abuse survivors.
- Do not touch the patient without permission, and avoid hugging or other nonessential physical contact.
- Never allow the patient to disassociate.
- Be honest with the patient about your ability and knowledge (or lack of) in this area.

BUILDING BLOCK 18-1

Another therapist is working in the gym with a 15-year-old male with Osgood Schlatter. You notice this patient moves away when the therapist touches his thigh and appears uncomfortable when the therapist is standing close to him. Your colleague has expressed frustration with this patient's lack of coordination and body awareness making accurate exercises very difficult in the clinic and at home. In addition, the patient is very particular about the time of his appointment, which plinth he wants to work on, how the Thera-Band is arranged, and always cleans the mat before he sits on it. Discuss how you might share your concerns of possible sexual abuse history in this patient with your colleague and what steps might be taken to make his therapy more tolerable for him and more effective.

EVIDENCE and RESEARCH 18-6

An estimated one of three girls has been abused before the age of 14. One in six boys will be sexually abused before the age of 18. Only one of five cases is reported. Some studies show that there is a higher incidence of gynecologic problems among sexual abuse survivors.[50,51] 40% to 50% of women with chronic pelvic pain (CPP) have a history of abuse.[52–55]

EXAMINATION/EVALUATION

All patients could benefit from screening for PFM dysfunction, especially patients with lumbo-pelvic-hip pain (**Evidence and Research 18-7**).

EVIDENCE and RESEARCH 18-7

Bi et al.[56] investigated the effect of PFM training on outcomes in patients with chronic LBP. The authors reported that the addition of PFM training to routine LBP treatment resulted in significantly lower scores for pain severity and the Oswestry Disability Index when compared with the control group.

Understanding the risk factors for PFM dysfunction helps the therapist identify patients who may benefit from in-depth questioning. Screening tools are provided to identify PFM impairments and dysfunctions. Therapists are cautioned that questionnaires can be misleading[56] and full urologic workup is indicated if conservative treatment is not successful. This section also outlines the information that is gathered by specialized therapists from internal vaginal examinations and from patient self-evaluations. Other examination tools used by the specialized therapists include external observation, EMG and pressure biofeedback, and real-time ultrasound imaging.

Risk Factors

Risk factors are related to the causes of various dysfunctions (see **Display 18-4** and **Case Study 18-1**). Patients with medical histories that include many risk factors may be screened using a more detailed questionnaire (**Evidence and Research 18-8**).

DISPLAY 18-4

Risk Factors for Underactive and Overactive PFM

Underactive PFM[59–62]

- Vaginal childbirth, pregnancy.
- Increased body mass index, increased waistline.
- Chronic or prolonged coughing, as with pulmonary diseases, smoking.
- Arthritis, functional impairments, hip fracture, falls.
- Long-term incorrect lifting or straining with a Valsalva maneuver (i.e., increased intra-abdominal pressure with bearing down), including incorrect straining with exercise.
- Chronic constipation.
- Menopause and estrogen use.
- Neurologic dysfunctions that may affect peripheral nerves of the pelvis and many CNS diseases including dementia.
- Medical comorbidities such as diabetes mellitus (DM), peripheral vascular disease, congestive heart failure, thyroid problems.
- Decreased awareness of PFMs with disuse atrophy.
- Pelvic surgery, previous hysterectomy.
- Age—although UI increased with age, it is not a significant factor after adjustment for confounding conditions. UI does occur in young women, especially athletes.[63–65]

DISPLAY 18-4

Risk Factors for Underactive and Overactive PFM (*continued*)

Overactive PFM

- Back and pelvic pain with joint dysfunction, especially if related to a direct fall on the buttock or pubic bone[66]
- Muscle imbalance of the hip muscles, abdomen or pelvis, or lumbar spine, including shortened muscles or connective tissue in the trunk and pelvis[66]
- Habitual PFM holding (e.g., excessive emotional stress, or fighting the urge to urinate)[67]
- Abdominal adhesions and adhered scars in the pelvic region[68]
- Deep episiotomy or perineal tearing with childbirth
- Pelvic surgery[69]
- Pelvic conditions, such as endometriosis, irritable bowel syndrome, or interstitial cystitis[70,71]
- History of or current fissures or fistulas
- Connective tissue disease such as fibromyalgia
- History of or current sexually transmitted disease or recurrent perineal infections, including yeast infections
- Dermatologic conditions such as lichen sclerosis and lichen planus

CASE STUDY 18-1

Mary Smith is a 50-year-old mother of two with LBP. She works in a busy office and does not exercise often. List Ms. Smith's risk factors for underactive and overactive PFMs.

EVIDENCE and RESEARCH 18-8

Nygaard et al.[58] conducted a retrospective study of 96 women with UI who received supervised PFM training. Premenopausal and postmenopausal patients reported significant improvement in symptoms of UI.

Screening Questionnaires

A brief screening questionnaire should be given to all patients. Two types, brief or detailed, can be used to determine whether patients have dysfunctions of the pelvic floor. Questions should be clear and direct. A broad question such as "Are you incontinent?" usually results in a false-negative response.

Brief Screening Questionnaire

Evaluation of all patients, especially those with the risk factors listed in Display 18-4, should include three questions:

- Do you ever leak urine or feces?
- Do you ever wear a pad because of leaking urine?
- Do you have pain during intercourse?

Detailed Screening Questionnaire

Therapists must understand the dysfunctions of the PFM, their diagnostic classifications, and the types of incontinence to fully understand the interpretation of the results of this screening tool. A detailed screening questionnaire should be given if the patient responds affirmatively to the questions of the brief screening questionnaire. The longer version should be administered to a patient with pelvic, trunk, or back pain who is recovering slower than expected (see **Display 18-5**). If the patient has symptoms of overactive PFM (i.e., positive response to questions 13 through 19), proceed with full evaluation of the sacroiliac, hip girdle, and pelvic fascia (see **Case Study 18-2**).

Interpretation of Detailed PFM Questionnaire

Positive response to:

- Questions 1 to 14: indicates underactive PFM that may be treated using PFE
- Questions 1 to 3: indicates stress incontinence
- Questions 4 to 8: indicates urge incontinence
- Questions 13 and 14: indicates pelvic organ prolapse
- Questions 13 to 19: indicates overactive PFM, incoordination, or urinary retention
- Questions 15 to 17: indicates obstruction and may need physician evaluation to rule out mechanical obstruction

DISPLAY 18-5

Detailed PFM Questionnaire

The patient should respond with *never, sometimes,* or *often* to the following questions:

1. Do you leak urine when you cough, laugh, or sneeze?
2. Do you lose urine when you lift heavy objects such as a basket of wet clothes or furniture?
3. Do you lose urine when you run, jump, or exercise?
4. Do you ever have such an uncomfortable, strong need to urinate that you leak if you do not reach the toilet? Do you sometimes leak with this strong urge?
5. Do you develop an urgent need to urinate when you hear running water?
6. Do you develop an urgent need to urinate when you are nervous, under stress, or in a hurry?
7. When you are coming home, can you usually make it to the door but then lose urine just as you put the key in the lock?
8. Do you have an urge to urinate when your hands are in cold water?
9. Do you find it necessary to wear a pad at any time because of leakage?
10. Does your bladder awaken you from sleep? How many times each night?
11. How often do you leak urine or feces?
12. How often do you inadvertently leak gas?
13. Do you ever feel as though you are "sitting on a ball" or that there is something "in the way" when you are sitting?
14. Do you ever feel as though something is "falling out" of your perineal area?
15. Do you find it hard to begin urination?
16. Do you have a slow urinary stream?
17. Do you strain to pass urine?
18. Do you have pain during vaginal penetration, including intercourse, insertion of a tampon, or vaginal examination?
19. Do you have pelvic pain with sitting, wearing jeans, or bike riding?

CASE STUDY 18-2

You have asked Ms. Smith the PFM screening questions. She does report urine leakage with sneezing but does not wear pads. She denies pain with intercourse. Create a list of follow-up questions to ask Ms. Smith to determine more about her condition.

Results of the Internal Examination

A complete PFM evaluation is necessary to prescribe an appropriate exercise. It includes an extensive history, symptom documentation, identification of associated factors, and internal vaginal or rectal examinations. Surface EMG or pressure biofeedback evaluation may also be added. The specialized therapist obtains the following information from the internal examination of the PFMs[31]:

- *Muscle performance* is assessed in the form of power and endurance.
- *Power* is defined as the ability to contract (manual muscle grade of 0 through 5). This grade provides information on how much lift (i.e., supportive function) and closure (i.e., sphincteric function) the PFMs have. The muscle bulk of the PFMs can be palpated to help determine possible duration of rehabilitation and rehabilitation potential. Patients with a small, thin PFM require a longer rehabilitation time and generally have less rehabilitation potential than those with good PFM bulk.
- *Endurance* is defined as the ability to hold a slow-twitch muscle contraction and repeat the contraction. Clinicians also determine how many fast-twitch muscle contractions can be done. The quality of the contractions is also evaluated.
- *Resting tone between contractions* is assessed, looking specifically for altered tone impairments.
- *Coordination* of the PFMs and the relationship with associated muscles are assessed. Muscle dominance patterns or inappropriate contractions of the gluteal muscles, adductor group, and abdominal muscles are assessed.
- *Other impairments*, such as pelvic floor trigger points, decreased sensation, and scars or myofascial adhesions, may limit strengthening.

DISPLAY 18-6
Contraindications or Precautions to Internal Evaluation of the PFM

- Pregnancy
- Within 6 weeks of vaginal or cesarean delivery
- Within 6 weeks after pelvic surgery
- Atrophic vaginitis, a condition of fragile skin seen in cases of estrogen deficiency
- Active pelvic infection
- Severe pelvic or vaginal pain, especially pain during penetration or intercourse
- Children and presexual adolescents
- Lack of informed consent
- Lack of therapist's training (The therapist should obtain specialized training in performing internal evaluations of the PFM. Training can be obtained in postgraduate courses or through individual instruction from a midwife, physician, nurse, or trained physical therapist.)

Internal examination of the PFMs is the gold standard for determining if the patient is performing a PFM contraction correctly.[72,73] However, internal examinations cannot or should not be performed in some cases (see **Display 18-6**). During this time, the specialized therapists would choose one of the alternative examination techniques.

Patient Self-Assessment Tests

When an internal evaluation cannot be performed, self-assessment tests can help patients and the therapist identify some of the impairments of the PFMs. Therapists can use the results of self-assessment tests to prescribe PFEs with some accuracy.

A possible evaluation tool used when the therapist cannot perform an internal evaluation is the digital vaginal self-examination (i.e., finger in the vagina test). Begin with patient education, as outlined later in the active PFEs. This section also includes information about verbal cues for the proper contraction of PFMs. After a brief introduction to the PFMs and the exercise, the patient should be instructed in the digital vaginal self-examination test (see **Patient-Related Instruction 18-1**). This method is

Patient-Related Instruction 18-1

Testing Your PFM by Performing the Digital Vaginal Self-Examination

The following test can help you determine your current ability and monitor your recovery. Perform this test before beginning your PFM exercise program and then periodically throughout the training period, approximately every 2 to 4 weeks. Fluctuations in muscle ability occur in response to fatigue, medications, hormones, and other factors. The PFMs are more likely to be weak at the end of the day, when you are sick, and just before menstruation.[27] For an accurate comparison, repeat the test at the same time of the day and the same time of the monthly menstrual cycle as the original test. Any exercise program takes time and dedication. As with other muscles, the PFMs may take 4 to 6 months to strengthen. After you have performed the test, report the following information to your therapist: how many seconds you can hold the contraction, how many of these long-hold contractions you can do, and how many quick contractions you can do.

Digital Vaginal Self-Examination (Finger in Vagina or Rectum)

Place your finger into the vagina or rectum up to the level of the second knuckle. Palpate the muscle on either side of the vagina or rectum while you contract the PFM, pulling the muscles up and in. You should feel the muscles contract around your finger and pull your finger up and in. If you feel tissues pushing out of your body or bulging, ask your health care professional to evaluate the area.

often accepted by female patients and can be taught to male patients (i.e., finger in the rectum test) in the same manner if they are having trouble learning the correct contraction with other methods. Men can also be taught to palpate the perineal body (just behind the testicles). They should notice a tightening of the tissue if the PFM is contracting correctly. Many factors influence continence and PFM function. Some practitioners use the stop urine test to determine PFM function. Current literature does not support the value of this test.[74]

The finger in the vagina test cannot evaluate all aspects of muscle function but can give some indication of the muscles' abilities and provide guidance in prescribing exercises. Patient progress should be judged by reexamination of the PFM function; however, if this is not possible, it may be judged by decreasing symptoms. Patients can perform the test at home and report to the therapist, or the test can be done in the clinic if sufficient privacy is available (i.e., closed-door treatment room with a plinth or recliner is suggested). In the clinic, the therapist can briefly step out of the room while the patient performs the test or can remain in the treatment room with the patient adequately draped. The patient should provide the following information:

- Duration (in seconds) of PFM endurance contraction
- Number of repetitions of PFM endurance contractions
- Number of repetitions of quick muscle contractions

A second self-assessment test, the jumping jack test, is a test of advanced strength (see **Patient-Related Instruction 18-2**). It is usually not given to sedentary, incontinent patients. It is helpful for athletes and other active individuals who know how to do the PFE well. Patients may use this test to judge continued progress after active therapy has ended (see **Building Block 18-2**).

Patient-Related Instruction 18-2

Jumping Jack Test

This test is used only to evaluate PFM ability under physical stress. To begin, empty your bladder, and then perform five jumping jacks. If no urine leaks out, wait ½ hour, and do five more jumping jacks. If no leakage occurs, wait 1 hour, and repeat the five jumping jacks. The test proceeds until leakage occurs. Make a note of how long after urination and how many jumping jacks you could do before urine leakage occurs. It is important to continue drinking as usual during the test. There are no normative values for this test, but some therapists feel a patient should be able to do 5 to 10 jumping jacks 2 to 3 hours after urination without leaking.

Circle the number of jumping jack at which urine leakage occurs

Immediately—1 2 3 4 5
½ hour—1 2 3 4 5
1 hour—1 2 3 4 5
1½ hours—1 2 3 4 5
2 hours—1 2 3 4 5
2½ hours—1 2 3 4 5
3 hours—1 2 3 4 5
3½ hours—1 2 3 4 5
4 hours—1 2 3 4 5

BUILDING BLOCK 18-2

Your patient is a 24-year-old female 2 month postsurgical repair of an anterior cruciate ligament. She has been progressing nicely in her recovery and is now returning to jumping practice in preparation for return to volleyball. During one of her therapy sessions, she suddenly stops and excuses herself to the bathroom. Upon her return, she is not as aggressive with her jumping and appears self-conscious. During one of her exercises, you notice a small wetness in the perineal area. Describe how you might approach this patient's apparent urinary leakage during therapy. Describe how to perform the patient self-assessment tests.

Ultrasound Imaging for PFM Dysfunction

Over the past 10 years, the interest and availability of ultrasound imaging in PT have increased. Imaging of the PFM gives the general physical therapist a valid tool to objectively measure the PFM without internal palpation.[75] This modality can also be used to provide biofeedback to the patient and enhance PFM contraction learning. The ultrasound probe is placed transverse or sagittal in the suprapubic region with the sound waves directed caudal into the pelvis (**Evidence and Research 18-9**).

EVIDENCE and RESEARCH 18-9

Ultrasound imaging has been shown to be an effective assessment tool for PFM volume, anatomy, and movement.[76,77]

Sample patient goals

- The patient will have decreased number of nighttime voids from ___ no. to___ no.; allowing improved sleep and decreased fall risk.
- The patient will be able to participate in _____ (sport, housework, and work) with ___% decrease in urinary leakage.
- The patient verbalizes understanding of independent home exercise program to increase PFM function.
- The patient achieves increased time between voids to ___ no. hours for work and social activities.
- Activities of daily living (ADLs) are not limited by urgency UI or frequency (see **Case Study 18-3**).

THERAPEUTIC EXERCISE INTERVENTIONS FOR COMMON PHYSIOLOGIC IMPAIRMENTS

This section outlines the physiologic impairments and possible treatments of the PFMs and related structures. Several types of impaired PFM functions are possible:

- Impaired muscle performance of the PFMs, abdominal muscles, and hip muscles
- Pain and altered tone of the PFMs, hip muscles, and trunk muscles

CASE STUDY 18-3

Ms. Smith states that she does not exercise partly because of fear of leaking and has had to leave the movie theater during a movie to urinate. You have both decided it is important to address this dysfunction. You explained the self-assessment tests last week, and the patient has performed them as you requested and is reporting the results.

Results of jumping jack test—1½ hours first jumping jack

The number of repetitions and amount of hold time per contraction—5-second hold 10 times

The number of quick contractions—20

List three goals specific to UI for this patient.

- Mobility impairments causing PFM dysfunction as a result of adhesions, scar tissue, and connective tissue disorders
- Posture impairments
- Coordination impairments of the PFMs, PFMs during ADLs, PFMs with the abdominal muscles, and abdominal muscles alone

Impaired Muscle Performance

Pelvic Floor Muscles

Impaired muscle performance (impairment in strength, power, or endurance) is the most commonly treated impairment of the PFMs and is usually the primary impairment in the underactive PFM diagnostic classification. PFM performance may be impaired by the following:

- Trauma during vaginal delivery
- CNS or PNS neurologic dysfunction
- Surgical procedures
- Decreased awareness of PFMs
- Disuse
- Prolonged increased intra-abdominal pressure
- Pelvic congestion or swelling
- Back or pelvic pain

The PFMs are 70% slow-twitch muscle fibers with the critical role of providing support to pelvic organs against gravity in all upright positions. PFMs are postural muscles and must be able to maintain some baseline tone for long periods. Weak, easily fatigued, saggy muscles do not support the pelvic organs. Poor endurance of the PFMs is a common finding in many women without symptoms of PFM dysfunction. Most women probably have endurance impairment of the PFMs long before functional impairments of leaking urine or prolapse occur. Teaching PFEs to *all* adults may help to prevent PFM dysfunctions in the future.[4] This is especially true with prenatal and postpartum women and women after menopause or gynecologic surgery.

The treatment for impaired muscle performance is active PFEs.[78–81] These strengthening exercises are explained later in the "Therapeutic Exercise Intervention for Common Diagnoses" section.

Abdominal Muscles

Impaired abdominal muscle performance often results in a pendulous abdomen and can contribute to PFM dysfunction, especially incontinence. Restoring abdominal wall length and strength and avoiding Valsalva maneuvers (bearing down) during exercises and ADLs are the goals of PFM dysfunction treatment. Valsalva maneuvers can contribute to incontinence and may increase the chance of pelvic organ prolapse.[82] Treatment of impaired abdominal muscle performance is described in detail in Chapter 17.

Hip Muscles

Hip impairments (see Chapter 19) are often underlying causes of overactive PFM. The piriformis, obturator internus, and adductors are the most likely muscles involved because of their proximity to the PFMs. Any muscle impairment affecting the sacroiliac joint may also contribute to overactive PFM (see Chapter 17).

Active PFEs

PFEs, known as Kegel exercises by many patients, specifically address impaired muscle performance of the PFMs. Proper contraction and relaxation of the PFMs are necessary for normal function and are the focus of treatment for most PFM impairments. A correct technique is essential and should ideally be confirmed with vaginal or rectal palpation. If this is not possible, use patient self-assessment described above or rehabilitative imaging ultrasound. Teaching PFE without internal palpation or biofeedback is difficult for the therapist and the patient. However, this section gives the therapist a comprehensive plan for teaching an effective and individualized PFE program:

- Patient education
- Verbal cues for proper PFM contraction
- Home exercise programs
- Methods for putting the exercise program together

Dosage

The therapist uses the results from the patient's self-evaluation test (i.e., digital vaginal self-examination test) to prescribe an individualized exercise program for PFM strengthening. The therapist should remember the basic principles of overload (i.e., the muscle must be challenged to its fullest capacity to improve strength) and specificity (i.e., patients should exercise the muscle correctly in isolation). Patients can be taught these ideas and can learn to progress in their own programs.[83] PFEs must be individualized for the patient to reach his or her full rehabilitation potential. Many well-intentioned publications give "cookbook" exercise programs that are too hard for the average incontinent patient (e.g., hold for 10 seconds and repeat 10 to 15 times). Patients try to follow these instructions, realize that their symptoms are not changing, and ultimately abandon the exercises. These same patients have achieved good results with careful instructions and individualized programs.

Duration How many seconds should the patient hold the endurance muscle contraction? If the evaluation reveals that the patient can hold the contraction for 3 seconds (not uncommon for weak muscles), the therapist asks the patient to hold the PFM contraction (i.e., Kegel contraction) for 3 to 4 seconds before resting and repeating the exercise. Sustained PFM contractions are progressed to a maximum of 8 to 12 seconds.[84,81]

Rest How long should the patient rest between endurance muscle contractions? Increased resting tone (i.e., overactive PFM) and weak muscles require longer rest times. Twice as much rest time as hold time is advised for a weak muscle (e.g., 3-second hold, 6-second rest, and repeat). Rest time is decreased as strength increases (e.g., 10-second hold, 10-second rest, and repeat). A quality PFM contraction requires complete relaxation at the end of each exercise.[83] Incomplete relaxation does not train a muscle in its full range of motion and may result in excessive tension and pain. Complete relaxation between contractions produces a more functional muscle.

Endurance Contraction Repetitions How many endurance contractions should the patient do in one set before fatigue? For the patient previously described, the therapist would determine how many 3-second contractions the patient can complete. The average patient with endurance impairment is able to perform only 5 to 10 repetitions before fatiguing. The exercise program must be individualized for maximum benefit.

Quick Contraction Repetitions How many quick contractions should the patient do in one set? A complete PFE program includes quick muscle contractions. The therapist prescribes the number of quick contractions based on how many can be done at the initial evaluation. Quick contractions involve quick, maximal recruitment of the PFMs, followed by quick relaxation. These contractions are usually held for <2 seconds. Quick contraction of the PFM is necessary to avoid leaking during quick movements such as sneezing, jumping, and running.

Sets How many sets should the patient do in 1 day? Patients with weak PFMs should do a set of contractions (as determined previously) several times during the day. The sets should be spaced throughout the day and performed up to three to four times per day, with a total of 30 to 60 pelvic floor contractions per day[73] (**Evidence and Research 18-10**).

EVIDENCE and RESEARCH 18-10

A meta-analysis of PFE and symptom reduction shows that as little as 24 contractions per day can be beneficial.[84]

Activity

Posture Gravity pulls down on the pelvic floor in upright positions. Patients with very weak PFMs should therefore do their exercises in the horizontal position (i.e., gravity neutral). Patients with moderately strong PFMs can perform exercises in the sitting position (i.e., against gravity) and advance to the standing position as they feel stronger. Results of the manual muscle test (MMT) using an internal examination of the PFMs provide the basis for prescribing exercise positions accurately. All patients should eventually progress to doing PFEs while standing, because it is necessary for the muscles to function well in this position (i.e., most incontinence occurs while standing). Some publications recommend that women practice PFEs while driving or waiting in line. However, initially, patients should learn these exercises in a quiet place so they can concentrate and perform the exercises correctly. After the exercises are learned well, patients can do them while waiting in line or watching TV.

Accessory Muscle Use Contraction of the abdominal, adductor, and gluteal muscles can result in an overflow to the PFMs,[85] facilitating strengthening of weak PFMs. Simply stated, overflow is the intentional contraction of associated muscles to increase recruitment of very weak muscles. This technique is usually reserved for patients with an MMT result of 1/5 or 0/5 or in patients who are unable to learn the isolated technique, such as those with cognitive deficits. Conversely, if the patient has an MMT result of 3/5 or higher, the therapist discourages the use of accessory muscles. Eventually, all patients should learn to contract the PFMs without accessory muscles. However, an abdominal contraction with bearing down is never desirable and will result in poor results (**Evidence and Research 18-11**).

EVIDENCE and RESEARCH 18-11

Several studies[86,87] have shown the close synergy of the abdominal muscles (particularly the transversus) and the PFM (see Chapter 17). Therefore, it is neither necessary nor desirable to keep the abdominal muscles completely silent during a PFM contraction.

A pilot study of 27 women with SUI investigated outcomes of a 6-week protocol of pelvic floor muscle training (PFMT) compared to resisted hip rotation (RHR) exercises. The PFMT group was instructed to perform isolated PFM contractions, while the RHR group was instructed to perform seated hip external rotation and internal rotation exercises. Both groups demonstrated significant improvement in all outcome measures. The authors concluded that PFMT and RHR are both effective interventions for the treatment of SUI.[88]

Patient Education Before teaching patients how to do the PFEs, they should be educated about the location and function of the PFMs, and the importance of normal PFM function.

There are many commercially available charts, posters, and handouts that give a two-dimensional view of the location of the PFMs. However, many patients find three-dimensional models more helpful. Pelvic models that have the PFMs and obturator internus muscles in place help in explaining the proximity of the PFMs to the muscles of the buttocks and hips. Alternatively, the therapist can use a standard pelvic bone model and place her hand from the coccyx to the pubic bone to signify the muscles. The patient should understand that the PFMs are internal (approximately 2 inches into the vagina) and are in close proximity to the hip muscles. However, it is neither necessary nor desirable to contract the hip muscles while exercising the PFM, unless the therapist is using overflow principles.

An explanation of Dr. Kegel's three functions of the PFMs (the three Ss) is usually sufficient for the patient[6]:

- *Supportive*: They hold the pelvic organs up.
- *Sphincteric*: They stop urine, feces, and gas from escaping until the person reaches the toilet.
- *Sexual*: They help women grip the penis and increase sexual feelings. They help men form and maintain an erection.

The therapist should teach the differences in function between quick and endurance contractions. The analogy of sprinters and marathoners helps to explain the quick and endurance properties of the muscle. Sprinters depend on the quick muscle fibers, which are mainly responsible for the sphincteric function. The quick fibers contract quickly before a sneeze or cough. Marathon runners depend on the endurance muscle fibers, which provide the supportive function and hold up the organs. A combination of quick and endurance fibers assists in sexual function.

The following points are examples of the importance of normal muscle function. The information can be individualized for each patient:

- A well-exercised muscle has a good blood supply and may recover better from trauma such as childbirth or surgery.
- It is easier to learn these exercises before changes occur from surgery, pregnancy, childbirth, or aging. All women should have a basic knowledge of the PFMs and how they should be exercised. PFEs should be a part of a woman's basic self-care, such as brushing her teeth and showering.
- Incontinence is a symptom not a disease. It is not an inevitable sequel of pregnancy, surgery, or aging.
- Exercising these muscles before and after bladder suspension surgery may enhance the operative results.[89] Some patients still have symptoms after bladder surgery or become incontinent several years later. Strengthening the PFMs may reduce the likelihood of recurring symptoms.

The normal PFM function is helpful in the treatment of low back and pelvic pain.[90] Weakness or tension in this muscle group may result in stress to adjacent hip muscles and perpetuate activity limitations. Hip, buttock, and leg pain may not resolve unless this muscle group is functioning normally (**Evidence and Research 18-12**).

EVIDENCE and RESEARCH 18-12

PFEs started during pregnancy result in less incontinence and pain after delivery.[91,92] 87% of patients can significantly reduce or eliminate incontinence with PFEs.[73] About 49% of patients verbally instructed in PFEs are doing them incorrectly.[93] Approximately 25% are pushing down (bearing down) on the pelvic floor.[93] Precontraction of PFM before moderate cough results in 98% decrease in UI.[83]

Home exercises are an essential aspect of PFM strengthening. Before patients begin to perform these exercises on their own at home, they must have a complete understanding of their muscles and how to exercise them, avoiding a Valsalva maneuver. The therapist must describe the exercises correctly and encourage patients to use the home exercises described in the next section. **Display 18-7** provides verbal cues that can be used to instruct a patient how to perform a PFM contraction. The therapist should be aware of a patient's comprehension of the following exercises. Many patients nod and agree just to end the discussion of an embarrassing subject. The therapist should address this form of exercise with the same professionalism and completeness as she does for any other exercise. This approach can place the patient at ease, and it emphasizes the importance of the exercises (**Evidence and Research 18-13**).

DISPLAY 18-7
Verbal Cues Used to Teach Pelvic Floor Contractions

- Best female instruction—Tighten the muscles that you would use to stop gas from escaping at an embarrassing time.[96]
- Best male instruction—"shorten the penis" or "stop the flow of urine."[94]

Other instructions

- Tighten and lift the muscles around your vagina, and pull them up and inward, as if to stop urine flow.
- Pull your muscles up and in, as if you had the urge to urinate and could not stop to use the toilet.
- Gently push out, as if to pass gas, and then quickly pull the muscles back up and in.

EVIDENCE and RESEARCH 18-13

Stafford et al.[94] investigated the activation of PFMs in 15 healthy men with various verbal cues utilizing transperineal ultrasound imaging which was validated with fine wire EMG recording. The investigators concluded that the instructions to "shorten the penis" resulted in the greatest striated urethral sphincter activity and "tighten around the anus" resulted in the greatest anal sphincter activity. Instructions to "elevate the bladder" resulted in the greatest increase in intra-abdominal pressure. It was suggested not to use the cue "elevate the bladder" when instructing men to perform PFE.

Henderson et al.[95] conducted a cross-sectional study of 779 women to determine how many women could correctly perform a PFM contraction with the instruction "squeeze the muscles in the vagina and hold like you are holding urine," if this ability differed between women with or without pelvic floor dysfunction and if women could learn correct contraction with basic instruction. 120 women could not perform a correct PFM contraction; however, 78% were able to learn with the instruction to "use your vaginal muscles instead of your bottom muscles." Women with pelvic organ prolapse were less likely to learn than women with neither pelvic organ prolapse nor SUI.

Follow-up of the home exercise program is important. To improve compliance, it may be helpful for patients to keep a diary of the exercise routine and list how many times per day incontinence occurs. At subsequent sessions, ask patients the following information:

- How many, how long, and in what position they are doing the exercises
- If they feel the contraction
- If the muscles are getting stronger
- If the symptoms are decreasing

These home exercises are used in conjunction with the self-assessment test described in the evaluation section of this chapter (see **Self-Management 18-1**). After going over the self-assessment test and home awareness exercises with the patient, this information may be copied and given to the patient to take home with her. The patient should perform the tests and awareness exercises at home and then report to the therapist for documentation of results and development of an individualized PFE program.

SELF-MANAGEMENT 18-1
Home Awareness Exercises

These exercises are used to help you understand what you should be doing during the Kegel or PME. Try the exercises at home, and report the results to your physical therapist. Remember that this is an internal muscle, and you should try not to contract the leg or buttock muscles. During these exercises try to identify

1. If you are doing the exercises correctly
2. How long you can hold the contraction (in seconds) up to 10 seconds
3. How many repetitions you can perform holding the contraction for the previous length of time
4. How many quick contractions you can perform

Index Finger on Perineal Body

Place your index finger on the perineal body (i.e., the skin between the vagina or penis and the rectum) or lightly over the anus. This can be done over your underpants in some cases. Contract the PFMs, and feel the perineal tissue moving away from your finger, up and into the pelvic cavity. If the PFM is very weak, you may not feel much movement. However, you should never feel the anus or perineal tissue moving toward your finger or bulging. If you feel tissues moving toward your finger, stop exercising, and ask your physician, midwife, physical therapist, or other health professionals to instruct you in the proper PFM contraction.

Finger into Vagina or Rectum

Place your index finger into the vagina or rectum up to the level of the second knuckle. Palpate the muscle on either side of the vagina or rectum while you contract the PFMs, pulling them in and up. You should feel the muscles contract around your finger and pull your finger up and in. If you feel tissues pushing out of your body or bulging, ask your health care professional to examine the area.

Visual Exercise

Women Lie on your back with your knees bent and your head resting on several pillows. Hold a mirror so that you can see your perineal body and rectum. Contract the PFMs up and in, and watch the perineal tissues moving up into the body. It may be difficult to see the movement if the muscles are very weak. Seek further professional instruction if any tissue comes toward the mirror or bulges outward.

Men Stand in front of a long mirror, and watch the penis as you contract the PFM up and in. The penis should move slightly upward during the contraction.

Sexercise (for Women)

Contract the PFMs around the penis during intercourse.

Putting It All Together—The Exercise Program

The exercises described in Self-Management 18-1 are designed to help the patient identify and effectively contract the PFMs. However, it is important to create an exercise program that challenges the PFMs of each patient.

For example, if a patient's self-assessment test (e.g., digital self-examination) shows that the PFM contraction was held for 5 seconds and repeated 5 times and that 10 quick contractions were performed, her evaluation results would be as follows:

- Duration of endurance contraction hold: 5 seconds
- Repetitions of endurance contractions: 5 times
- Repetitions of quick contractions: 10 times

With this information, the therapist could prescribe the following exercise prescription (see **Display 18-8**).

Self-assessment and modification of the exercise program continue periodically throughout rehabilitation. Remember to ask the patient how often and how many PFM exercises she can do (see **Case Study 18-4**). Ask if her symptoms are improving (i.e., decreasing incontinence).

Pain

Pelvic Floor Muscles

Increased PFM tension with or without muscle shortening occurs in response to many situations outlined in the "Overactive PFM" section of this chapter. Pain and altered tone impairments are usually the primary impairments of overactive PFM[97] and may be caused by the following:

- Lumbopelvic or hip impairments
- Tonic holding patterns of the PFMs
- Abdominal adhesions
- Adhered scars in the trunk and perineum
- Fissures and fistulas

Coccyx pain is rarely a result of sacrococcygeal joint mobility impairment, but it usually is caused by referred pain from tension and trigger points in the surrounding muscles. The PFMs, obturator internus, gluteus maximus, and piriformis can refer pain to the coccyx (**Fig. 18-8**).

DISPLAY 18-8
Sample Exercise Prescription

- Duration of endurance muscle contractions: 5 seconds
- Rest between endurance muscle contractions: 10 seconds (*double rest for patients with weak PFMs*)
- Repetitions of endurance muscle contractions: 5 times (*complete relaxation between contractions*)
- Repetitions of quick muscle contractions: 10 times (*to train the fast-twitch muscle fibers*)
- Sets per day: 3 to 4 (*exercise weak muscles in short sessions, frequently*)
- Position: *gravity eliminated—lying down on back or side*
- Accessory muscle use: *not at this time*
- Functional training: "*squeeze before you sneeze*" (*contract PFM before and during coughing, sneezing, lifting, straining*)

CASE STUDY 18-4

Develop a PFE program for Ms. Smith using the self-assessment information provided earlier.

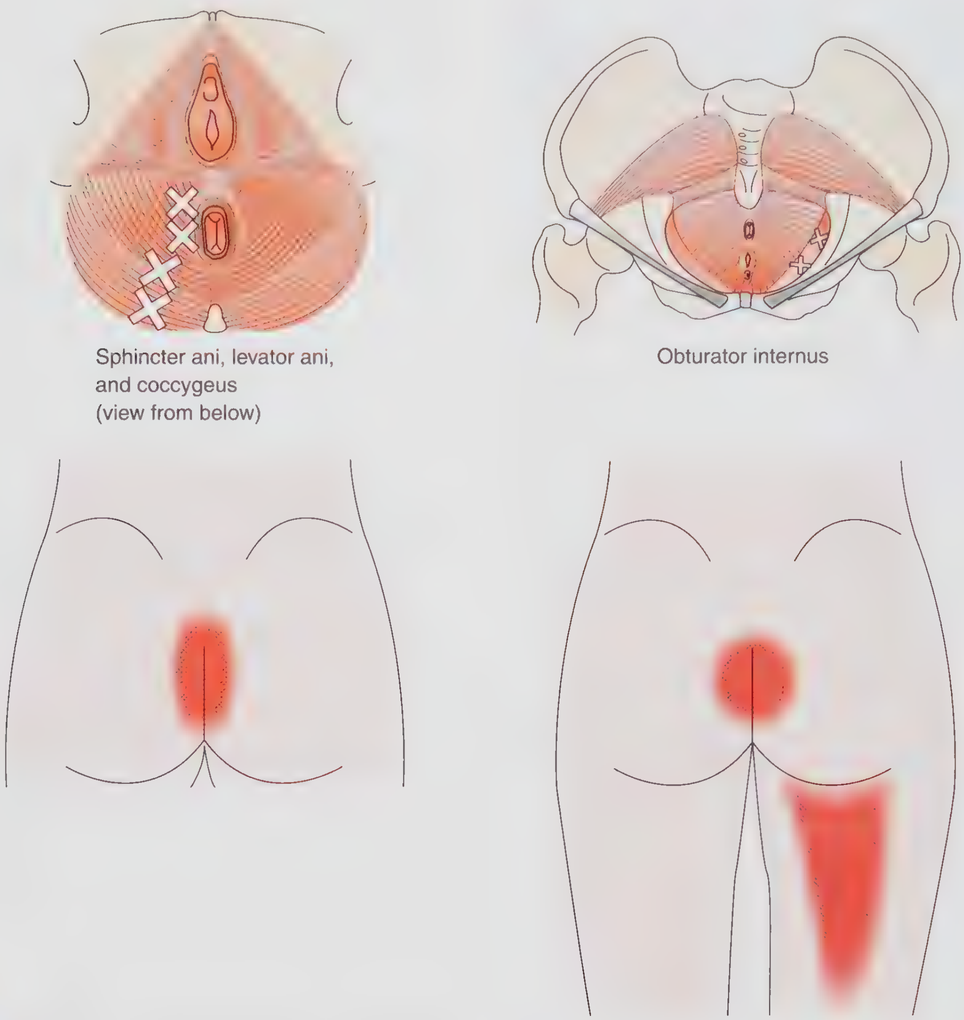


FIGURE 18-8 Trigger points (x) and their referral pain patterns (*shaded areas*).

Treatment of increased PFM tension includes manual soft tissue manipulation of the PFM vaginally, rectally, or externally around the ischial tuberosities and coccyx. Surface EMG biofeedback and PFEs may also help restore the normal tone of the PFMs. In some cases, the PFMs become "frozen" and cannot relax or contract effectively (see **Patient-Related Instruction 18-3**).[68] Modalities such as electrical stimulation, ultrasound, hot, and cold may be used on the perineum to treat the spasm. The therapist should learn the logistics of applying the modality onto the perineum.[98] Modality parameters and other treatment considerations are the same as those used for increased muscle tension in other areas of the body.

Patient-Related Instruction 18-3

Importance of Relaxing the PFMs

PFMs must be completely relaxed for normal function. For example, if you hold a brick in your hand all day and at the end of the day are asked to throw the brick 10 feet, you would probably not be able to throw it, because your arm muscles would be cramped and tired. Tonic holding of the PFMs often results in a crampy pain in the groin, rectum, or tail bone area. One goal of recovery is to be able to contract and relax the PFMs well.

Hip Muscles

Any muscle imbalance at the hip and trunk may contribute to overactive PFM through sacroiliac joint impairments.[90] It is often difficult to pinpoint the origin of pain in the lower pelvic region. Increased muscle tension and trigger points are common causes of pain in the perineum, groin, and coccyx areas. Travell and Simon[13] described referred pain patterns originating from trigger points in the adductors, PFMs, obturator internus, and piriformis (**Figs.** 18-8 and **18-9**). Spasm and trigger points in these muscles may be primary or secondary impairments and should be treated in all patients with PFM dysfunction. The treatment for increased hip muscle tension includes soft tissue manipulation, modalities (i.e., ultrasound, electrical stimulation, hot or cold packs), therapeutic exercises for stretching and strengthening, and patient education about body mechanics and postures.

Trunk Muscles

Iliopsoas and abdominal trigger points and tension may be the primary muscular impairment in pelvic pain conditions. Increased iliopsoas tension may irritate the pelvic organs that overlie them and vice versa, making iliopsoas altered tone impairments an important condition to treat in cases of visceral dysfunction. Treatment of these muscles is essential to full recovery.[99]

Joint Mobility and Range of Motion (Including Muscle Length) Impairments

An increase in PFM resting tone is often related to sacroiliac, sacrococcygeal, pubic symphysis, and lumbar joint mobility impairments. These impairments may be primary or secondary and include hypomobility or hypermobility (see Chapter 7). Mobility restriction of scar tissue and connective tissue in the perineum and groin can also affect PFM's function greatly.

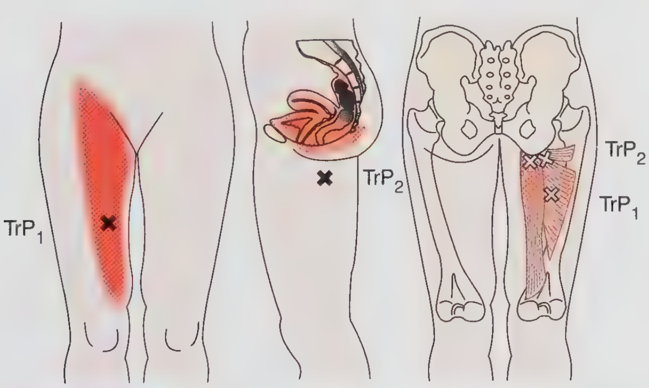


FIGURE 18-9 Trigger points (TrP) of the hip adductors (x) and their referral pain patterns (*shaded areas*).

Joint Integrity and Mobility Impairments of the Lumbopelvic Region Resulting in PFM Dysfunction

Hypomobility or hypermobility of the sacroiliac joint, pubic symphysis, or sacrococcygeal joint may cause the secondary impairment of PFM altered tone.[90,100] Pain from lumbopelvic–hip joint integrity or mobility may lead to a tonic holding pattern of the PFMs similar to that seen in the cervical muscles after an acceleration/deceleration injury (i.e., whiplash). The hypogastric plexus (T10 through L2) provides sympathetic innervation to the pelvic and perineal areas. Normal joint mobility in the T10 through L2 region may normalize sympathetic nerve output to the perineum and decrease pelvic pain symptoms. This hypothesis is based on clinical findings and has not been researched in experimental trials (see **Case Study 18-5**). Sacroiliac mobility impairments may also cause pain-induced PFM weakness. Any malalignment of the pelvis can alter the origin and insertion alignment of the PFMs and impair function by causing altered muscle tone or weakness. Significant joint integrity and mobility impairments of the lumbo-pelvic-hip complex should be treated with joint mobilization, positioning, soft tissue mobilizations, therapeutic exercise, and other modalities to achieve full recovery in PFM dysfunction.

Lumbopelvic Joint Mobility Impairments Resulting from PFM Dysfunction

A unilateral increase in PFM resting tone may contribute to and perpetuate pelvic joint mobility impairments. In some cases, altered PFM tone that is untreated may be the reason for continued mobility impairments. This is seen commonly in the sacroiliac joint and less frequently in the sacrococcygeal joint. Because of PFM attachment onto the sacrum, unilateral PFM tone impairments can result in torque of the sacrum similar to the torque created by a unilateral piriformis tonic holding pattern. Unilateral PFM altered resting tone can occur as a result of trauma, such as adductor strain with insertion injury, birth injury, or a fall on the pubic rami. PFM tone impairments can be caused by sacroiliac joint mobility impairment and then become the reason for continued joint dysfunction. Whether it is the primary or secondary impairment, normalizing PFM resting tone is necessary to restore and maintain normal sacroiliac joint mobility in these cases.

Lumbopelvic Joint Mobility Impairments Resulting from Adhesions

Visceral adhesions may cause sacroiliac joint mobility impairments, especially if unilateral adhesions from the organ to the sacrum are severe. Therapists with additional training use visceral mobilization techniques to manipulate organs and abdominal fascial tissue. These techniques are used to stretch adhesions and restore normal movement of lumbopelvic joints and pelvic organs.

CASE STUDY 18-5

During the pelvic examination, you identify signs of sacroiliac dysfunction. Explain to Ms. Smith how her urinary leakage may be related to her LBP.

For example, in endometriosis, endometrial tissue implants in the abdominopelvic cavity outside the uterus. As with the tissue inside the uterus, the explanted tissue responds to hormones during the menstrual cycle causing irritation, inflammation, and eventually scars and adhesions. Adhesions from endometriosis can be extensive throughout the abdomen and are often treated with laparoscopic laser surgery. Adhesions can pull on the ilium, coccyx, or sacrum and constrict bowels or fallopian tubes, altering joint and organ function. Bowel adhesion to the pelvic side wall is found in 14 out of 15 patients with chronic pelvic pain.[85] Soft tissue mobilizations of abdominal adhesions and organs can enhance organ function and may be the necessary link in maintaining normal mobility in the pelvic joints.

Scar Mobility Restrictions

Episiotomy is a common obstetric procedure that involves making a cut in the perineal body immediately before vaginal delivery, usually to ease delivery (**Fig. 18-10**). Vaginal tissue may tear as an extension of an episiotomy or in lieu of an episiotomy at the time of delivery. Episiotomies and tears may result in adhesions and pain wherever the scar tissue occurs—at the perineal body, tissue inside the vagina, and even toward or into the rectum. Adhesion pain usually occurs in the immediate postpartum stage and abates in most women after 4 to 6 weeks. However, this pain persists in some women and can be so severe that intercourse is impossible and every bowel movement hurts. Sitting may be impossible, or sitting tolerance may be limited. An increase in PFM resting tone and adhesions are the most common impairments in these patients.[101] Treatment includes soft tissue manipulation and friction massage of scars externally and internally. Modalities, such as ultrasound, hot packs, and cold packs, also are used. PFEs and biofeedback are important in restoring the normal contraction and relaxation of muscles (see **Building Block 18-3**).

BUILDING BLOCK 18-3

A 40-year-old female with thoracic pain recently underwent a tummy tuck. She has limited trunk extension and weakness in the upper back. What measurements would be important to collect in the abdominal region? List three abdominal treatments that may decrease her thoracic pain.

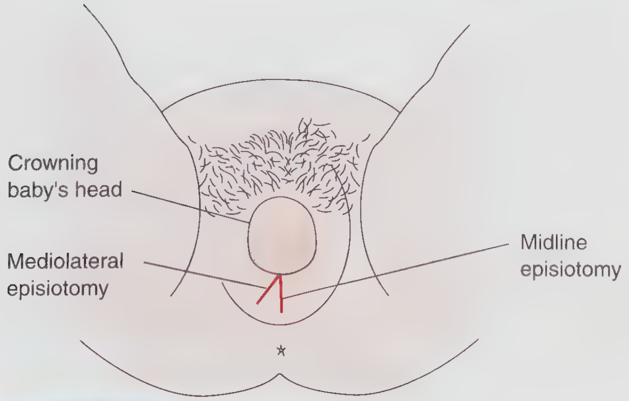


FIGURE 18-10 Possible sites of episiotomy.

Connective Tissue Mobility Restrictions

Muscle strains often result in irritation to connective tissues and shortening of fascia and tendons. Groin injuries commonly traumatize the adductor muscle group. This is a very large muscle group that inserts onto the pubic ramus and ischial tuberosity. Physical therapists often treat the distal adductor muscle and fascia, whereas restrictions in connective tissue mobility and increased resting tone of the proximal adductor muscles are often left untreated. Tissue at the insertion of the adductor muscles to the pubic arch should be evaluated and treated in patients with persistent groin pain. A similar condition may occur in the hamstring muscles. The hamstring tendon sends a slip of connective tissue to the sacrotuberous ligament, which eventually fuses with the posterior sacroiliac ligaments. Impaired mobility of connective tissue at the proximal hamstring muscle may be related to persistent sacroiliac joint dysfunction. These conditions may occur with increased resting tone of the PFMs. Treatment of connective tissue mobility impairment includes soft tissue mobilization, therapeutic exercise, and modalities (i.e., ultrasound, electrical stimulation, and hot packs).

Posture Impairment

Poor posture and body mechanics are commonly associated with joint mobility impairments. Education about proper posture and body mechanics is included in the treatment of all patients with joint dysfunction of the lumbopelvic area. Sitting posture demands special attention in patients with overactive PFM (see **Patient-Related Instruction 18-4**).

Coordination Impairment

Coordination impairment is related to inappropriate patterns of timing and recruitment of the PFMs and abdominal muscles. This impairment includes incoordination of the PFM contraction, incoordination of the abdominal contraction, incoordination of the PFMs during ADLs, and incoordination of the PFMs with the abdominals.

Pelvic Floor Muscles

Coordination impairment of the PFMs is the inability of all the PFMs to contract and relax at the appropriate times. Manual evaluation of the PFMs and biofeedback training may reveal the patient's inability to create and hold a synchronous contraction. This problem is usually related to decreased awareness of the PFMs. In nonneurologic conditions, the patient can usually learn the correct sequencing and timing of contraction through some form of biofeedback (e.g., surface EMG; pressure; contracting around a finger, penis, or similar object).

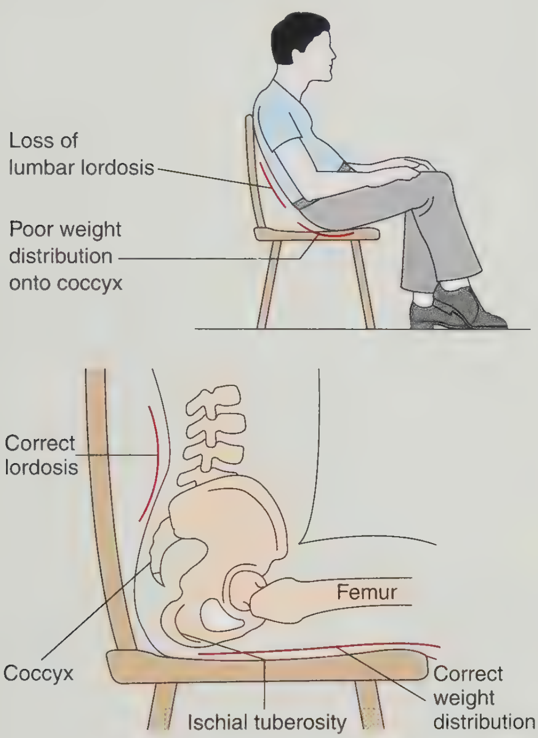
Pelvic Floor Muscles During ADLs

Coordination impairment of the PFMs during ADLs is observed in stress incontinence, with urine leaking during lifting, coughing, and sneezing. In some cases, leaking results from impaired performance of the PFMs. However, some patients have fairly good PFM strength but do not contract the PFMs at the proper time during the activity. All patients must learn to contract the PFMs before and during increased intra-abdominal pressure (e.g., cough, lift, sneeze) (see **Patient-Related Instruction 18-5**).

Patient-Related Instruction 18-4

Proper Sitting Posture

- Proper sitting posture is essential for relief of perineal and tail bone pain.
- Weight should be shifted forward on the two "sit bones" and thighs.
- There should be no pressure on the tail bone.
- Push your buttocks back in the chair so there is no space between your very low back and the chair.
- Use a small towel roll at your waist to maintain the inward curve if needed.
- A firmer chair can support your posture better and decrease pressure on the tail bone.
- Poor sitting posture places weight on the coccyx.



Proper sitting posture places weight on the ischial tuberosities and posterior thigh.

Patient-Related Instruction 18-5

Squeeze Before You Sneeze

Practice contracting the PFMs immediately before sneezing, coughing, laughing, lifting, or straining. This is similar to training yourself to bring your hand to your mouth before you sneeze. By voluntarily contracting the PFMs before increases in abdominal pressure, you will eventually create a habit, and the PFMs will contract automatically.[83]

In addition, it is necessary to relax the PFM during activities such as micturition and defecation. Inability to relax during these activities may result in obstructed voiding and defecation in which the bowel and bladder are unable to empty completely (see **Building Block 18-4**). Inability to relax during intercourse may result in painful penetration (also known as dyspareunia) (**Evidence and Research 18-14**).

BUILDING BLOCK 18-4

A 34-year-old tennis player is having SUI during the serving maneuver of her game. What might be the pathophysiology of this condition? What could you suggest she do to decrease her leakage?

EVIDENCE and RESEARCH 18-14

One study showed that training patients to contract their PFMs prior to performance of ADLs that increase intra-abdominal pressure can decrease urine leakage up to 70%.[83,102]

Pelvic Floor Muscles with Abdominal Muscles

The therapist should understand proper contraction of the PFMs with the abdominal muscles to correctly instruct the patient. An exercise to experience this can help the student to understand the relationship of the PFMs and abdominal muscles. Start by sitting up in a chair and pouching the abdominal muscles outward. Keep the abdomen pouched out and contract the PFMs, notice the amount of effort needed and the force generated by the PFMs. Next, sit up in the chair and pull the abdominals inward, supporting the abdominal contents and the back. While holding the abdominal contraction gently and contracting the PFMs, notice the effort needed and the force generated by the PFMs (**Evidence and Research 18-15**).

EVIDENCE and RESEARCH 18-15

Needle EMG studies show that the abdominal muscles participate in a synergy with the PFMs.[86,87]

Most persons feel a stronger PFM contraction when the abdominals are pulled inward properly. This is especially evident in the presence of PFM weakness. The PFMs cannot contract effectively when the abdominals pouch out, while bearing down, or during a Valsalva maneuver. In PFM training, it is especially important not to bear down and bulge the abdominals outward with the PFM contraction.

Bearing down is associated with PFM relaxation during bowel movement. PFM contraction during defecation is an example of PFM coordination impairment. This results in difficulty passing feces and often causes constipation and pain, which may be diagnosed as obstructed defecation. The patient must learn how to relax the PFMs at the proper time in association with the proper abdominal contraction for defecation (**Table 18-3**).

Abdominal Muscles

Coordination impairment of the abdominal muscles results in an inability to pull the muscles inward. These impairments must be treated before considering PFM timing with the abdominals. See Chapter 17 for specific training techniques.

TABLE 18-3

Coordination of the PFM

ACTIVITY	NORMAL PFM ACTION	NORMAL ABDOMINAL ACTION	DYSFUNCTIONAL PFM ACTION	RESULT OF DYSFUNCTIONAL ACTION
Lifting	Contraction	Inward contraction by obliques	Relaxation or weak contraction	Leaking urine
Bowel movement	Relaxation	Bulging contraction by rectus abdominis with Valsalva maneuver	Contraction	Difficulty passing feces, constipation, pain

CLINICAL CLASSIFICATIONS OF PELVIC FLOOR MUSCLE DYSFUNCTION

PFM dysfunctions have two clinical classifications, which are used internationally by specialized physical therapists, nurses, and physicians.[7] Two additional classifications are presented for a complete view of pelvic floor rehabilitation. Clinical classifications are intended to guide the therapist in treatment planning. However, the type and severity of physiologic impairments within the dysfunction vary, and treatments must be individualized. Each classification has a brief description of the syndrome and a discussion of the cause, common impairments, and activity limitations. There are many possible causes for these dysfunctions, which often result from a combination of pathologic conditions and comorbidities. In many cases, the primary cause is unknown. Therapists should have some understanding of the causes and comorbidities of the dysfunction they are treating. It is necessary to identify the correct impairment for effective treatment.

Much of the information on PFM dysfunctions is based on the clinical observations of pelvic floor physical therapists around the country. All four clinical classifications are presented to provide a complete view of the dysfunctions treated by physical therapists. The medical diagnoses associated with supportive and overactive PFMs are discussed later in this chapter (see **Fig. 18-11**).

There are two internationally accepted clinical classifications:

1. Underactive PFM
2. Overactive PFM

Other classifications are:

1. Incoordination dysfunction
2. Visceral dysfunction

Underactive PFM

Underactive PFMs results from the loss of strength and integrity of contractile tissues; this dysfunction is weakness and sagging of the PFMs. Common medical diagnoses often associated with underactive PFMs are stress incontinence, mixed incontinence, and pelvic organ prolapse (see **Patient-Related Instruction 18-6**). The supportive role of the PFMs in continence is discussed earlier in this chapter.

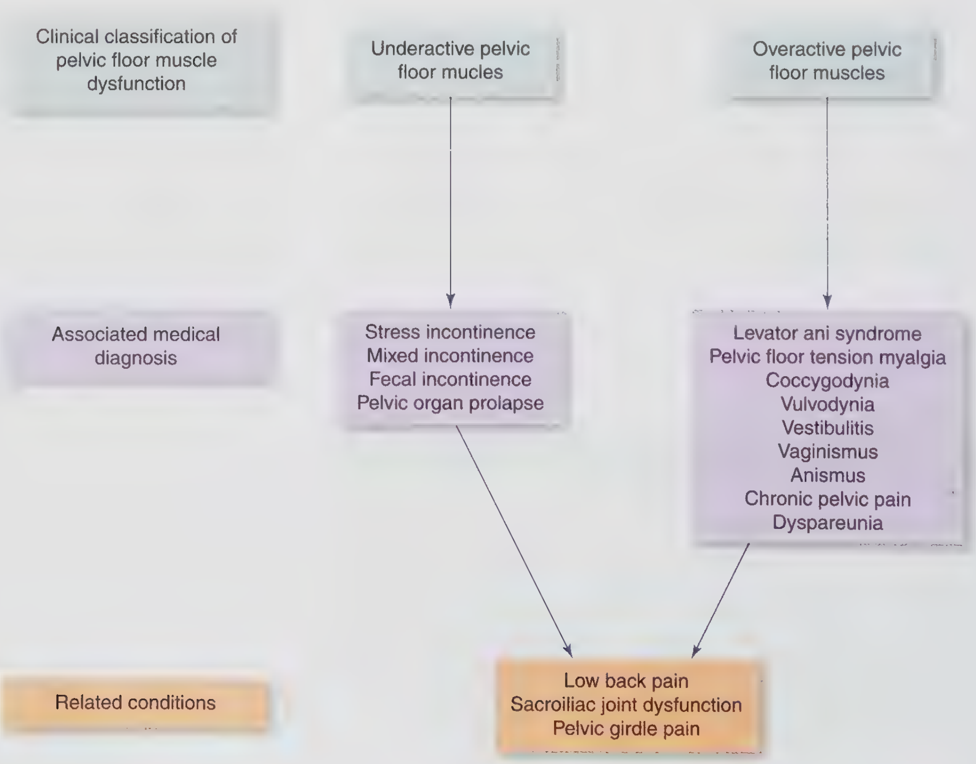
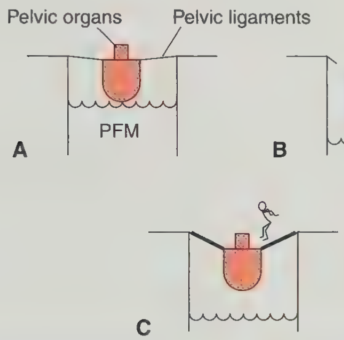


FIGURE 18-11 Classification of different types of pelvic floor dysfunction.

Patient-Related Instruction 18-6

Boat at the Dock–Role of PFMs in Organ Prolapse

- Imagine there is a boat tied to a dock **(Fig. A)**. The pelvic organs (i.e., bladder, uterus, and rectum) are the boat. The ropes holding the boat to the dock are the ligaments that support the organs from above. The water is the PFM.
- If the water level drops **(Fig. B)** (i.e., loss of support or weakness of the PFMs), the boat (organs) hangs on the ropes (ligaments). Eventually, the ropes stretch out and break, resulting in the boat (organs) falling down (i.e., prolapse).
- If you pull the boat back up by replacing the ropes (i.e., organ suspension surgery) without raising the water level (i.e., PFMs strengthening) **(Fig. C)**, the boat will continue to hang on the ropes and eventually falls down again (i.e., recurrent prolapse). Falling happens quicker if you jump on the boat (i.e., increase pressure in the abdomen from cough, sneeze, lift, or improper exercise).
- Long-lasting results are more likely if you raise the water level (i.e., PFM strengthening) and stop jumping on the boat (i.e., reduce unnecessary increases in abdominal pressure). In this case, the ropes (ligaments) may or may not need to be replaced (i.e., ligament and pelvic organ surgery).



Etiology and Comorbidities

Severe birth injury may result in anatomic impairments of the PFMs and nerves in the area. Altered muscle length or tension may occur with stretch during delivery. Stretching of connective tissue or muscle beyond its elastic capacity renders the tissue permanently long. The increased length of connective tissue means that the muscle must generate more force to accomplish the same function. Functional weakness and impaired muscle performance result. Hypertrophy of the remaining muscles often produces the desired effect of improved support of the PFMs.

Muscle atrophy can result from central and PNS dysfunction, including nerve damage from pelvic surgery. Temporary neurologic dysfunction, such as mild stretch to the pudendal nerve during delivery, often responds well to PFE. In conditions of mild or incomplete nerve damage, the remaining PFMs often become hypertrophied and produce good functional outcomes. Pelvic surgery may result in complex anatomic changes that affect PFM function.[103] (**Evidence and Research 18-16**)

EVIDENCE and RESEARCH 18-16

One study reported 15% to 20% of patients undergoing radical pelvic surgery had permanent voiding dysfunctions.[104]

Prolonged increased intra-abdominal pressure may result in stretching of the PFMs or their tendons and may contribute to pelvic organ prolapse. Repeated, incorrect lifting or straining with Valsalva maneuvers and chronic or prolonged coughing or vomiting perpetuate incontinence and prolapse symptoms and slows recovery of PFM strength. These chronic increases in intra-abdominal pressure may initiate PFM impairment. Pregnancy and abdominal obesity increase intra-abdominal pressure. Obesity correlates with increased incontinence.[104–106]

Hormones released during pregnancy loosen the connective tissue of PFM tendons, which causes the muscles to sag. Because pregnancy is a temporary condition, most physicians and therapists are not concerned about symptoms of underactive PFMs during pregnancy. However, 9 months of prolonged intra-abdominal pressure, especially with improper lifting at work, during exercise and ADLs, or with lifting another child, and prolonged, hormone-induced lengthening may result in significant postpartum supportive PFM dysfunction, even with a cesarean delivery.[107]

Many young children are taught not to touch or look at the perineum. In some cases, this early training results in adults with decreased awareness of the PFMs. Decreased awareness does not necessarily result in PFM weakness, but disuse atrophy may occur when decreased awareness is combined with other risk factors, such as menopause and bed rest. The PFMs are used less when a Foley catheter is in place and while patients are on prolonged bed rest. Decreased awareness of PFM contraction often exists concurrently with other impairments and makes rehabilitation more challenging. Many patients with severely decreased awareness can benefit from biofeedback instruction to identify the correct muscle contraction.

Common Impairments

The most common physiologic impairments of underactive PFM are:

- Impaired PFM performance
- PFM weakness
- Increased PFM length
- Increased connective tissue length
- Muscle atrophy
- Endurance impairment of the PFMs
- Impaired abdominal muscle performance
- Abdominal muscle weakness
- Increased length of the abdominals

The less common physiologic impairments associated with underactive PFM should also be treated for full recovery. Coordination impairment of the PFMs during ADLs often exists to some degree in underactive PFMs; coordination impairments of the abdominal muscles also occur with underactive PFMs. When the PFMs are fairly strong and incoordination is significant, the patient is given the diagnosis of incoordination dysfunction. Pain impairments of the PFMs may be a concurrent problem that may lead to pain-induced weakness. In this case, the origin of pain must be treated to reach maximum muscle strength. Joint mobility impairment of the lumbo-pelvic-hip region may also affect the PFMs. A summary of impairments and suggested interventions for underactive PFM is provided in **Display 18-9**.

DISPLAY 18-9
Summary of Impairments and Suggested Interventions for Underactive PFMs

- Impaired performance and endurance of the PFM: weakness, increased length, atrophy
- PFE with facilitation, overflow, biofeedback
- Neuromuscular electrical stimulation
- Coordination impairment of the PFM: decreased awareness of how to contract correctly
- PFE with biofeedback and during ADLs
- Coordination and impaired performance of the abdominals
- Therapeutic exercise for the abdominals
- Proper contraction of abdominals with function
- Pain in PFM and mobility of pelvic joints
- Soft tissue mobilization, scar mobilization
- Joint mobilization, muscle energy techniques
- Modalities such as heat, cold, ultrasound, and electrical stimulation

Activity Limitations

Patients may exhibit symptoms of stress incontinence, mixed incontinence, and organ prolapse. Loss of urine with coughing, sneezing, laughing, lifting, or exercising often requires the use of absorbent products (i.e., incontinence pads or diapers). Some patients limit or modify activities for fear of leaking urine.[108] Patients may avoid shopping trips, overnight vacations, outdoor activities, and sports because of incontinence. Urinary frequency is urination more than seven times in a 24-hour period, and urination sometimes occurs as often as every 30 to 40 minutes. Frequency in conjunction with urinary urgency may require modification of ADLs, because patients usually do not venture far from the toilet. Lack of PFM support may be painful and result in decreased ability to ambulate or exercise.

Overactive PFM

Overactive PFM is a complex category related to pain and increased resting tone of the PFMs. Common medical diagnoses associated with overactive PFM include:

- Levator ani syndrome
- Pelvic floor tension myalgia
- Coccygodynia
- Vulvodynia
- Vestibulitis
- Vaginismus
- Animus
- Chronic pelvic pain
- Dyspareunia

Overactive PFM may result from pelvic joint dysfunctions, hip muscle imbalance, and abdominopelvic adhesions and scars affecting PFM function.

Etiology and Comorbidities

The cause of overactive PFMs is often more difficult to identify than the cause of other dysfunctions. Lumbopelvic joint mobility impairments or pathology is one of the most common findings in patients with overactive PFMs. Injuries, such as a fall onto the coccyx or pubic ramus, are common for these patients. Lumbopelvic joint dysfunction may result from PFM dysfunction or may directly or indirectly cause an increase in PFM resting tone. Tonic holding patterns may result from the proximity of muscles to traumatized pelvic joints.

Hip joint integrity and mobility, pain, and muscle performance impairments contribute to overactive PFM through its effect on the pelvic joints. Altered tone of the associated muscles, particularly the obturator internus and piriformis, can directly irritate the PFMs, causing a tonic holding pattern.

Abdominal or perineal adhesions and scars can cause overactive PFMs. Pelvic organs must slide freely during physiologic functions such as peristalsis, bowel movement, or vaginal penetration during intercourse. Abdominal adhesions can restrict pelvic organ movement and cause pain and altered tone of PFMs during bowel movements or intercourse. Severe adhesions of the uterosacral ligaments may restrict sacroiliac joint mobility. Adhesions may be a result of pelvic or abdominal surgery or an inflammatory condition of the abdomen, such as endometriosis. Perineal scars (often found in third- or fourth-degree episiotomies) can cause adhesions to the rectum and vaginal walls. These scars can be so painful that patients dread every bowel movement. Other painful conditions such as interstitial cystitis, endometriosis, fissures, and fistulas may also cause holding patterns in response to pain. Holding patterns of the PFMs may occur as a response to excessive generalized stress or reflect an emotional connection to the perineum.[109] Excessive holding of the PFMs because of pain or stress often leads to trigger points, ischemic changes, and tissue shortening.

Connective tissue diseases such as fibromyalgia are associated with overactive PFMs, particularly vulvodynia. Pelvic pain, as discussed earlier, may be a problem for sexual abuse survivors. The exact connection is unknown, but emotional holding of the PFMs and physical trauma to the perineum may play a part in the eventual development of overactive PFMs.

Common Impairments

There are many possible primary physiologic impairments in overactive PFMs. Careful evaluation is necessary to determine the most significant impairments in each patient. The most common impairments of overactive PFM are:

- Altered tone of the PFMs
- Trigger points of the PFMs
- Altered tone and trigger points of associated muscles of the hip, buttock, and trunk
- Impaired muscle performance and coordination impairments of the hip, leading to muscle imbalance around the hip
- Joint mobility impairments of lumbopelvic joints, particularly the sacroiliac, pubic symphysis, and lower lumbar facet joints
- Mobility impairments of scar and connective tissue
- Posture impairment, contributing to pelvic joint dysfunction

Pain impairment because of hypersensitivity of the perineal skin is common in vulvodynia, and Witzeman et al.[110] showed that PFM pain is correlated with dyspareunia in women with provoked vestibulodynia. A summary of impairments and suggested interventions is provided in **Display 18-10**.

DISPLAY 18-10

Summary of Impairments and Suggested Interventions for Overactive PFM

- Altered tone of the PFM: increased resting tone and trigger points
  - Biofeedback for training the PFMs to relax
  - Rhythmic contract and relax of the PFMs (quick PFE)
  - Soft tissue mobilization, vaginally or rectally
  - Electrical stimulation on the sacrum, vaginally or rectally
  - Relaxation training, autonomic nervous system balancing
  - Vaginal or rectal dilators
  - Ultrasound at the insertion of the PFM at the coccyx
  - Heat or cold over the perineum
- Altered tone of the associated muscles of the hip, buttock, and trunk
  - Soft tissue mobilization
  - Therapeutic exercises for stretching
  - Modalities such as ultrasound, electrical stimulation, heat, and cold
- Muscle impairments and coordination impairments of the associated muscles of the hip, buttocks, and trunk: muscle imbalances around the trunk and hip joint
  - Therapeutic exercises for strengthening and stretching
  - Coordination training of muscles around a joint (i.e., around the hip) or between several areas (hip and abdominals)
- Mobility impairment of scar and connective tissue of the perineum, inner thighs, buttocks, and abdominals
  - Soft tissue mobilization, scar mobilization
  - Visceral mobilization
  - Modalities such as ultrasound, heat, and microcurrent
- Mobility impairments (e.g., hypermobility, hypomobility) of pelvic joints: sacroiliac, pubic, lumbar, hip, and sacrococcygeal
  - Joint mobilization, muscle energy techniques, positional release, craniosacral therapy
  - Posture and body mechanics education
  - Therapeutic exercises for muscle imbalances
  - Modalities such as ultrasound, heat, cold, electrical stimulation, and TENS
- Faulty posture leading to undue stress on the pelvic structures
  - Instruction in proper sitting and standing posture and body mechanics
  - Use of cushions, lumbar rolls, and modified chairs
- Pain in the perineum with hypersensitivity of the skin and mucosa
  - Modalities such as cold, heat, ultrasound, and electrical stimulation
  - Education on avoiding perineal irritants, and therapeutic pain education

PFE, pelvic floor exercise; PFM, pelvic floor muscle; TENS, transcutaneous electrical nerve stimulation.

Activity Limitations

Overactive PFMs have activity limitations similar to other pelvic pain syndromes, such as low back and pelvic girdle pain. The ability to work (e.g., lift, sit, push, drive, and clean house), recreate, ambulate, sleep, and perform ADLs may be limited. Activity limitations unique to overactive PFM may result in a decreased ability or inability to sit because of severe perineal pain. Some patients cannot wear jeans or ride a bike. Routine Pap smears can be painful or impossible. The affected woman often has a decreased ability or an inability to have sexual intercourse or sexual contact of any kind.

Many women and men are embarrassed to talk to their doctors, family, and friends about pelvic, perineal, or genital pain. It is difficult to explain the reasons for activity limitations if you are unable to tell someone the location or the nature of the pain. This creates emotional stress. Patient with chronic pelvic pain often suffer in silence for many years before they find a medical professional who is able to treat them effectively.

Incoordination Dysfunction

Incoordination dysfunction can be divided into neurologic and nonneurologic syndromes. Detrusor sphincter dyssynergia is a type of incoordination resulting from a neurologic lesion in the spinal cord between the brain stem and T10. The PFMs and smooth muscle internal sphincter contract during a bladder contraction so that urine is unable to be expelled. This condition should be monitored by a physician. Symptoms of neurologic incoordination are similar to the obstructed voiding symptoms listed in the screening evaluation questionnaire. The therapist should refer the patient to the physician if neurologic incoordination or obstructed voiding is suspected.

Incoordination dysfunction may be a minor dysfunction with underactive or overactive PFMs, or it may occur as the primary dysfunction. Nonneurologic incoordination dysfunction is characterized by absent or inappropriate patterns of timing and recruitment of the PFMs. Common medical diagnoses associated with incoordination dysfunction include stress incontinence, constipation with obstructed defecation, and pelvic pain.

Etiology and Comorbidities of Nonneurologic Incoordination Dysfunctions

The cause of pure nonneurologic incoordination dysfunction is often related to decreased awareness of the PFMs and abdominals. Muscle atrophy is not significant in this dysfunction. Decreased awareness may reflect an emotional condition or a social conditioning. Pain in the pelvic or abdominal area may disrupt recruitment patterns. Surgical intervention may result in inhibition of the muscles—the muscles forget what to do, when to do it, and how it should be done. Some patients have never been aware of the PFMs and have developed poor recruitment patterns.

Common Impairments of Nonneurologic Incoordination Dysfunctions

PFM weakness may be a minor impairment. Most of these patients are found to have good PFM strength on the MMT. Coordination impairment is the primary physiologic impairment. Coordination impairment of the PFMs is discussed previously in the "Coordination Impairment" section.

Activity Limitations of Nonneurologic Dysfunctions

The most common activity limitation of incoordination dysfunction is stress incontinence with urine leaking during increased intra-abdominal pressure, such as during coughing, sneezing, or lifting. Patients also may have obstructed defecation with constipation and rectal pain (see **Building Block 18-5**).

BUILDING BLOCK 18-5

You have been working with a 20-year-old female with LBP and poor trunk stability for 3 weeks. Her symptoms are somewhat better but she continues to have pain. You suspect she would benefit from PFM training. How can you measure her PFM ability? How would you explain to her why it is important to do these exercises?

Visceral Dysfunction

Visceral dysfunction is a pseudo-PFM dysfunction. It is a disease or abnormality of the abdominopelvic visceral tissues that leads to pain and musculoskeletal impairments. Detrusor instability, often found in patients with urge incontinence, is the most widely seen visceral dysfunction directly related to the PFMs. It is characterized by irritated detrusor contractions and is often related to PFM impairments. Urge incontinence responds well to underactive PFM treatments. The causes, impairments, and treatment of urge incontinence are discussed later in Therapeutic Exercise Intervention for Common Diagnoses.

Etiology and Comorbidities

Visceral dysfunction encompasses several medical diagnoses:

- Urge incontinence
- Endometriosis
- Pelvic inflammatory disease
- Dysmenorrhea
- Surgical scars
- Irritable bowel syndrome
- Interstitial cystitis/bladder pain syndrome

These conditions may result in impairments whose primary origin is abdominopelvic pain or adhesions caused by organ disease. Knowledge of the causes and medical management of these diseases are necessary to treat the resulting impairments. A multidisciplinary approach is optimal when dealing with visceral dysfunction. Treatment of comorbid musculoskeletal impairments often results in decreased pain and increased function.

Common Impairments

Weakness of the abdominal muscles, especially the oblique and transversus layers, may occur in response to pain in the abdomen, causing a pendulous abdomen with poor visceral and lumbar support. Secondary lumbopelvic joint mobility impairment and posture impairments may result. Altered tone or impaired muscle performance (e.g., weakness) of the PFMs may also occur as a result of pain in the lower pelvic organs. Chronic pelvic pain postures often occur with long-standing abdominopelvic pain.[111] This can result in the following:

- Posture impairment
- Mobility impairments of pelvic and lumbar joints
- Altered tone, pain, and trigger points in trunk and lower extremity muscles
- Impaired performance of the hip muscles with length and tension changes

Abdominal adhesions and scar mobility restrictions may result in decreased mobility or motility of abdominal and pelvic organs and pelvic joints. When organ mobility is restricted, cramping, pain, and altered organ function may result. For example, abdominal adhesions may form around parts of the bowel, constricting the bowel lumen and making passage of feces painful.

Mobility impairments play a major role in visceral dysfunctions. Visceral mobilization techniques are used by physical therapists to restore normal mobility of organs.

Activity Limitations

Activity limitations vary greatly in cases of visceral dysfunction. In the case of dysmenorrhea (i.e., painful menstruation), patients may have 2 to 3 days each month of intense abdominal pain that confines them to bed. Other conditions result in constant abdominopelvic pain and cause activity limitations such as those of patients with trunk or back pain, who have a decreased ability to work, sit, walk, lift, have intercourse, play sports, exercise, or perform ADLs. Activity limitations may be directly related to organ dysfunction. For example, interstitial cystitis causes the person to urinate as often as every 15 minutes. Irritable bowel syndrome may result in alternating diarrhea and constipation, with many patients experiencing abdominal pain and bloating. These functions are unpredictable and often force patients to remain near the toilet for fear of severe cramping or incontinence of feces.

THERAPEUTIC EXERCISE INTERVENTIONS FOR COMMON DIAGNOSES

This section describes the most common medical diagnoses for the pelvic floor region and suggests PT interventions. The diagnostic classifications mentioned in the previous section group impairments of body functions into common syndromes. The medical community uses a different classification system, and physical therapists should be aware of the medical classifications, testing, and medical treatment of these conditions to enhance their ability to provide effective PT intervention.

The associated medical diagnoses discussed here are commonly associated with underactive and overactive PFMs. Medical diagnoses associated with underactive PFM usually fall into two categories—incontinence and pelvic organ prolapse. Both can be extremely complex conditions with many associated impairments and comorbidities. Some conditions associated with underactive PFMs are impairments of body structures and cannot be changed with PT intervention.

The most common medical diagnoses associated with overactive PFMs include chronic pelvic pain, levator ani syndrome, coccygodynia, vulvodynia, vaginismus, anismus, and dyspareunia. The most common impairments of body functions for each diagnosis are discussed with the diagnosis in the following section. Any impairment may be significant, and failure to address all significant impairments may limit the patient's progress. Any and all combinations of impairments listed for overactive PFM can be associated with these diagnoses. Each patient should be evaluated thoroughly, impairments identified, and treatment plans developed based on the severity and significance of each impairment.

Incontinence

Incontinence is defined as the complaint of any involuntary leakage of urine, feces, or gas.[112] Careful evaluation of these patients often reveals PFM weakness and treatable comorbidities (**Evidence and Research 18-17**).

EVIDENCE and RESEARCH 18-17

More than 13,000,000 persons in the United States have UI. This figure includes approximately 50% of nursing home patients. Several large studies have found overall UI prevalence of 13% to 25%.[4,65] Approximately 80% of these incontinent patients can be significantly helped with noninvasive behavioral techniques used by physical therapists, occupational therapists, and registered nurses.[73]

Incontinence can be a limiting condition that may occur during sports activities and cause embarrassment.[113] Some women even stop exercising because of incontinence. This disruption in exercise ability may have a significant effect on PT for other areas of the body. The therapist may encounter poor compliance with exercises that cause incontinence. The instructions included in this chapter may be enough to correct or minimize symptoms so that the patient can return to active exercises (**Evidence and Research 18-18** and **18-19**).

EVIDENCE and RESEARCH 18-18

Nygaard et al.[108] conducted a questionnaire study of women who exercised. The authors found that 47% had incontinence during exercise. Twenty percent of those women modified their exercise routines solely because of incontinence.

EVIDENCE and RESEARCH 18-19

Women with urge UI and nocturia are three times more likely to fall.[114,115]

Incontinence also may limit elderly persons' activity levels. In some cases, incontinence causes embarrassment and may result in seclusion from social activities, family functions, and work.[116] PFM strengthening can help these patients return to an active lifestyle without fear of embarrassing leakage.[117] Incontinence also may result in secondary conditions such as skin breakdown, which can be a serious medical consequence for the elderly patient. All PT patients should be questioned about leakage, and, if appropriate, instructions should be given to help remedy the situation.

Understanding the most common types of incontinence assists therapists in developing treatment plans. Physicians broadly categorize bladder dysfunctions as the failure to store urine and the failure to empty urine. Stress, urge, and mixed incontinence are examples of a failure to store urine. Overflow incontinence is the failure to empty urine. The full screening questionnaire provided earlier helps to identify the type of incontinence. Stress and mixed incontinence are the two types directly related to underactive PFMs (see **Table 18-4**). The pathophysiology of incontinence is complex. Recent research into this complexity is beyond the scope of this chapter. A simplified explanation of incontinence is provided here and should give the beginning practitioner a good basis for general clinical assessments.

Stress Incontinence

Stress incontinence is defined as involuntary leaking of urine on effort or exertion such as during coughing, laughing, sneezing, and lifting.[112] Continence is maintained when the pressure in the urethra is higher than the pressure in the bladder. Strong PFMs help to increase the pressure in the urethra.[118] The perineal membrane and the sphincter urethrae muscles play a large role in the closure of the urethra (see Fig. 18-4).

TABLE 18-4

Types of Incontinences, Symptoms, Diagnosis Classification, and Possible Treatments

TYPES OF INCONTINENCES	SYMPTOMS	DIAGNOSIS CLASSIFICATION	POSSIBLE TREATMENT
Stress incontinence	Small urine leak with cough, sneeze, exercise	Underactive PFM, PFM weakness	PFEs, biofeedback, vaginal cones, electrical stimulation
Urge incontinence	Moderate or large urine leaks with strong urge to urinate	Visceral dysfunction, may have PFM weakness also	Bladder training, PFEs if needed, biofeedback, electrical stimulation
Mixed incontinence	Symptoms of stress and urge incontinence	Underactive PFM, PFM weakness, visceral dysfunction	Bladder training, PFE biofeedback vaginal cones, electrical stimulation
Overflow incontinence	Small amounts of urine leaking constantly with cough and sneeze, straining to start urination, feeling of incomplete emptying	Possible incoordination dysfunction (PFM contraction during urination), visceral dysfunction (atonic bladder), overactive PFM (PFM spasm or pain)	Medical evaluation may be needed, advanced PFM rehabilitation with biofeedback, electrical stimulation, MFR, PFE, bladder training
Functional incontinence	Long or difficult trip to the toilet with leaking on the way	Mobility impairment of decreased ambulation ability, poor transfer ability, decreased finger coordination	Gait training, strengthening exercises for lower and upper extremities, environmental modifications

MFR, myofascial release; PFEs, pelvic floor exercises; PFM, pelvic floor muscle.

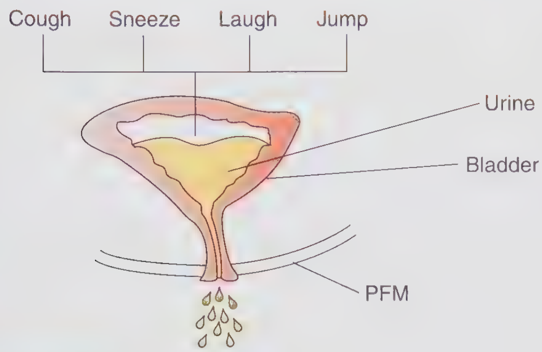


FIGURE 18-12 Stress incontinence.

In stress incontinence, the patient coughs, and pressure in the abdominal cavity is increased, pressing down on the bladder. If urethral pressure is low (usually because the PFMs are not strong enough), the urethra is forced open slightly, and a small amount of urine leaks out (**Fig. 18-12**). The causes of stress incontinence are similar to the causes of underactive PFM. Impairments of body functions include impaired PFM performance, shortened endurance, and coordination impairments. The treatment for pure stress incontinence includes PFM exercises, functional PFM training, biofeedback, and electrical stimulation[79,80] (**Evidence and Research 18-20**).

EVIDENCE and RESEARCH 18-20

A randomized controlled trial of 130 subjects with stress and mixed UI was conducted to determine if symptoms of UI can be reduced by PFEs and if symptoms can be eliminated by strengthening the PFMs to a MMT grade of 5. At the end of a 12-week PFE program, the exercise group reported a statistically significant improvement in UI symptoms and demonstrated improved PFM strength compared to the control group.[119]

McLean et al.[120] reported that following a 12-week PFM training program, women with SUI demonstrated hypertrophy of the urethral sphincter, decreased bladder neck mobility with a cough, and a significant improvement in UI.

Pereira et al.[121] conducted a randomized controlled trial to investigate the effect of vaginal weights for PFM training versus PFM training without vaginal weights in 45 postmenopausal women with SUI. Both groups received treatment for 6 weeks and reported significant improvement in UI and quality of life at 3 month and 12 month follow-up. There was no significant between-group difference.

A 3-month period of PFM training has been shown to improve the quality of life in patients with SUI.[122]

Urge Incontinence

Urge incontinence is defined as leaking urine associated with a strong urge to urinate.[112] The normal urge to urinate is a result of activation of stretch receptors in the detrusor muscle. During this urge, the detrusor remains stable and does not contract. In some patients, a very strong urge to urinate is associated with inappropriate detrusor contractions. Unstable detrusor contractions are contractions of the bladder muscle at incorrect times (e.g., when not positioned over the toilet to void). Strong, unstable detrusor contractions, as seen in overactive bladder or detrusor overactivity, increase bladder pressure and may result in incontinence. The volume of urine leaked is usually larger than that with stress incontinence and may include the entire contents of the bladder. In some cases, urge incontinence may occur without unstable detrusor contractions (i.e., sensory urgency).

The underlying cause of urge incontinence is often unclear and may include PNS or CNS nerve damage. It is suspected that poor bladder habits (especially going to the bathroom too frequently) and bladder irritants (such as caffeine, nicotine, and alcohol) contribute to the condition. PFM weakness with impaired muscle performance and endurance impairment is often found in patients with urge incontinence. Coordination impairment of the PFMs during detrusor contraction may also be present. In this situation, the PFMs do not contract in response to the urge to urinate, and a small increase in bladder pressure may cause urine leakage. Primary treatment for urge incontinence can include bladder retraining, avoiding bladder irritants, PFE, low-frequency electrical stimulation, and medications.

Mixed Incontinence

Mixed incontinence is a combination of stress and urge incontinence symptoms and is thought to be a progression of incontinence symptoms over time. These patients report leaking urine with increases in intra-abdominal pressure and with a strong urge to urinate. The causes of mixed incontinence are similar to the causes of underactive PFMs; the PFMs are usually weak. Treatment of this condition is similar to the treatment for stress and urge incontinence: bladder training, avoiding bladder irritants, PFM exercises, electrical stimulation, and, in some cases, medications.

Overflow Incontinence

Overflow incontinence results from a failure to empty the bladder fully. Obstruction of the urethra by tumor, scar tissue around the urethra, an enlarged prostate, overactive PFM, or other mechanical blockage may prevent the bladder from emptying. Decreased contractility of the bladder from a neurologic deficit, such as peripheral nerve injury associated with radical pelvic surgery, cauda equina injury, or diabetes, also may contribute to overflow incontinence.

In overflow incontinence, the bladder does not empty fully, and high volumes of urine are maintained in the bladder. When the bladder pressure is higher than the urethral pressure, small amounts of urine "spill out." This small but constant leaking may or may not be related to increased intra-abdominal pressure and is characteristic of overflow incontinence. PT impairments may include pain and altered tone of the PFMs. Mobility impairment may be caused by adhered scars. Many cases involve neurologic incoordination of the PFMs or primary visceral dysfunction and require medical intervention. A full medical evaluation is essential. Therapists should refer the patient to the doctor if overflow incontinence is suspected. PT treatment by pelvic floor specialists may include biofeedback, electrical stimulation, myofascial release, PFEs, and bladder training (see **Building Block 18-6**).

BUILDING BLOCK 18-6

Your new patient is a 75-year-old male with Parkinson's disease and difficulty walking. He is currently using a walker in the house and has poor balance. During an intake interview with your new patient, he admits that he has some urine leakage and gets up three to four times during the night. Discuss why nocturnal urination is of concern in this patient. List four ideas to address this concern.

Functional Incontinence

Functional incontinence is defined as the loss of urine due to gait and locomotion impairment. Incontinence is a secondary condition in pure functional incontinence; the primary impairment is a gait and locomotion impairment—an inability to get to the toilet quickly enough. It is not unusual for an elderly or disabled patient to require 5 to 10 minutes to rise from a chair, ambulate with a walker to the toilet, maneuver in front of the toilet, lower his or her clothes, and sit down. Elderly patients often have less ability to store urine because of PFM weakness and less ability to defer the urge to urinate than younger persons. The mobility-impaired patient may leak urine on the long journey to the toilet. Patients may also have PFM dysfunction or impairments of body structures. However, treatment of gait and locomotion impairments and adjustments to the environment can improve function, and physical therapists are well suited to help these patients. Some ideas for helping these patients are detailed in **Display 18-11** (**Evidence and Research 18-21**).

DISPLAY 18-11
Helping Patients with Functional Incontinence

- Improve the speed of sit-to-stand transfers by raising the height of the chair, providing a chair with arms, improving shoulder depression and elbow extension strength, and improving lower extremity strength in the quadriceps and gluteals.
- Improve the speed of ambulation to the bathroom by providing appropriate assistive devices, clearing obstacles from the pathway to the toilet, bringing the patient's chair closer to the toilet (e.g., move the sitting room to the side of the house nearest the toilet) or bringing the toilet closer to the patient (e.g., place a commode or urinal near the bed or sitting room), and improving balance and coordination, strength, and endurance of the lower extremities.
- Improve the speed of ambulation in the bathroom by clearing obstacles (especially rugs) and providing grab bars for ambulation without assistive devices if the bathroom is too small for the device to fit easily.
- Improve speed of lowering clothes by providing patient with Velcro-open pants, suggesting that women wear skirts and dresses, and improving finger coordination and dexterity to manage buttons and zipper more quickly.
- Improve stand-to-sit transfer onto the toilet by providing a raised toilet seat and handrails and by improving lower extremity function.
- Consider impairments of mental function in a patient's ability to recognize the bathroom. It may be helpful to place a picture of a toilet on or near the door or to leave the door open. In severe cases, even when patients are brought to the toilet, they may still not understand what to do.
- Absorbent garments (i.e., diapers and pads) are available for men and women in a variety of sizes. Helping patients and caregivers to choose appropriate garments may allow increased participation in work, social, and recreational activities. Always make sure that the physician has been informed of the patient's incontinence and that conservative treatments have been tried.

EVIDENCE and RESEARCH 18-21

A study of 50 elderly (age 60 to 74) women with SUI was conducted to investigate the effect of PFEs on incontinence and self-esteem. The results demonstrated a statistically significant difference in average self-esteem scores in the treatment group versus the control group.[123]

Pelvic Organ Prolapse

Pelvic organ prolapse is the second largest category of medical diagnosis associated with underactive PFMs. The cause of prolapse may be complex and is often associated with underactive PFM and prolonged increases in intra-abdominal pressure. A simple explanation of prolapse and PFM function is presented in the Patient-Related Instruction 18-6. The most common types of organ prolapses (**Fig. 18-13**) are cystocele (i.e., protrusion of the bladder into the anterior vaginal vault), uterine prolapse (i.e., displacement of the uterus into the vaginal canal), and rectocele (i.e., protrusion of the rectum into the posterior vaginal vault).

Common symptoms include a sensation of organs "falling out," feelings of pain or pressure in the perineum[112] that may limit functional activities in standing, feeling that there is something bulging in the vagina, sensations of sitting on a ball, difficulty defecating (i.e., rectocele), difficulty urinating (i.e., cystocele), or painful intercourse (i.e., uterine prolapse). All patients should learn how to protect the PFMs from undue stress. However, it is essential that patients with pelvic organ prolapse learn how to avoid increased intra-abdominal pressure. PT treatment involves educating patients on decreasing intra-abdominal pressure (see **Patient-Related Instruction 18-7**) and PFM exercises (**Evidence and Research 18-22**).

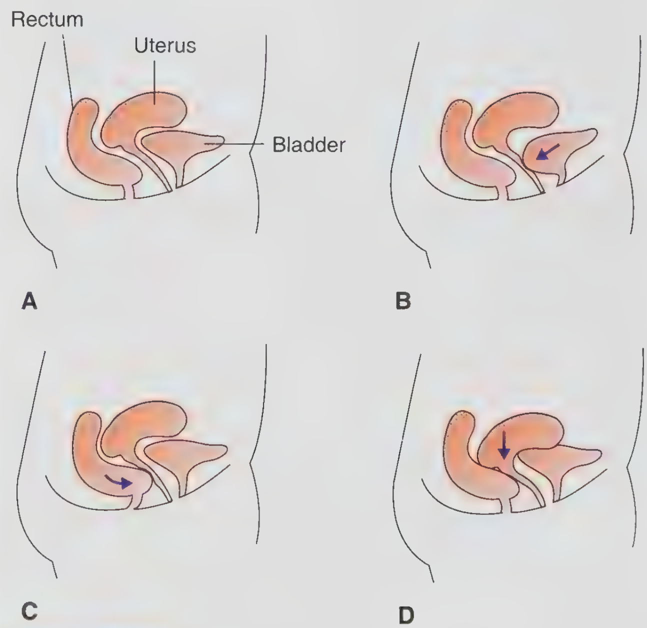


FIGURE 18-13 Common types of organ prolapses. **(A)** Normal organ positions. **(B)** Cystocele. **(C)** Rectocele. **(D)** Uterine prolapse.

Patient-Related Instruction 18-7

Decreasing Intra-abdominal Pressure

- Avoid constipation, and do not strain with defecation (i.e., bowel movement). Drink lots of fluids to help avoid constipation and soften stools. Consult with a dietitian or physician about dietary changes and medications to avoid constipation.
- If you have difficulty getting out of the chair, scoot to the edge of the chair, lean forward, and push up with the arms. Avoid bearing down and breath holding. Instead, contract the abdominals inwardly, breathe out, and contract the PFMs while you stand up.
- Lift properly with inward contraction of abdominals and outward breath on effort. Avoid bulging the abdominals outward and bearing down.
- Exercise correctly using an inward abdominal contraction. Avoid bearing down and pouching the abdominal muscles outward. Unnecessary increases in intra-abdominal pressure may occur while lifting weights that are too heavy and with abdominal exercises that are too advanced. Curl-ups or sit-ups commonly cause the abdominals to bulge. Avoid curl-ups if you have organ prolapse. Patients with PFM weakness should advance to weight lifting, advanced abdominal exercises, and jogging slowly and carefully.
- If you are a postpartum woman, it is especially important to restore adequate PFM strength before returning to high-impact aerobics, jogging, and advanced weight lifting. The jumping jack test (see Patient-Related Instruction 18-2) can be used to determine the ability of the PFM to withstand stress. It is important to continue active rehabilitation of the PFM during your return to vigorous exercise. If incontinence persists or worsens, you may have to delay the return to vigorous exercises until more strength of the PFM is gained.
- It is important to seek medical treatment for chronic coughing or vomiting and to contract the PFM before and during coughing or vomiting. You can counterbrace the PFMs by contracting during coughing and vomiting. Support the perineal tissue with gentle upward pressure of the hand over the perineum during coughing and vomiting spells.

EVIDENCE and RESEARCH 18-22

A multicenter, randomized controlled trial of 447 patients with symptomatic pelvic organ prolapse of stage I, II, or III investigated outcomes of individualized PFM training versus no muscle training with a "prolapse lifestyle advice leaflet." At 12-month follow-up, patients in the intervention group reported a greater improvement in prolapse symptoms on the POP-SS (pelvic organ prolapse symptom score) compared to the control group; this difference was statistically significant and reached the minimally important change for the POP-SS. 80% of patients in the intervention group were still performing muscle training exercises at 12 months.[124]

Ninety women participating in group exercise were assessed for PFM contraction utilizing transabdominal ultrasound to determine the ability to perform a correct PFM contraction and bladder-base movement during an abdominal curl exercise. 25% of the subjects did not demonstrate a correct PFM contraction and all subjects demonstrated depression of the bladder-base with an abdominal curl exercise. The authors concluded that "exercising women may be at risk of PFM dysfunction when performing abdominal curl activities."[125]

A randomized controlled trial evaluated the effect of PFEs on sexual function in women with pelvic organ prolapse. Fifty women received 6 months of PFEs and lifestyle advice, while the control group (59 women) received lifestyle advice only. 39% of the women in the PFE group versus 5% in the control group reported improved sexual function. "Women reporting improvement in sexual function demonstrated the greatest increase in PFM strength and endurance."[126]

Kashyap et al.[127] conducted a study to compare the effect of individual PFM training instruction versus a self-instruction manual for PFM training in women with pelvic organ prolapse. While both groups demonstrated improvement in the Pelvic Organ Prolapse Symptom Scale, visual analog scale, and Pelvic Floor Impact Questionnaire, the group that received individual training reported significantly greater improvement compared to the self-instruction group.

Chronic Pelvic Pain

Chronic pelvic pain is the most common diagnosis associated with overactive PFM. It is analogous to the diagnosis of LBP—it does not give specific information about what type of impairment may be present. The most common impairments are altered tone and performance impairments of the associated muscles of the trunk and hips, poor posture, and mobility impairments of the pelvic and lumbar joints. Therapists should remember the role of the PFMs in sacroiliac dysfunctions. All patients with chronic pelvic pain should be screened for PFM dysfunction, evaluated, and treated if needed (see **Building Block 18-7**).

BUILDING BLOCK 18-7

Your new patient is a 45-year-old female with primary complaint of left buttocks and posterior leg pain. List five risk factors for overactive PFMs that might be present in this patient. What finding would lead you to consider a PFM dysfunction and how would you address it?

Levator Ani Syndrome

Levator ani syndrome is another diagnosis that may be used universally for patients with vaginal or rectal pain. Patients report pain in the coccyx, sacrum, or thigh. Levator ani syndrome refers to increased resting tone and trigger points in the pelvic diaphragm layer of the PFMs. Patients often report pain with defecation and increased pain with sitting. Some patients say they feel like they are "sitting on a ball" (this can also be a symptom of organ prolapse).

Pelvic floor tension myalgia is pain in the PFMs, which is usually associated with increased resting tone or chronic tension. This diagnosis is similar to levator ani syndrome, and many practitioners use the two names interchangeably.

Coccygodynia

Coccygodynia indicates pain at the coccyx bone. Pain at the coccyx is usually not related to the sacrococcygeal joint. More often, it is related to trigger points of the PFMs, obturator internus, gluteus maximus, or piriformis. Patients often have

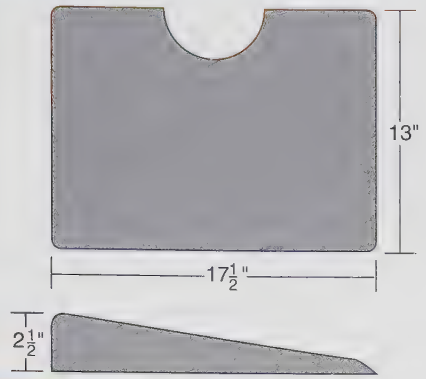


FIGURE 18-14 Coccygodynia seat cushion.

sacroiliac joint mobility impairments and less frequently have sacrococcygeal joint mobility impairments. Coccygodynia is a common sequel of falls directly on the buttocks. Patients report pain with sit-to-stand transfers, possibly because of gluteal muscle contraction or sacroiliac dysfunction. Coccygodynia patients have pain that limits sitting.

The most common impairments associated with levator ani, tension myalgia, and coccygodynia include altered tone of the PFMs and associated muscles; mobility impairments of scars, connective tissues, and pelvic joints; and faulty posture, especially in sitting. All patients with this diagnosis must learn to sit with their weight balanced on the ischial tuberosities and not on the tail bone (see Patient-Related Instruction 18-4). Some patients need to use a special cushion to relieve pressure on the coccyx. The most effective cushion is a seat wedge approximately 2.5 inches tall with a small cutout in the posterior aspect (**Fig. 18-14**). A typical donut-shaped cushion places direct pressure on the coccyx and is therefore not recommended.

Vulvodynia

Vulvodynia is a broad diagnosis of pain in the external genitalia, perineum, and vestibule. It can be a severe, often idiopathic condition that may or may not be associated with PFM dysfunctions. It is categorized as localized (involving only one area) or generalized (symptoms in many areas of the perineum). It is also categorized as provoked (only occurring with palpation or penetration) or unprovoked (pain is present at all times even without contact).[128] Patients report stabbing pain in the vagina and less commonly the rectum. Many patients are completely unable to have vaginal penetration of any kind (e.g., intercourse, speculum evaluation, tampon insertion). Symptoms are increased with sitting and by wearing tight pants.

The causes of vulvodynia are complex and can include overactive PFMs, environmental irritants or reactions, alteration in the vaginal mucosal properties and nerve inputs in the area, or a complication of pelvic surgery. Infection by bacterial and viral organisms (i.e., yeast infections are common) commonly precede the onset of vulvodynia but their relationship to the condition is not understood.[129] Vulvodynia is a difficult condition to treat. A multidisciplinary approach is best. All impairments should be considered, especially mobility impairments of the pelvic and lumbar joints, mobility impairments of scars, and altered tone of the PFMs and associated muscles. These patients need special instructions in avoiding perineal irritants (see **Patient-Related Instruction 18-8**) and may benefit from pain-reducing modalities such as transcutaneous electrical nerve stimulation at the sacral nerve roots.

Patient-Related Instruction 18-8

Avoiding Perineal Irritants

Avoid unnecessary irritation to the vaginal tissue to encourage healing of the area. The vaginal tissue is like the tissue in your mouth. It needs to stay moist and should not be vigorously cleaned with harsh soaps. Here are some suggestions to decrease the irritation of the vaginal tissue:

Clothing

- Avoid tight clothes, especially jeans and pantyhose. It is also helpful to avoid bike riding, because pressure and rubbing on the perineum can increase irritations.
- Wear 100% cotton white underpants that are washed separately in hot water with a mild detergent; avoid bleach and fabric softeners.

Hygiene

- Use white, unscented toilet tissue and pat dry after urination. Some women spray the vaginal area with a fine mist of plain water then pat dry.
- Wash the outside of the vaginal area gently with mild soap (i.e., natural glycerin-based soaps without deodorants or fragrances). Do not douche unless it is suggested by your doctor.
- Avoid dripping shampoo or other soaps on the vaginal area while in the shower.
- Soak in the tub with clear water—no bubble bath, bath beads, or other fragrance additives. Do not wash yourself in the tub; wash in the shower.

Menstruation

- Avoid tampons if possible.
- Avoid pads with fragrances. Consider trying cotton washable menstrual pads.
- Do not douche, unless suggested by your doctor.

Medications

- Speak to your doctor before using any prescription or over-the-counter cream on the perineum. Many creams can be irritating and make the situation worse.
- Do not self-medicate for yeast infections.
- Some contraceptive creams or jellies and lubricants can irritate. Speak to your doctor about an appropriate contraceptive method. Pure olive oil can be used as a vaginal lubricant without irritation by many women.

Vaginismus

Vaginismus is defined as increased tension of the muscle around the vagina, the superficial muscle layer, or pelvic diaphragm layer. Patients report symptoms similar to those of vulvodynia, although to a lesser degree. Dyspareunia (i.e., painful intercourse) is the common symptom of vaginismus. Muscle tension may be a secondary impairment in response to a medical condition, such as atrophic vaginismus or fistula (i.e., a small opening in the skin similar to a small cut at the corner of the mouth). Primary dyspareunia may occur with vaginismus as a result of fear of penetration.

Nonrelaxing Puborectalis Syndrome

Nonrelaxing puborectalis syndrome or anismus is increased tone of the anal sphincters. It is similar to vaginismus in that it may be a secondary impairment caused by trauma, fissure, fistula, or hemorrhoids at the anal opening. Patients report severe pain with defecation, which often leads to constipation because patients delay defecation. Other PFMs may or may have increased tension.

Dyspareunia

Dyspareunia is the symptom of painful penetration and can be associated with all of the diagnoses previously described. It can be divided into two categories: pain at initial penetration or pain with deep penetration. Pain with initial penetration may be caused by superficial muscle spasm (i.e., vaginismus), skin irritation (i.e., vulvodynia), or adhered, painful episiotomy. Deep penetration dyspareunia may be related to altered tone of the PFMs (e.g., levator ani syndrome, tension myalgia) or organ prolapse with visceral adhesions. The most common impairments found in vaginismus, anismus, and dyspareunia are altered tone of the PFMs and associated muscles and mobility impairment of scars and connective tissue.

ADJUNCTIVE INTERVENTIONS

Many patient-related instructions have been included throughout this chapter. Education is essential for this patient population. When was the last time someone talked with you about how to urinate? Take time and make sure your patients understand anatomy and good bladder health, because they are often too embarrassed to admit that they do not know.

PT for the PFMs applies the same principles of treatment used for other weak and painful muscles. Therapeutic exercise principles are the same, and modalities are used for the same reasons. This section lists the modalities used in underactive and overactive PFMs. Several techniques are explored in more detail to enhance the therapist's ability to treat PFM impairments.

The skilled practitioner can employ various modalities and techniques to enhance the effect of active PFE for the treatment of underactive PFMs, including the diagnosis of incontinence. Modalities and techniques are chosen based on the patient's degree of muscle weakness. For a MMT grade of 0 to 2, the practitioner can include the following modalities or techniques:

- Facilitation with muscle tapping of the PFMs inside the vagina
- Overflow exercises of the buttocks, adductors, and lower abdominals
- Biofeedback with a pressure or a surface EMG device
- Electrical stimulation
- Bladder training
- Coordination of PFMs during ADLs

For MMT grade of 3 to 5, the practitioner can include weighted cones inserted into the vagina and PFEs in more stressful activities, such as weight lifting. These patients continue to benefit from bladder training and biofeedback but should be weaned away from facilitation, overflow, and electrical stimulation.

Many other interventions are used in conjunction with exercises for the treatment of overactive PFMs (see Display 18-10). Interventions used for altered muscle tone in other areas of the body can be used with the PFMs as well. Later sections describe perineal scar mobilization and a method for externally palpating the PFMs.

Biofeedback

It is necessary to give all patients some form of feedback, whether it is with the finger in the vagina, a mirror, or biofeedback machines during PFEs. Some practitioners use biofeedback machine evaluation and treatment with all PFM dysfunction patients. Surface EMG and pressure biofeedback are two methods of machine biofeedback. This type of biofeedback is especially helpful if the patient has decreased sensation or decreased motivation.

Pressure biofeedback involves an air chamber connected to a manometer, which records pressure changes. The air chamber is inserted into the vagina, and the patient contracts the PFMs around it. The PFM contraction creates an increase in pressure in the vagina that is recorded and displayed for the patient and therapist. Some pressure devices collect specific data on pressure changes; others are used only for immediate feedback to the patient. Therapists must be careful to instruct PFE correctly, because bearing down increases pressure and may be misinterpreted as proper PFM contractions.

Surface EMG can provide even more information about the muscle contraction, patterns of recruitment, and resting tone. It is a powerful tool in treating PFM dysfunction.[130] An internal vaginal or rectal probe or surface electrodes are used to pick up the electrical muscle activity of the PFMs and display it for the patient. Stand-alone surface EMG units provide feedback in the form of a bar graph or line of lights. This gives information about one part of the contraction at a time. These units are helpful for home training. Computer-assisted surface EMG units can show the electrical muscle activity of the entire PFM contraction or several contractions in a row on one screen (**Fig. 18-15**). This allows the therapist to compare recruitment at different times in the contraction. Surface EMG is the ideal method of feedback in down training (i.e., relaxation training) for patients with overactive PFMs. Biofeedback therapy for patients with stress, urge, or mixed incontinence is given an A rating by the Agency for Health Care Policy and Research guidelines on the management of UI.[73] This means that properly designed research studies support the effectiveness of biofeedback for the treatment of these patients.

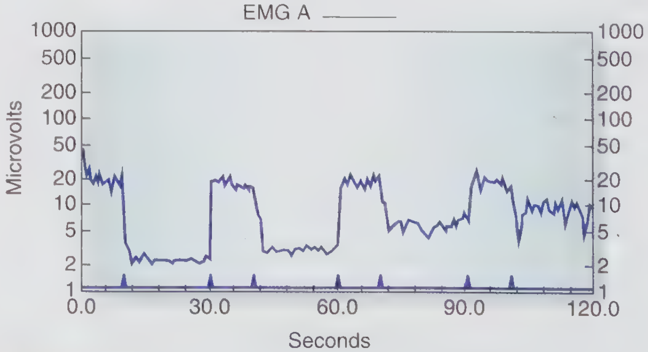


FIGURE 18-15 Printout of computer-assisted surface electromyographic treatment showing elevating baseline. (From Shelly B, Herman H, Jenkins T. Methodology for Evaluation and Treatment of Pelvic Floor Dysfunction. Dover, NH: The Prometheus Group, 1994.)

Basic Bladder Training

Bladder training is scheduled voiding to regain normal voiding patterns. It is used in cases of urgency, frequency, urge incontinence, or mixed incontinence. Have the patient record the time of day he or she urinates in the toilet, the time of urine leakage (i.e., incontinence), and why urine leaked (e.g., cough, sneeze, lift). It is also helpful for the patient to record the amount and type of fluid intake. Information should be collected for 3 to 6 days. This type of record is called a bladder diary (see **Fig. 18-16**). Bladder diaries can be simple or complex. The purpose of the simple bladder diary is to determine the features shown in **Table 18-5**.

Column # Directions

1 Urination in toilet: check, measure, or count # of seconds.
2 Make a check if a urine leak occurs, note small or large.
3 Note the reason for the accident (jump, sneeze, lift, water, urge).
4 Note type and amount of fluid intake.

Fill in the day and date at the top of each column.

Name____________________ Acct.#____________________

DAY												
	toilet	leak	reason	fluid	toilet	leak	reason	fluid	toilet	leak	reason	fluid
6 am												
7 am												
8 am												
9 am												
10am												
11am												
12am												
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12pm												
1am												
2am												
3am												
4am												
5am												
TOTAL												
# of pads												

Stop Test Results____________________ **Patient's Signature**____________________

Type of pad used____________________

FIGURE 18-16 Bladder diary.

TABLE 18-5

Features Determined from a Bladder Diary

MEASURE	PURPOSE
Average voiding interval	Determine bladder schedule
Frequency of voids in 24 h	Bladder habits and outcome data
Nocturnal voiding frequency	Bladder habits and outcome data
Number of incontinence episodes in 24 h	Outcome data
Cause of accidents	Stress or urge symptoms
Total fluid intake	Counsel on normal fluid intake
Number of bladder irritants per day	Counsel on decreasing bladder irritants

Abrams P, Cardozo L, Fall M, et al. The standardization of terminology of lower urinary tract function: report from the standardization sub-committee of the International Continence Society. Am J Obstet Gynecol 2002;21:167–178.

The cause of the accidents helps identify the type of incontinence. Total fluid intake and the number of bladder irritants can be used to counsel patients on appropriate fluid intake. Bladder irritants must be limited for successful treatment of urge incontinence. However, limiting overall fluid intake does not decrease incontinence.[104] Patients should be encouraged to drink six to eight cups of fluid per day.

The average voiding interval (i.e., average time between urinations) is the most important piece of information gained from the bladder diary for bladder retraining. Ask the patient to urinate in the toilet at the average voiding interval you determined from the bladder diary, whether they need to urinate or not. For example, if the average voiding interval was 1 hour, ask the patient to void in the toilet every 60 minutes—no sooner and no later. The bladder eventually becomes accustomed to the schedule, and urgency decreases. Most patients can increase the voiding interval by ½ hour every week. Do not increase the voiding interval if incontinence or urgency is worse or unchanged. Patients do not follow the bladder training schedule at night. Nocturnal voiding gradually improves as the daytime voiding interval increases. The goal is a voiding interval of 2 to 5 hours during the day, with seven or fewer voids per day.

Urge deferment is taught to allow patients to maintain the voiding interval. If the urge arrives before the prescribed voiding interval, patients are encouraged to use the techniques in **Patient-Related Instruction 18-9**. Patients need to practice several different techniques to find the most effective technique for them. After the urge has passed, patients should try to wait until the correct time to urinate (**Evidence and Research 18-23**).

EVIDENCE and RESEARCH 18-23

Patients unable to complete a bladder diary have been shown to have less success with behavioral therapy for UI.[79]

Patient-Related Instruction 18-9

Urge Deferment

- Sit down; pressure on the perineum helps calm the bladder.
- Relax and breathe; nervousness and anxiety contribute to urgency.
- Small PFM contractions help to reflexively relax the bladder.
- Raise up on the toes; contracting the plantar flexors can quieten the bladder.
- Keep the mind busy; attend to a task involving a lot of attention. Tell yourself you cannot stop to go to the bathroom, count backward, or pretend you are in the car and there is no bathroom available.
- Practice mind over matter; the mind has great influence over the bladder. For example, you are on a 2- or 3-hour car ride, and you feel the urge to urinate. If you say to your bladder, "Not now; calm down; I'll go later," the urge goes away. The bladder may become conditioned to produce the sensation of urgency and bladder contractions with certain activities (e.g., before leaving home, before a speech, walking past the bathroom, arriving home, while unlocking the door). It is important to break these habits and establish control over the bladder. (Rather than the bladder controlling your actions.)

Scar Mobilization

Adhesion of perineal scars can cause pain with intercourse (i.e., dyspareunia), pain with bowel movement, and weakness or increased resting tone of the PFMs. The goal of scar mobilization is to lengthen connective tissue and scar adhesions, allowing fascial layers to slide easily over one another. Complete vaginal scar management includes internal myofascial release of scars, mobilization of scars by patients or their partners, ultrasound, PFE, and heat if needed. One method for teaching mobilization of scar tissue is described in **Patient-Related Instruction 18-10**.

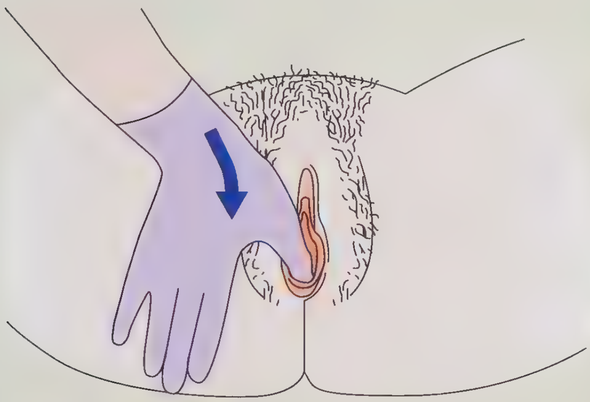
The therapist can describe the technique using the patient's web space between the thumb and the first finger as the posterior vagina (**Fig. 18-17**). This allows the therapist to give the patient the experience of the amount of pressure that is appropriate and to show how to perform the oscillations. Oscillations are similar to friction massage in that the goal is to slide the skin over the second layer of fascia, thereby breaking adhesions and restoring mobility.

Tolerance to scar mobilization varies with the severity of adhesions. Most women find that pain with deep myofascial release of scars decreases as the adhesions loosen. Dyspareunia usually decreases as scars loosen. Some women find it difficult to effectively massage their own vaginal scars. It may be difficult to reach the vagina, or it may be difficult to cause self-inflicted pain. In this case, partners can be trained in a similar manner to assist with treatment. Scar mobilization before intercourse can help decrease dyspareunia. Scar mobilization should not be performed in the presence of open wounds, rash, or infection. Postpartum women should wait at least 6 to 8 weeks after delivery and should check with the physician if questions arise.

Patient-Related Instruction 18-10

Self-Mobilization of Scar Tissue

- Wash your hands thoroughly before beginning
- Choose one of the following positions:
  - Lying on the bed with pillows to prop the head up
  - Sidelying on the bed
  - In the tub
- Use your index finger to reach around from the back while sidelying, or use your thumb to reach the vagina from the front.
- Apply firm, downward pressure on the scar, usually located on the posterior vaginal wall. This probably feels uncomfortable but should not be extremely painful. Constantly holding pressure results in softening of tissue, similar to the feeling of your thumb sinking into a stick of butter.
- Maintain downward pressure for 1 to 3 minutes; then begin gentle oscillations in all directions. Do not allow your finger or thumb to slide over the skin; take the skin with you as your thumb oscillates. Continue these oscillations for several more minutes.
- Move on to another area of the scar, or finish the session.
- Use a hot towel on the perineum or soak in a hot tub to help dissipate any residual soreness.



Episiotomy scar massage.

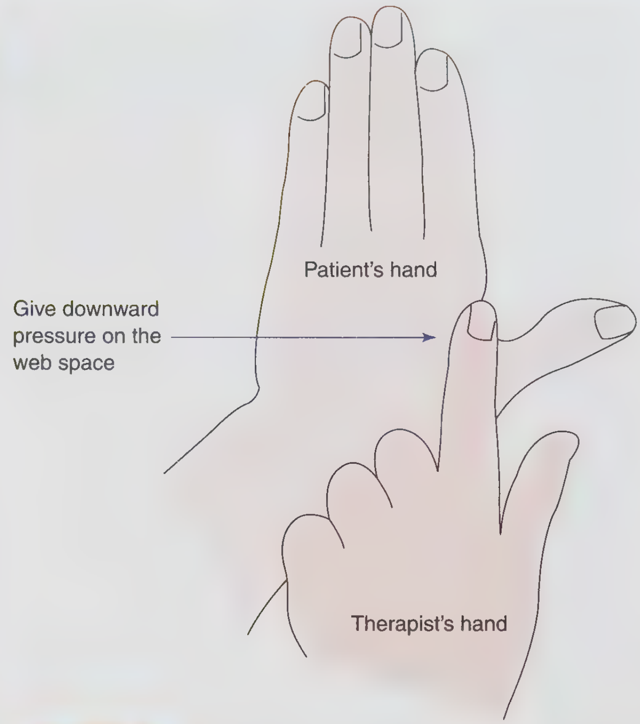


FIGURE 18-17 Describing self-mobilization of a vaginal scar using the patient web space.

Externally Palpating the Pelvic Floor Muscles

It is possible to palpate the PFMs externally at the insertion to the coccyx and along the length of the muscle at the medial ischial tuberosity. The benefits of this palpation are limited, but it is helpful in palpating and treating trigger points in some parts of the levator ani and obturator internus muscles. This method does not give access to all areas of the PFMs. This palpation requires skilled instruction and practice to perfect. Patient position, therapist preparation, therapist position, hand positions, and technique are described in **Display 18-12**.

DISPLAY 18-12

Externally Palpating the PFMs

- Patient position: Place the patient in sidelying with the top leg in approximately 60 to 80 degrees of hip flexion and the knee comfortably bent. Put two or three pillows under the top leg to provide stability in neutral abduction or adduction, and allow the patient to relax the leg fully. Total patient relaxation is necessary for deep PFM palpation.
- Therapist's position: The therapist is positioned behind the patient and finds the tip of the ischial tuberosity on the uppermost ilium.
- Therapist's preparation: This palpation may be done through underpants but is more effective if the fingers are on bare skin. The therapist should wear a vinyl glove on the palpating hand because it will be close to the anus and perineum.
- Hand position: The most effective hand position is supination, with all four fingers adducted in full finger extension. Keep the hand parallel to the table, and place the fingertips on the skin between the ischial tuberosity and the anus (just medial to the ischial tuberosity).
- Technique: Apply gentle inward pressure, directing your fingertips toward the anterior-superior iliac spine of the top ilium. Closeness to the ischial tuberosity results in the skin pulling taught and restricting deep palpation. In this case, reposition the

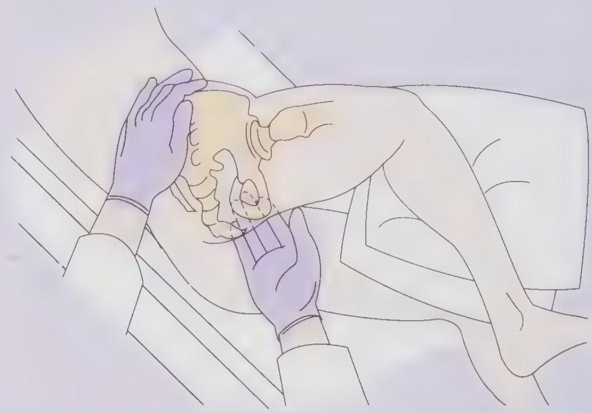
(continued)

DISPLAY 18-12

Externally Palpating the PFMs (*continued*)

fingers more medially toward the rectum, taking up some skin slack (see figure below). The levator ani muscles are rather deep, being the third layer in the pelvic floor. Depth from the skin varies greatly and can be more than 1.5 inches. When a firm resistance is felt, ask the patient to contract the PFMs. You should feel a firm PFM contraction pushing your fingers outward.

- With the PFMs at rest, assess for pain, muscle tone, and connective tissue restriction in the usual manner. Angling the fingers anteriorly and posteriorly can give information about different areas of the levator ani muscle group. The obturator internus is a little more difficult to palpate. A review of anatomy is necessary to orient yourself to the location of the muscle in the sidelying position. Keep the palpating hand in the position described previously, and gently change the angle of the hand so that the wrist and elbow drops and the fingers move upward into the tissue above. The obturator internus is located in this area. The muscle should feel somewhat soft. Have the patient contract the muscle to ensure correct location. External rotation can be tested by asking the patient to lift the top knee upward toward the ceiling while keeping the foot on the supporting surface. The therapist resists this motion with a hand on top of the knee. A small isometric contraction should result in palpable muscle tension. The palpation depth is important. Shallow palpation results in palpation of the medial ischial tuberosity. In this case, continue straight, inward pressure until the tissue releases to a deeper level, and then angle the wrist down and the fingers upward. Myofascial release of the muscle or connective tissue can be carried out in this position if impairments are identified.



External palpation of PFMs. (Adapted from Hoppenfeld S. Physical Examination of the Spine and Extremities. New York, NY: Appleton-Century-Crofts. 1976.)

KEY POINTS

- The PFMs include four skeletal muscle layers: anal sphincter (continence), superficial genital muscles (sexual functioning), perineal membrane (continence), and pelvic diaphragm (continence, pelvic support).
- The pelvic diaphragm includes the levator ani which is made up of the coccygeus, pubococcygeus, puborectalis, and iliococcygeus and is the largest muscle group in the pelvic floor. These muscles are skeletal muscles under voluntary control and have 70% slow-twitch and 30% fast-twitch muscle fibers. They span from the pubic bone to the tail bone and between the ischial tuberosities. The PFM is close to many hip muscles (i.e., obturator internus and piriformis), but it is neither necessary nor desirable to move the legs while contracting the PFMs.
- The three functions of the PFM are supportive (i.e., prevents pelvic organs from prolapsing), sphincteric (i.e., prevents involuntary loss of urine, feces, and gas from the urethra and rectum), and sexual (i.e., increases sexual appreciation and maintains erection).
- All patients should be screened for PFM dysfunction with these simple questions. Do you ever leak urine or feces? Do you ever wear a pad because of leaking urine? Do you have pain during intercourse? If indicated, a more comprehensive questionnaire can be given to attempt to identify the type of incontinence and other limiting factors.
- Patients can be given self-assessment tests and taught self-awareness exercises: jumping jack test, digital self-examination (finger in the vagina), index finger on the perineal body, visual exercise, sexercise, and squeezing around an object. These home exercises help to develop the exercise program and ensure the patient is contracting the PFM correctly.
- Through home self-assessment, the patient reports the number of seconds a PFM contraction can be held, repetitions of endurance contractions, and repetitions of quick contractions.
- Impairments that affect PFM function include performance impairments of the PFMs, abdominals, and hip muscles; pain and altered tone of the PFMs, hip muscles, and trunk muscles; lumbopelvic joint mobility impairments; posture impairments; and coordination impairments of the PFMs and the abdominal muscles.
- PFM dysfunctions have two clinical classifications that are used by pelvic physical therapists internationally: underactive PFM (i.e., loss of support usually as a result of impaired PFM performance) and overactive PFM (i.e., pain and altered tone impairment in the PFMs). Two additional classifications include incoordination dysfunction (i.e., coordination impairment with poor timing and recruitment of PFMs) and visceral dysfunction (i.e., dysfunctions of the pelvic viscera with possible PFM involvement). PFM dysfunctions can result in significant activity limitations and affect the quality of life.
- Incontinence is the most common result of underactive PFM. The most common types of incontinence are stress incontinence (i.e., loss of urine and increased intra-abdominal pressure with a cough, sneeze, laugh, or lift), urge incontinence (i.e., very strong urge to urinate, usually associated with a bladder contraction, which results in leaking urine), mixed incontinence (i.e., combined stress and urge incontinence), overflow incontinence (i.e., obstruction at the urethra or a flaccid bladder that allows

high volumes of urine to collect in the bladder and spill over), and functional incontinence (i.e., leaking of urine because of an inability to ambulate to toilet quickly).

- Pelvic organ prolapse is another common diagnosis resulting from PFM weakness. Forms include cystocele (i.e., bladder prolapse into the vagina), uterine prolapse (i.e., uterine displacement into the vagina), and rectocele (i.e., rectal prolapse into the vagina).
- The PFMs contribute greatly to the stability of the trunk, and impairments of the PFMs are present in many orthopedic dysfunctions including LBP and chronic pelvic pain. Treatment of PFM dysfunction will greatly enhance outcomes of orthopedic treatment in this area.
- With the results of screening questionnaires, the physical therapist should be able to develop an exercise program, including the duration of endurance contraction, rest between endurance contractions, repetitions of endurance contractions, repetitions of quick contractions, number of sets per day, exercise position, need for overflow facilitation from accessory muscle, and other treatments that may be helpful.
- All physical therapists should be aware of the PFMs and be prepared to give generalized strengthening instructions.
- Teaching PFEs involves educating the patient on the location and function of the PFMs and the importance of normal PFM function, providing accurate verbal clues, and teaching home assessment and awareness exercises. The most effective verbal cue for females seems to be "Pull your sphincter muscles up and in as if you do not want gas to come out." Many patients become discouraged and abandon PFEs. Therapists must continue to monitor the patient's progress and to actively encourage participation in the PFE program.

CRITICAL THINKING QUESTIONS

1. Imagine you have urge UI and are being sent to PT for shoulder pain. For some reason the therapist always puts you on the plinth farthest from the bathroom near the kitchen where someone always seems to be washing dishes during your therapy time. Your therapist is a very attractive younger person of the opposite sex and you are embarrassed to share your dilemma. Describe how you would feel about your situation. Describe the impact on your life (i.e., work, family, social interactions, emotions). List some things you might change because of your condition.
2. You are treating a 30-year-old man who fell off a ladder onto his right buttock. After 3 weeks of quality treatment, he has experienced significant decrease in low back and sacroiliac pain, but he can only sit for 1½ hours and experiences pain with sit-to-stand transfers and when going up stairs. He finally admits that his tail bone hurts and that it feels as though he is "sitting on a ball." Your evaluation shows no dysfunction in the lumbar spine and persistent hypomobility of the right sacroiliac. Which muscles should you assess for dysfunction, and how would you treat them? Think about how you would explain to the patient that his pain may be related to the PFMs.

LAB ACTIVITIES

1. Work in groups of two. One person pretends to be the patient. Pick a scenario from the list below or make up your own. Possible patient scenarios—add details as needed
   A 24-year-old female 4 months after vaginal delivery of her third child with buttocks pain and stress incontinence
   A 61-year-old male with urgency and LBP
   A 55-year-old male a fall on the tail bone during roller-skating. Now with coccyx pain
   An 81-year-old female with DM, rheumatoid arthritis, chronic obstructive pulmonary disease, mild dementia, and limited ambulation
   An 18-year-old gymnast with LBP, dysmenorrhea, and occasional urine leakage
   A 44-year-old female with endometriosis and abdominal pain
   A 70-year-old male status post prostatectomy with mixed incontinence symptoms, LBP, and abdominal weakness
   A. Practice administering the screening and long questionnaires.
   B. Practice explaining the location and function of the PFMs and the importance of PFEs using words, posters, and models. Write down layman's terms used to describe the area.
   C. Practice explaining the appropriate self-assessment test and home awareness exercises to the patient.
2. Bladder diary interpretation—two examples given (see additional files)
3. Develop a PFE program—two examples given (see additional files)
4. Perform the self-assessment test and self-awareness exercises at home, and develop an appropriate exercise program for yourself. Exercise programs should include the following:
   a. Results of jumping jack test
   b. The number of repetitions and amount of hold time per contraction
   c. The amount of rest that should be taken between contractions
   d. The number of quick contractions per set
   e. The number of sets per day
   f. Suggested position of exercises (i.e., lying down or upright)
   g. Other methods of strengthening that should be considered
5. Practice palpating the PFMs externally at the ischial tuberosity. Evaluate for pain, trigger points, spasm, and connective tissue tension. Make sure you are on the correct muscle by having the patient contract that muscle.
6. Sit up tall in the chair, and push your abdominal muscles outward. Keep the abdomen distended, and contract the PFMs. Notice the amount of effort needed and the force generated by the PFMs. Next, sit up in the chair, and pull the abdominals inward, supporting the abdominal contents and the back. Hold the abdominal contraction gently and contract the PFMs. Notice the effort needed and the force generated by the PFMs. Next, try to contract the PFMs and bear down, pouching out the abdominals. Try to contract the PFMs and then pull the abdominals inward correctly.

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CHAPTER

19

The Hip

CARRIE M. HALL

The primary roles of the hip joint are to support the weight of the head, arms, and trunk (HAT) during erect standing postures and dynamic weight-bearing activities such as walking, running, and stair-climbing and to provide a pathway for transmission of forces between the lower extremities and pelvis. The structure and function of the hip affect the function of the entire lower kinetic chain and the upper quadrants through its articulation with the pelvis proximally and the femur distally.

Neither structure nor function of the hip joint can be examined without considering the weight-bearing function of the joint and the interdependence with the other joints of the lower extremity and lumbopelvic (LP) region. These issues are examined in this chapter. Anatomy and kinesiology review can be found on thePoint.lww.com/BrodyHall4e. Common anatomic impairments and the evidence-based components of examination and evaluation of the hip joint also are described. Therapeutic exercise interventions are suggested for the treatment of physiologic impairments and selected diagnoses of the hip joint.

IMPAIRMENTS OF BODY STRUCTURES

Six impairments of body structures (or anatomic impairments) of the hip joint are worthy of consideration because of the impact they have on hip function: femoral torsion, angle of inclination, lateral center edge angle, leg length discrepancy (LLD), pincer morphology, and cam morphology. Each impairment of body structure, independently or in combination with other impairments (body structure or function), warrants careful consideration about the impact on hip joint function and the function of joints proximal or distal to the hip.

Angles of Inclination and Torsion

Femoral Angle of Inclination

Angles of inclination and torsion are normal anatomic relationships of the femur. However, the degree of inclination or torsion can become abnormal when the values are greater or less than normal. Abnormal angulations of the femur are considered impairments of body structures. These anatomic impairments of the femur can significantly alter hip joint mechanics, which can alter the mechanics of adjacent segments proximally and distally in the kinetic chain. Understanding the impact of these structural impairments assists the practitioner in developing an individualized intervention.

In early infancy, the angle of inclination is about 150 degrees because of the abducted position of the femur in utero. The angle decreases with age to the normal adult value of 125 degrees.[1,2] The angle is somewhat smaller in females and somewhat larger in males.[2] A pathologic increase in the angle is called coxa valga (**Fig. 19-1A**), and a pathologic decrease is called coxa vara (Fig. 19-1B).[2] Research has shown a much higher incidence of coxa valga (48%) versus coxa vara (4%).[3]

The position of the greater trochanter influences the mechanical stress of the hip joint, the extent of contraction of the gluteus medius (GM) and minimus muscles, and the mechanical stress of the femoral neck.[4] A normal neck-shaft angle appears to achieve a maximum lever arm of the abductor muscles and the best compromise between articular pressure and bending stress on the femoral neck. Coxa vara can result in shortening of the lever arm of the abductor muscles, resulting in lower articular pressure,[5] whereas a valgus hip results in a greater hip abductor moment arm and higher articular pressure.[6]

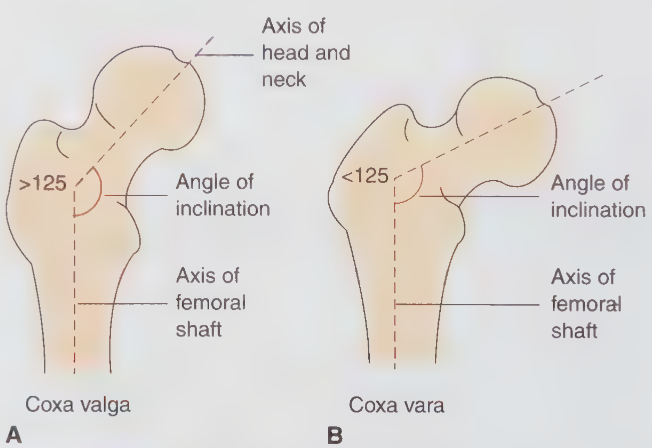


FIGURE 19-1 Abnormal angles of inclination. **(A)** A pathologic increase in the angle of inclination is called coxa valga. **(B)** A pathologic decrease in the angle of inclination is called coxa vara.

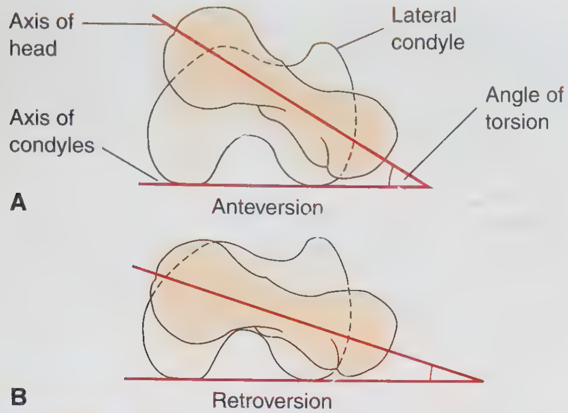


FIGURE 19-2 **(A)** A pathologic increase in the angle of torsion is called anteversion. **(B)** A pathologic decrease in the angle of torsion is called retroversion. (From Norkin CC, Levangie PK. Joint Structure and Function: A Comprehensive Analysis. 2nd Ed. Philadelphia, PA: FA Davis, 1992.)

Angle of Torsion

The newborn infant has a maximum angle of femoral torsion of approximately 40 degrees. This decreases to approximately 16 degrees by the age of 16 years.[7] The angle is normally about 12 to 15 degrees in the adult, but it may range from 8 to 30 degrees and, as with the angle of inclination, varies between sexes and among persons.[1,8] A pathologic increase in the angle of torsion is called anteversion (**Fig. 19-2A**), and a decrease is called retroversion (Fig. 19-2B). Anteversion and retroversion can be screened for during a clinical examination (see "Examination and Evaluation").

Because the hip joint can only tolerate a limited amount of torsion (12 to 15 degrees) without jeopardizing its congruence, a pathologic increase (>15 degrees) or decrease (<12 degrees) in the angle of torsion is manifested distally at the femoral condyles. In the standing position, the femoral condyles of an individual with femoral anteversion are oriented medially, and in femoral retroversion, they are oriented laterally when the femoral head is in a position of maximum congruence. The individual with femoral anteversion functioning with the femoral condyles facing laterally risks losing congruence of the femoral head in the acetabulum. Similarly, the individual with femoral retroversion functioning with the femoral condyles facing medially also risks losing congruence of the femoral head in the acetabulum. As these impairments are anatomic and cannot be directly treated therapeutically, the practitioner must be aware of these impairments of body structures when guiding femoral alignment during exercise and function.

Center Edge Angle or Angle of Wiberg

A line connecting the lateral rim of the acetabulum and the center of the femoral head forms an angle with the vertical known as the center edge angle, also called the angle of Wiberg (**Fig. 19-3**). The center edge angle for the average adult is 22 to 42 degrees.[8] Although this is a normal angle, variations in the angle can lead to altered stability of the femoral head, in which case it would be considered an anatomic impairment.

A smaller center edge angle (i.e., more vertical orientation) of the acetabulum may result in decreased congruency of the head of the femur and the acetabulum, placing the head of the femur at increased risk of superior dislocation of the head of the femur. Children are at greater risk for this type of dislocation than adults, because the center edge angle normally increases with age.[9] It may be for this reason that congenital dislocation is more common at the hip than at any other joint in the body.[10]

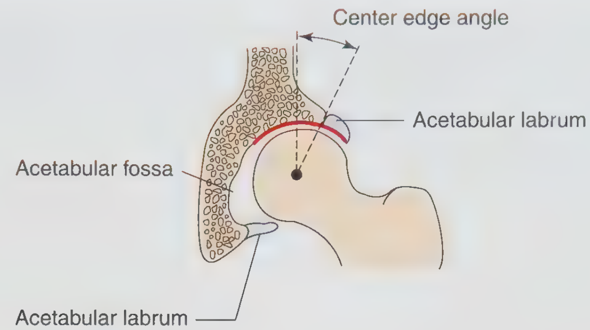


FIGURE 19-3 The center edge angle or angle of Wiberg.

Leg Length Discrepancy

Limb length discrepancy (LLD) is discussed in this chapter primarily, because the femur and pelvis constitute large contributions to both structural LLD (SLLD) and functional LLD (FLLD). However, the spine, knee, ankle, and foot are also involved in total LLD. The impact of LLD on kinetics and kinematics of the lower limb can be significant and must be well understood to develop a comprehensive plan of care (see **Evidence and Research 19-1**).

EVIDENCE and RESEARCH 19-1

Limb Length Discrepancy

LLD has been associated with hip pain, knee pain, low back pain (LBP), and with lower extremity stress fractures.[11–14] Studies have shown increased hip joint forces of up to 12% in the relatively short and long limbs with LLDs of 3.5 to 6.5 cm.[15] In general, an LLD of more than 2.0 cm results in asymmetry in contact time, first and second force peaks, and loading and unloading rates of the vertical ground reaction force in gait.[16] The most common mechanism for compensation of minor LLD is the induction of pelvic tilting in the coronal plane. In normal individuals, pelvic obliquity of 6.1 degrees can totally accommodate for a LLD of 2.2 cm.[16] With LLD >2 cm, the coronal plane mechanism is necessarily augmented by changes in the sagittal plane, which occur at the ankle and knee in standing. At initial contact, the knee responds with flexion of the long limb, whereas at terminal stance, the long leg ankle demonstrates increased dorsiflexion and the short leg ankle produces early heel rise and greater degrees of plantar flexion during stance.[17] The combination of these changes has the effect of shortening the functional length of the long limb in both the stance and swing phases while lengthening the shorter limb during the stance phase. Because of the changes in forces incurred at the hip and gait asymmetries, it appears that more than 2 cm of LLD can significantly affect kinetics and kinematics throughout the kinetic chain and therefore should be addressed. LLD of < 2 cm affect pelvic alignment and may need to be addressed depending on the associated impairments and pathology.

TABLE 19-1

Definitions of Structural and Functional Leg Length Discrepancies

TERM	TYPE OF IMPAIRMENT	DEFINITION	MEASUREMENT TECHNIQUE
Structural	Body structure or anatomic	Actual osseous length difference between the hemipelvis, femur, and tibia	Standing anteroposterior X-ray film or ultrasound imaging[16]
Functional	Body function or physiologic	Position of osseous structures as they relate to each other and to the environment during weight-bearing function	Actual difference between two pairs of identical reference points (e.g., greater trochanter and medial malleolus)

When measured from one common bilateral point of reference proximally to another common bilateral point of reference distally, there is a unilateral difference in the total length of one leg compared with the other. LLD is commonly thought of as resulting from a structural fault in the anatomic length of the long bones, hemipelvis, or asymmetric structural development of the spine (i.e., scoliosis), in which case it would be considered an impairment of body structures, or structural LLD (SSDD). However, LLD often is the result of the functional relationships of the spine, pelvis, long bones, and bones of the feet about all three axes of motion. For example, an individual standing in a neutral subtalar position, measured bilaterally from the tip of the medial malleolus to the horizontal plane (i.e., flat surface), should have equal measurements of both limbs. If the individual is allowed to pronate one foot, the medial malleolus of the pronated foot moves closer to the ground. The difference in height may be as much as ¼ to ¾ of an inch. This would be considered an impairment of body function as opposed to body structure, resulting in a functional LLD (FLLD). SLLD and FLLD are common clinical terms used to describe the two types of LLDs.[18,19] **Table 19-1** summarizes definitions of the clinical terms used to describe LLD. Evaluation and treatment of LLD is addressed in later sections.

Cam and Pincer Morphology

A condition commonly referred to as femoroacetabular impingement (FAI) can result from abnormalities in the shape of the femoral head and neck and acetabulum. Cam (**Fig. 19-4B**) refers to the morphology on the femur; pincer (Fig. 19-4C) refers to morphology on the acetabular side of the hip joint.[20,21] Either of these abnormalities or a combination of the two (Fig. 19-4D) can result in decreased space between the femoral head/neck and the acetabulum and theoretically subsequent impingement. This impingement theoretically occurs with the combined movement of hip flexion, adduction, and internal rotation.[22] However, the underlying cause of the morphologic changes is under considerable debate. It is possible that overload of the joint can cause changes to the bone and cartilage because of the abnormal arthrokinematic motions during activities of daily livings (ADLs) and sport (see **Evidence and Research 19-2**).

Delineating morphology from etiology of symptoms is paramount. Morphology, relative to the hip, is the form and structure of the bones of the hip, whereas FAI is considered the mechanical abutment of the femoral head against the acetabulum.[20] A misconception is that the presence of cam or pincer morphology automatically implies FAI and hence the underlying cause of symptoms and eventual pathology. There has been an 18-fold increase in the surgical procedures related to treatment of FAI between 1999 and 2009, varying by geographic region in the United States.[27,28] Furthermore, the FAI surgery rate has increased by over 600% among newly trained surgeons from 2006 to 2010[29] (see **Evidence and Research 19-3**).

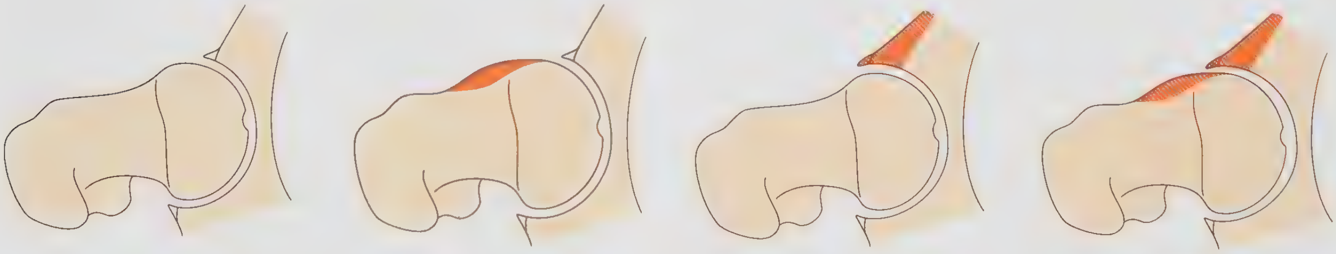


FIGURE 19-4 **(A)** Normal femoral head, neck, and acetabular labral anatomy. **(B)** Femoral sided impingement got its name, "cam," from the Dutch word meaning "cog" describing the femoral head and neck relationship as aspherical or not perfectly round. During motions such as hyperflexion and MR of the hip, the cam lesion is able to fully engage within the joint. This results in cartilage loss over the femoral head and corresponding acetabulum, as well as labral tears. Cam lesions predominately affect the cartilage within the hip joint, resulting in a characteristic peeling of the cartilage off the bone. Cartilage wear is the definition of arthritis; therefore, this type of impingement is considered a prearthritic condition. **(C)** The second category of FAI is the "pincer" type lesion, referring to the "over coverage" of the acetabulum in respect to the femoral head. Pincer comes from the French word meaning "to pinch." The "extra" bone of the acetabulum repetitively hits upon the femoral neck resulting in the pinching of the labrum in between. **(D)** Cam lesions often coexist with pincer lesions. cam lesions are believed to lead to articular cartilage injury first, whereas pincer lesions are believed to crush and tear the labrum first.

EVIDENCE and RESEARCH 19-2

Stress Across the Epiphysis as a Possible Etiology of Cam Morphology

In a 1926 classic article on epiphyseal displacement, this theory, named the static theory, was suggested as a possible etiology for cam morphology.[5] The static theory infers that growing bone is less able to stand strain than is adult bone and that in many adolescents, there is a disproportion between the superincumbent weight and the strength of the femoral neck, potentially resulting in displacement of the epiphysis, alterations of the neck, and laying down of bone to meet the altered mechanics of the hip. No other epiphysis is subjected to such cross strain. A recent retrospective study supporting this theory reviewed 72 hips in 37 male basketball players with a mean age of 17.6 years (range, 9 to 25 years) and 76 asymptomatic hips of 38 age-matched volunteers who had not participated in sporting activities at a high level.[23] Eleven (15%) of the 72 hips in the athletes were painful and had positive anterior impingement tests on physical examination. MR of the hip averaged 30.1 degrees (range, 15 to 45 degrees) in the control group compared with only 18.9 degrees (range, 0 to 45 degrees) in the athletes. The maximum value of the alpha angle throughout the anterosuperior head segment was larger in the athletes (average, 60.5 ± 9 degrees), compared with the control group (47.4 ± 4 degrees). The athletes had a 10-fold increased likelihood of having an alpha angle greater than 55 degrees at least at one measurement position. This study supports the theory that vigorous exercise may trigger cam deformity, as high skeletal stresses have been associated with a pathologic skeletal growth pattern and morphologic alterations in gymnasts and baseball players.[24,25] It is speculated that the cumulative effect of high stresses and perhaps more or less subtle differences in the direction of loading on the proximal femur during growth may modulate growth toward an abnormal shape. This notion was suggested by Murray and Duncan,[26] who observed the greatest prevalence (24%) of femoral head tilt deformities in adolescents who started a compulsory sports regimen during boarding school before the age of 14 years. The upstream question becomes, should we be looking at the hours spent in vigorous activity in pre-physeal closure children to prevent development of cam morphology?

EVIDENCE and RESEARCH 19-3

What Is the Level of Evidence for FAI Surgery?

The current evidence to answer this question is limited to case series (Level IV) studies. Although these case series demonstrate promising outcomes post FAI surgery, the outcomes are short term,[30–32] dependent on status of chondral damage,[33] and are notably less favorable in patients over the age of 40 years.[34] Currently, no systematic reviews or randomized controlled trials (RCTs) on the efficacy of FAI surgery compared to nonsurgical or sham treatments exist.[35] Recently, several trials on efficacy of FAI surgery have been registered at http://www.clinicaltrials.gov.offcampus.lib.washington.edu. These trials seek to determine whether the innovation of FAI surgery will stand the test of evidence-based principles. A good lesson to learn from previous findings is that case series for other surgeries (e.g., meniscus tear, shoulder impingement) are often favorable, but subsequent RCTs show no additional benefit over nonsurgical or sham therapy.[36–43] Furthermore, reported postsurgical complication rates are quite variable.[44,45] They range from the development of adhesions to deep vein thrombosis and chronic regional pain syndrome.[46] Complication rates also appear to be higher than previously reported.[29,47,48] Owing to variability and inconsistency in the current literature, reliable reporting of these complications has, therefore, been suggested as one of the principal requirements for future studies.[44] There is uncertainty as to how symptomatic FAI is best treated,[49] and the principal two management options are physical therapy with activity modification or surgery. Both modalities have been shown to improve symptoms in the short term.[50–55] However, no published studies compare efficacy with each other or with sham procedures. It is not known whether treatment provides sustained symptomatic benefit in the long term, or whether it delays or prevents development of osteoarthritis (OA). Future research is needed to answer these questions.

Similar to the proposal of "shoulder impingement syndrome" as a generic term for patients with shoulder pain,[56] the term "FAI syndrome" is suggested to more accurately encapsulate the nebulous nature of this condition.[56] As with the shoulder, it has become evident that "impingement syndrome" is not likely an isolated condition that can be easily diagnosed with clinical or imaging tests or most successfully treated surgically. Rather, it is likely a complex of conditions involving a combination of intrinsic and extrinsic factors. A mechanical impingement phenomenon as an etiologic mechanism of hip pain may be distinct from the broad diagnostic label of "impingement syndrome." Acknowledging the concepts of mechanical impingement and movement-related impairments may better suit the diagnostic and interventional continuum as they support the existence of potentially modifiable impairments within the conservative treatment paradigm. The diagnosis of FAI is no more informative than the diagnosis of "hip pain." Although both terms are ambiguous, the latter is less likely to presume an anatomic tissue pathology that may be difficult to isolate either with a clinical examination or with diagnostic imaging and may prevent potentially inappropriate surgical interventions.

From a physical therapy perspective, postural habits and movement patterns as potential mechanisms for the development of hip pain need to be further investigated. Researchers need to investigate homogenous patient groups with accurately defined specific pathologies, or with classification based on specific movement deviations. Diagnostic labels based on the movement system may allow more effective subgrouping of patients to guide treatment strategies.

EXAMINATION AND EVALUATION

Examination and evaluation of the hip can focus primarily on the hip in the case of specific hip pathology (e.g., rheumatoid arthritis, OA, avascular necrosis of the femoral head, labral pathology, FAI, or hip dysplasia). However, regardless of diagnosis, evaluation of the knee, ankle–foot, and LP regions may provide useful information (e.g., rigid, supinated foot contributing to reduced shock absorption to the arthritic hip) and identify impairments that are contributing factors to the patient's hip condition. Similarly, the hip is commonly included in the examination and evaluation of other regions to assess impairments of body structures or function of the hip that may be contributing to dysfunction in the affected region (e.g., a stiff hip contributing to lumbar hypermobility).

The descriptive examination and evaluation information presented in this section is not intended to be comprehensive or reflect any specific philosophical approach; it simply serves as a general review of pertinent tests performed in most hip examinations.

History

In addition to the general data generated from a patient/client history as defined in Chapter 2, the following information is important to obtain from a patient with impairment, activity limitation, participation restriction, or disability involving the hip joint:

- History of congenital hip dysfunction (e.g., congenital hip dysplasia treated with or bracing or surgery)
- Childhood hip conditions (e.g., slipped capital epiphysis, severe anteversion treated with bracing, FAI)
- Previous hip joint injury (torn labrum, stress fracture, femoral neck fracture)
- Family history of OA or rheumatoid arthritis.

These conditions along with age and gender received an evidence grade of Level I in a recently published clinical practice guideline.[57] Although the hip can become injured as a result of trauma, the clinician is more likely to encounter hip dysfunction as a result of cumulative microtrauma. In the latter case, it is important for the practitioner to gain an understanding of the ADLs, recreational, and occupational activities with which the patient is involved on a repetitive basis and identify which activities seem to provoke symptoms. Of particular interest is *a history of intense sport before skeletal maturity*. Much of this information can be obtained through patient-reported outcome measures (PROs). They are an important component of outcomes assessment, because they represent the patient's health status as assessed by the patient, without interpretation of the healthcare provider.[58] To be useful, PROs must be reliable, valid, responsive, and representative of the patient population of interest. It is beyond the scope of this text to present disease-specific PROs conclusively; the literature supports various PROs for specific conditions.[59,60]

Lumbar Spine Clearing Examination

The prevalence of LP conditions in the general population, combined with the fact that pathology in the LP region can manifest in referred pain patterns into the hip (e.g., posterior buttock and greater trochanteric region) and cause neurologically mediated weakness of hip joint musculature (particularly the gluteal musculature), supports routine lumbar screening during any hip examination. A typical lumbar clearing examination is outlined in Chapter 17. Although this scan may seem extensive, excluding or diagnosing lumbar or sacroiliac joint (SIJ) involvement is critical to accurate diagnosis of lower quadrant symptoms. Positive test results for the lumbar clearing examination can indicate a need for a more thorough lumbar or SIJ examination. It is not unusual to have symptoms from both the lumbar and hip region, complicating the examination and treatment of patients with lower quarter (LQ) dysfunction.

Other Clearing Tests

The practitioner should examine and evaluate associated regions. Although the hip may be the source of symptoms, it is common for multiple regions to be involved, particularly in patients with long-standing impairments, activity limitations, and participation restrictions. A thorough examination of all involved regions permits the clinician to develop an integrated and comprehensive plan of care. For example, impairments of the pelvic floor may affect function of the hip. Screening for pelvic floor dysfunction can alert the practitioner to any associated pelvic floor conditions (see Chapter 18).

Visceral involvement or serious disease or disorders should be excluded. Pain in the hip and pelvic region can also result from visceral sources (see Appendix 1). A thorough history and physical examination and evaluation can alert the practitioner to visceral involvement or serious disease or pathology.

The hip must be excluded as the source of symptoms experienced in other regions. Because the hip is largely innervated at the L3–L4 level, hip pathology occasionally causes pain to be referred to the knee.[61,62] This is well documented in children, in whom any examination for knee pain must include a hip examination,[63] but this must not be forgotten as a source of knee pain in the adult. A patient of any age complaining of knee pain without apparent knee pathology or impairments should have the hip examined as a potential source of pain.

Gait and Balance

Gait evaluation is an essential component of the examination of a person with a hip dysfunction. Analysis of gait should include observation of the hip along with the rest of the kinetic chain about all three planes of motion during each critical event in gait. Of particular importance are the relationship of pelvic and hip motion (i.e., amount of lateral pelvic tilt and hip adduction [see **Fig. 19-5**]) and the relationship of hip and lower extremity motion (i.e., hip medial rotation, tibial medial rotation, and foot pronation). Because the hip functions interdependently with other regions in the body, the relationship of distal and proximal segments to the hip must also be evaluated.

Video analysis can assist in this complex examination procedure, because the video can be taken from any angle and can be viewed in slow motion to allow precise observation of the components of gait. Hypotheses can be generated about the

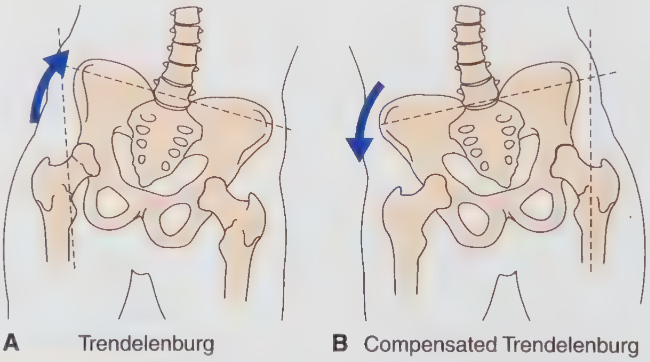


FIGURE 19-5 Trendelenburg sign. **(A)** Positive Trendelenburg sign with lateral pelvic tilt and hip adduction. **(B)** Compensated Trendelenburg sign with lateral pelvic tilt and hip abduction.

cause of any observed gait deviation that can be confirmed or negated as a result of the additional data collected.

Balance tests are often included in hip examinations because of the high incidence of falls resulting in hip injury and fracture. Balance testing should identify intrinsic (i.e., related to the individual) and extrinsic (i.e., associated with environmental factors) factors related to the risk of falling.

Low-tech balance assessments can identify risk factors for falls.[64] Strong correlations have been found among performance-based measures and fall risk, as well as between performance-based measures and self-report measures. Five variables are significantly related to fall risk[64]:

1. Berg Balance Scale score[65]
2. Dynamic Gait Index score[66]
3. Balance Self-Perceptions Test score[67]
4. History of imbalance
5. Type of assistive device used for ambulation.

High-tech, computerized, force-platform balance devices commonly measure the ability to maintain the center of pressure within the base of support against progressive perturbations. This information is highly objective and is often used to track progress in developing postural balance.

Joint Mobility and Integrity

Arthrokinematic motions are relatively limited at the hip joint in comparison with osteokinematic motions. Arthrokinematic tests of the hip should include lateral/medial translation, distraction and compression, and anteroposterior/posteroanterior glides.[68] The quantity of motion, the end-feel, and the presence/location of pain should be noted. Tests for joint integrity should assess for joint stability and pain provocation. Lee has developed arthrokinetic tests for joint stability at the hip and the reader is to refer elsewhere for details.[68]

Muscle Performance

Impairments in muscle performance can result from numerous sources, and tests of muscle performance combined with results of other tests should attempt to determine the presence and cause of reduced muscle performance. The following discussion highlights specific types of muscle performance testing procedures used to diagnose the presence and source of impairment of muscle performance.

Manual Muscle Testing

Manual muscle testing (MMT) of muscles surrounding the hip joint can provide information regarding muscle performance capability of each muscle or fiber direction of a single muscle (e.g., anterior vs. posterior GM).[69,70] Comprehensive MMT of the hip musculature can also determine the relationship of muscle performance capability of synergist and antagonist musculature around the hip (e.g., posterior GM vs. tensor fascia lata [TFL] as hip abductors). Essential muscles to test include the following:

1. Gluteus medius
2. Gluteus minimus
3. Iliopsoas
4. Deep hip lateral rotators
5. Gluteus maximus
6. Hamstrings
7. Quadriceps
8. TFL.

Positional strength testing can determine the length–tension properties of the relevant muscle (see Chapter 5). It is often of interest to the examiner to determine length-associated changes in muscles within a synergy. Management of a muscle functioning poorly resulting from length-associated changes is different from a weak muscle resulting from strain or disuse.[71] For example, length-associated changes are often present between posterior GM (abductor, extensor, and lateral rotator) and TFL (abductor, flexor, and medial rotator).[72] Typically, TFL is short and/or stiff relative to the posterior GM that allows it to produce more force in the short range and bias the position of the femur in medial rotation (MR) during function. To improve the synergy between abductors, it would appear appropriate to design rehabilitation programs using therapeutic exercises that promote activity of the posterior GM (in the short range) while minimizing recruitment of the TFL.[73–75]

Selective tissue tension tests can assist the practitioner in the differential diagnosis of a contractile versus noncontractile lesion.[76] If a selective tissue tension test is positive (through careful MMT positioning), interpretation of the resisted test can indicate severity of the tissue lesion from Grade I to Grade III and help guide prognosis and intervention.[77]

In addition, it is important to screen for a *neurologic cause* of reduced force production, particularly in reference to the fatigability of the muscle being tested. Hip musculature is innervated by the lumbar and sacral plexus; consequently, low back dysfunction often results in neurologic weakness around the hip. Numerous peripheral nerves can be involved in nerve entrapment syndromes around the hip, which can result in motor changes (see **Table 19-2** for an overview of these syndromes), This topic will be discussed in more detail in a subsequent section of this chapter.

Pain and Inflammation

Examination for pain and inflammation is done concurrently with other tests to determine the source. Inflammation is difficult to examine in the hip joint, because it is deep within the pelvis and cannot be readily palpated. Positive findings for a capsular pattern[76] (defined in **Display 19-1**) of hip mobility and end-feel assessment (i.e., pain before limitation of motion is reached) indicate former or active inflammation in the hip joint capsule.

Examination of the pain level should be incorporated into the subjective and objective portion of the examination. The patient should answer questions regarding pain level by using a visual, numeric, or verbal analog scale over a 24-hour cycle in relation to specific activities and in general.[78] During the physical examination, the patient should be questioned about the onset, location, and intensity of pain with respect to each test performed.

The specific source of symptoms may not be diagnosed without additional tests that are beyond the scope of physical therapy practice (i.e., radiologic, electrodiagnostic, and laboratory studies). However, the mechanical contribution to the development or fortitude of the symptoms can be diagnosed

TABLE 19-2

Regional Approach to Nerve Entrapment Syndromes

REGION	SUBREGION	NERVE
Anterior	Inguinal	Ilioinguinal nerve Genitofemoral nerve Iliohypogastric nerve T11/T12/L1 nerve root
	Suprapubic	Genitofemoral nerve Iliohypogastric nerve T11/T12/L1 nerve root
	Thigh	Lateral femoral cutaneous nerve of thigh Genitofemoral nerve Femoral nerve Obturator nerve
Lateral	Buttock	Ilioinguinal nerve Iliohypogastric nerve Lateral cutaneous nerve of thigh T12 nerve root
	Thigh	Lateral cutaneous nerve of thigh Posterior cutaneous nerve of thigh
Posterior	Buttock	Posterior rami of the lumbar, sacral, and coccygeal nerves Iliohypogastric nerve Lateral cutaneous nerve of thigh Posterior cutaneous nerve of thigh T12
	Thigh	Lateral cutaneous nerve of thigh Inferior medial and lateral cutaneous nerves Posterior cutaneous nerve of thigh

DISPLAY 19-1

Established Capsular Pattern[76]

1. 50 to 55 degrees of limitation of femoral abduction
2. 0 degrees of femoral MR from neutral
3. 90 degrees of limitation of femoral flexion
4. 10 to 30 degrees of limitation of femoral extension
5. Femoral lateral rotation (LR) and adduction are fully maintained

through careful examination and evaluation of the impairments that contribute to increased biomechanical stress to the hip joint.

Posture and Movement

Specific LP and lower quadrant alignment should be examined in all three planes. Hypotheses can be developed regarding the contribution of faulty alignments at the ankle, foot, knee, and LP regions to the alignment of the hip. The practitioner can also create hypothesis regarding muscles that are too long, or too short, based on joint position, verified by specific muscle length testing. Initial screening for LLD and lower extremity asymmetries should be performed by evaluating the following:

1. Iliac crest heights
2. Spine, pelvic, femur, tibia, and foot alignments
3. Bony landmarks of the pelvis, knee, and ankle.

Unique to the pelvis is taking into consideration anatomic variations of the acetabulum (i.e., anteversion, retroversion, acetabular depth) combined with the femur (i.e., anteversion, retroversion, coxa vara, coxa valga, cam morphology). This information can assist the practitioner in determining underlying mechanical contributions to pain as it relates to femoroacetabular congruence. Undercoverage or overcoverage can contribute to impingement or hypermobility/instability (see **Table 19-3**).

In addition, the specific alignment about all three planes of motion, of the spine, pelvis, hip, tibia, and ankle/foot complex, should be noted during simple ADLs, such as squatting, ascending and descending stairs and sit-to-stand transfers. Hypothesis regarding the interrelationships of the lower limb segments can be generated (i.e., foot pronation, genu valgum, hip adduction, and lateral pelvic tilt on the short side).

Range of Motion and Muscle Length

Range of motion (ROM) testing of the hip joint includes several assessments. *Quick tests* are functional movements that are used to ascertain the patient's willingness and ability to move and the requisite extent of the examination to follow. Such tests for the hip include flexing the hip and knee while putting the foot on a standard step height, forward bending, squatting, and sitting with one leg crossed over the other.

TABLE 19-3

Summary of Acetabular and Femoral Orientation Relating to Femoral Head Coverage

	UNDERCOVERAGE	OVERCOVERAGE
Anterior pelvic tilt		x
Posterior pelvic tilt	x	
Lateral pelvic tilt (acetabular abduction)	x	
Lateral pelvic tilt (acetabular adduction)		x
Pelvic rotation (acetabular retroversion)		x
Pelvic rotation (acetabular anteversion)	x	
Intrapelvic torsion (anterior-inferior rotation)		x
Intrapelvic torsion (posterior-superior rotation)	x	
Femur flexion		x
Femur extension	x	
Femur LR	x	
Femur MR		x
Femur adduction	x	
Femur abduction		x

Active and Passive Open Chain Osteokinematic ROM

It is important to determine osteokinematic mobility of the hip joint along the continuum of hypermobility to hypomobility about all three axes of motion by carefully stabilizing the spine and pelvis during passive ROM examination techniques. Often, reduced ROM is the only finding documented when excessive mobility is not only common, it is equally as problematic with respect to joint function. Controlling excessive mobility from excessive lengthening of articular, periarticular, and myofascial sources (i.e., acetabular dysplasia in the presence of overstretched anterior capsuloligamentous structures and excessive psoas length) is vital to reducing symptoms and improving function in subgroups of hip patients. Qualitative assessment of active and passive ROM combined with clinical reasoning can supply specific diagnostic information: (Note: Caution must be taken with ROM measures to ensure a neutral start position of both the femur and acetabular sides. In addition, if measuring rotation across the hip, knee joint laxity may hide hip hypomobility by moving excessively in frontal or transverse planes.)

- A firm overpressure applied to a motion is used to exclude or diagnose joint pathology. Overpressure can also be used to determine the hip end-feel and therefore the structures providing the barrier to further motion.
- Assessment of the sequence of pain and limitation can grade the irritability of the condition and guide the intensity of treatment.[76]
- The pattern of restriction can indicate the presence of a capsular pattern (see Display 19-1). This can be an indication of joint inflammation.[76]
- The combined results of passive and active movement testing can implicate a contractile or inert structure.[76] For example, the findings of passive movement painful in one direction and active movement painful in another implicate a contractile structure.

If ROM is limited in one direction, and excessive in another (e.g., hip MR is excessive while LR is limited), the femur may not be centered in the acetabulum and thus bias the ROM findings. To restore a centric position of the femur to determine the true ROM limitations of the joint, this author proposes the use of a simple pelvic repositioning technique to alter femoroacetabular alignment and determine the effect on ROM (see **Fig. 19-6**). Isometric contraction of adductors and medial rotators theoretically creates a directional change to the acetabulum toward more anteversion and isometric contraction of the posterior GM and lateral rotators toward more retroversion. Theoretically, this has an impact on three-dimensional acetabular position relative to the femoral head. It can be beneficial to use this technique as an exercise, combined with a more comprehensive program with posture and movement training to improve femoroacetabular congruence during function, similar to altering scapular mechanics to improve scapulohumeral congruence during function.

Muscle Length

Tests of muscular extensibility are also important in assessing ROM of the hip. Common extensibility tests include determining the length of several muscles:

- Medial and lateral hamstrings (hamstring length should be examined as a group and individually)

FIGURE 19-6 Pelvic sensitization: isometric contraction of left adductor into firm ball and right abductor into table leg, wall, door. Use this pattern in the presence of a left anterior-inferior innominate and right posterior-superior innominate. Check for hip ROM pre- and post-sensitization. If ROM improves, good prognosis for exercise to modulate symptoms related to FAI or hypermobility.

- Hip flexors (hip flexor length should be assessed individually for the iliopsoas, rectus femoris, and TFL)
- Hip adductors/abductors (particularly TFL)
- Hip rotators

The examiner should assess for a lack of extensibility and for excessive extensibility. A hypothesis should be developed regarding the impact that extensibility impairments will have on the function of the hip and related regions.

Work (Job/School/Play), Community, and Leisure Integration or Reintegration (Including Instrumental Activities of Daily Living)

Although measures of physiologic impairments are important for diagnosis, prognosis, and treatment planning, functional ability and quality of life are better indicators of outcome.[79] The Harris Hip Function Scale is an outcome measure that is specific to degenerative conditions of the hip.[80] This scale combines a patient's report of pain and his or her capacity for ambulation and self-care. These tasks account for 91% of the score, and deformity and hip ROM account for 9% of the score. The advantages of this scale are that it is heavily weighted toward function, is easy to administer, and is familiar to most clinicians. The Harris Hip Function Scale has been used as the gold standard in a number of studies and has been shown to be reliable with an intraclass correlation coefficient of 0.82 to 0.91. Other measures include the Hip Osteoarthritis Outcomes Score (HOOS) and the Lower Extremity Functional Scale (LEFS).[81] The Copenhagen Hip and Groin Outcome Score (HAGOS) is a validated outcome tool used for assessing hip pain in young to middle-aged, physically active patients with long-standing hip and/or groin pain.[82]

Special Tests

Numerous special tests are used to confirm or negate symptoms or suspected diagnoses of the hip. For the commonly used special tests discussed in this section, specific information regarding the technique of application can be found in the related references.

Trendelenburg Test

In unilateral stance, the weight of the head, arms, and trunk (HAT) act at a fixed distance from the hip, producing an adduction torque. The abductors, acting a fixed distance from the hip, must generate a force to produce an abduction torque sufficient to counterbalance the torque produced by the HAT (see **Fig. 19-7A**). The Trendelenburg test is used to evaluate the functional force or torque capability of the hip abductor muscle group. During gait, the patient may exhibit a positive Trendelenburg sign (see Fig. 19-7B) or compensated Trendelenburg sign (see Fig. 19-7C).[72] Other gait deviations of the hip indicate hip abductor torque impairment, such as excessive hip medial rotation, pelvic counter-rotation, or excessive lateral pelvic shift. These other gait deviations are also indicators of reduced hip abductor muscle performance and are particularly related to positional weakness of the GM.

Limb Length Discrepancy

Limb length discrepancy (LLD) is a relatively common problem with an estimated prevalence rate of 40%[83] to 70%[84] of the population. LLD can be subdivided into two etiologic groups: an SLLD defined as those associated with a shortening of bony structures, and an FLLD defined as those that are a result of altered mechanics of the lower extremities.[85] Definitions of FLLD versus SLLD are described earlier in this chapter. In addition, persons with LLD can be classified into two categories: those who have had LLD since childhood, and those who developed LLD later in life. In terms of functional outcomes such as gait, persons who have developed an LLD later in life are more debilitated by LLD of the same magnitude when compared to persons who have had LLD since childhood.[86]

The etiology of SLLD may be congenital or acquired. Of the congenital causes, the most common include congenital dislocation of the hip and congenital hemiatrophy or hemihypertrophy with skeletal involvement. Acquired causes can be a result of infections, paralysis, tumors, surgical procedures such as prosthetic hip replacement, and mechanical such as slipped capital femoral epiphysis.

If the examiner suspects that one of a patient's legs may be shorter than the other, specific tests are indicated to determine whether an SLLD or an FLLD exists. Radiographs or other imaging techniques should be used when accuracy is critical. Ultrasound measurement of LLD offers a reliable, noninvasive, and easily performed method.[87] This technique is superior to clinical measuring methods and radiologic examinations.[88] In general, although imaging techniques are considered to be the most accurate method for determining LLD, they are costly, time consuming, and, in the case of radiographs and computed tomography (CT), the patient is exposed to radiation. As a result, alternative clinical methods have been developed. Two methods have emerged over the years: (a) an "indirect method" performed in standing using lift blocks under the short leg and visually examining the level pelvis, termed the "iliac crest palpation and book correction" method (ICPBC)[84,89] and (b) a "direct method" done in supine measuring the distance of fixed bony landmarks with a measuring tape. Two commonly used tape measure methods include measuring the distance between (a) the anterior superior iliac spine (ASIS) and the lateral malleolus[84] and (b) the ASIS and the medial malleolus.[90] There is still disagreement regarding the validity and reliability of both the clinical methods. Both measures, between the ASIS and the lateral malleolus and the ICPBC method, appear to have acceptable validity and reliability when used as a screening tool.[89,91]

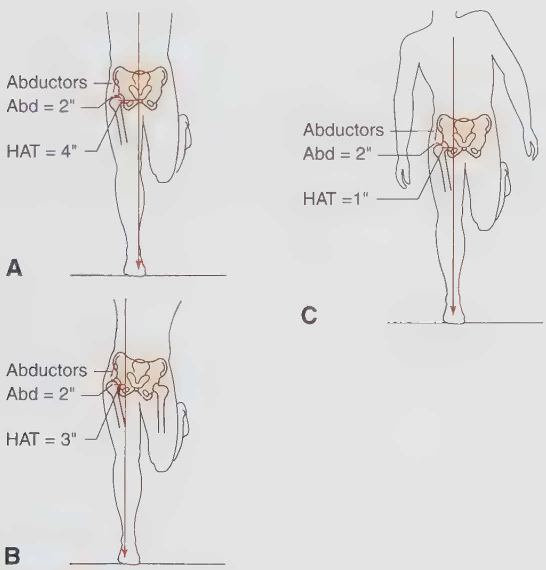


FIGURE 19-7 **(A)** R unilateral stance. **(B)** The pelvis drops on the opposite side of the stance limb when the abductor force cannot counterbalance the torque produced by HAT. This is called a positive Trendelenburg sign and is used as a compensation for hip abductor weakness. **(C)** When the trunk is laterally flexed toward a stance limb, the moment arm of the HAT is substantially reduced, whereas that of the abductors remains unchanged. The result is a substantially diminished torque from the HAT and a corresponding decreased hip abductor force to counterbalance the HAT torque. This is called a compensated Trendelenburg sign. Patients will use this gait pattern to reduce the joint reaction force and thus alleviate pain.

Angle of Torsion

There are several methods for measuring the angle of torsion, including radiography, CT, magnetic resonance imaging (MRI), and ultrasound sonography. However, only one clinical method, the trochanteric prominence angle test (TPAT, also known as the Craig's test), has been described to measure angle of torsion by determining the angle formed by the vertical line and the tibial crest, when the greater trochanter is most prominent laterally[92–96] (**Fig. 19-8**). The developers of this test demonstrated that this measurement correlates well with intraoperative measurements, and it is considered to be more accurate than radiographic techniques.[96] Yet, a more recent study concluded that clinical application of the TPAT is limited by both the variable anatomy of the proximal femur and examiner difficulties related to the soft tissues surrounding the hip joint.[93] However, this method may be acceptable if the goal of the test is to screen for abnormality. If accuracy is desired, two- or three-dimensional CT imaging is thought to be the most precise method for determining femoral anteversion.[97]

Differences in hip rotation ROM can also indicate abnormal femoral torsion. To predict an abnormally high anteversion angle (above mean +2 standard deviations [SD]), the difference between medial and lateral rotation (measured in hip extension) must

FIGURE 19-8 TPAT test. The TPAT presumes that when the subject is prone, with the hip in extension, and the most prominent portion of the greater trochanter is rotated into maximum lateral position, the femoral neck will be parallel to the floor. The angle of rotation of the shank segment relative to vertical at this point reflects the overall angle of torsion.

be 45 degrees or more, whereas an abnormally low anteversion angle (lower than mean −2 SD) could be predicted when LR is at least 50 degrees higher than medial rotation[98] (**Evidence and Research 19-4**).

EVIDENCE and RESEARCH 19-4

Trochanteric Prominence Angle Test (TPAT) or Craig's Test

Previous investigations have reported a wide range of reliability coefficients (0.45 to 0.97) and measurement errors (1.1 to 8.4 degrees) of the TPAT.[96,99–101] The application of TPAT may be limited by obesity, scarring about the proximal femur, and ligamentous laxity in the knee joint.[93,96] In particular, several reports indicate that using the tibia as a lever in 90-degree knee joint flexion increases the medial knee joint space (KJS) because of laxity of the knee joint.[102–104] Thus, any potential increase in KJS could affect the angle between the vertical line and the tibial crest during the TPAT.

Anterior Impingement/FABER

In the FAI literature, the anterior impingement test (flexion and MR in 90 degrees of hip flexion) is positive in 88% to 99% of patients while the FABER test (flexion, abduction, LR in 90 degrees of hip flexion) is positive in 69% to 97% of patients who have subsequently surgically confirmed FAI.[105,106] A review of additional common special tests for the hip can be found in the research.[107–109]

THERAPEUTIC EXERCISE INTERVENTIONS FOR COMMON PHYSIOLOGIC IMPAIRMENTS

After examination and evaluation of the hip and all related regions, the clinician should have a thorough understanding of the activity limitations affecting the patient and their participation restrictions. The diagnosis and prognosis are formulated, and an intervention is planned.

The decision to treat any impairment lies in its relationship to the activity limitation and participation restriction. Prioritization of impairments is critical to effective and efficient intervention. Exercise intervention should be kept as functional as possible. However, if the impairment is significant, specific exercise may be necessary to improve the mobility, level of performance, and motor control until it can be incorporated into a functional activity. Specific exercise and functional activity examples are provided in the discussion of exercise intervention for common impairments of body functions affecting the hip.

Pain

Pain is undoubtedly the most common reason persons seek physical therapy for hip-related dysfunction. In one study, 14.3% of adults 60 years and older reported significant hip pain on most days over the previous 6 weeks.[110] Although athletic injuries to the adolescent hip have been reported in the literature over the past 25 years,[111,112] this anatomic area in this patient population receives increased attention because of the advent of hip arthroscopy and the development of more advanced imaging of this joint through MR arthrography.[113–116] Unique attributes of the adolescent hip places it at risk for injury and pain leading to functional limitations and participation restrictions at a young age when activity levels should be high (see **Evidence and Research 19-5**).

EVIDENCE and RESEARCH 19-5

The Adolescent Hip

About 30 million children in the United States participate in organized sports programs, with over one-third of school-age children sustaining an injury that requires evaluation and treatment by the medical community.[117] There are physical and physiologic differences between the adolescent athlete and adult athlete that may cause the former to be more prone to sports injury. Adolescent athletes may have a temporary decline in coordination and musculoskeletal imbalance, as limb mass increases at a faster rate compared with limb length.[118] In addition, as muscle tendon growth lags behind bony growth, there is a lack of flexibility, which may predispose to injury. This increase in functional demand on the muscles can cause increased stress on the tendons, musculotendinous junctions, and apophyses. Adolescents have open growth plates, and increased stress to the growth plate can lead to damage to this area and possibly early physeal closure. Growing cartilage is more susceptible to stress and may predispose the adolescent to an overuse injury. All of these factors place the adolescent athlete at risk for injury during sporting activity.[119]

The most important aspect of therapeutic exercise intervention for hip pain is the differential diagnosis of the etiology as well as the mechanical cause of the pain. Traumatic and overuse soft tissue injuries include muscular, bursal, tendinous, or ligamentous inflammation, contusions, strains, and sprains. Skeletal injuries can involve the physis or apophysis in children, and skeletal disorders include fractures, subluxations, dislocations, stress injuries, infections, bony changes (i.e., cam and pincer morphology), and avulsions. Patients with nontraumatic hip pain from systemic conditions such as rheumatoid arthritis, juvenile arthritis, ankylosing spondylitis, tumors, and metabolic

DISPLAY 19-2

Guidelines for Pain Relief Involving the Hip Joint

- *Activity modification*: Initially, the clinician should encourage patients to maintain muscle performance and ROM of the hip while avoiding risk activities, such as running, carrying heavy loads (especially contralateral to the painful hip[122]), or prolonged standing.
- *Physical agents or electrotherapeutic modalities*: The use of cryotherapy, moist heat, or electrotherapeutic modalities may help modulate pain or decrease inflammation. Because of the anatomic position of the hip, these modalities may have limited effectiveness in treating intra-articular inflammation or sources of pain.
- *Manual therapy*: Appropriate use of joint and soft tissue mobilization can improve physiologic impairments related to pain and inflammation, such as joint mobility and tissue extensibility. Joint mobilization can also be used to modulate pain (see Chapter 7).[123]
- *Therapeutic exercise intervention*: Gentle active ROM exercises in the pain-free range can be used to modulate pain, similar to the Grade III joint mobilizations described by Maitland.[123]
- *Assistive devices*: When a person has a limp caused by pain, use of an assistive device in the contralateral hand is necessary to reduce the load on the hip. A cane in the contralateral hand of a patient can reduce the joint reaction force by as much as 30%.[124,125] Patients often are reluctant to use an assistive device for fear of "giving in to the condition." Patient-related instruction must include an explanation that temporary use of an assistive device will reduce the load at the hip and allow the pain and inflammation to resolve. Exercise to improve mobility and force- or torque-generating capability of the appropriate musculature is required to discontinue use of the assistive device without risk of recurrence of symptoms.
- *Weight loss*: Overweight persons must work diligently on weight loss through proper nutritional counseling and aerobic activity tolerated by a painful hip, including non–weight-bearing activity such as aquatic activities or cycling. It is possible that cumulative exposure to excessive body mass may increase the risk of developing hip OA[126,127] and the worsening of the disease.[128,129]
- *Biomechanical support*: Carefully prescribed foot orthotics can improve skeletal alignment and potentially influence contact forces at the hip.[130]

bone disease should be suspected when the severity or course of the injury is atypical. Persistent hip pain can originate from intra-articular disorders such as avascular necrosis, OA, loose bodies, labral tears, or pyarthrosis. Hip pain also may be secondary to a lumbar spine disorder. Nerve entrapment syndromes involving the ilioinguinal, genitofemoral, obturator, and lateral femoral cutaneous nerve of the thigh may present as hip pain or paresthesias (to be discussed in more detail under **Nerve Entrapment Syndromes**).

Pain from the hip joint can be referred anteriorly to the groin, laterally in the region of the greater trochanter spreading down the lateral thigh, or may radiate down the anterior and medial thigh to the knee. Occasionally, referred knee pain can occur with little or no pain in the hip, particularly in the pediatric population.

Pain posterior to the hip or in the buttock is frequently associated with lumbar spine pathology, but it can also arise from the hip. Pain from the spine commonly radiates down the posterior thigh, occasionally to below the knee, but hip pain rarely radiates below the knee. Acute synovitis or arthritis can produce pain in the entire hemipelvis. Pain related to iliotibial band (ITB) fasciitis/fasciosis can be experienced in the lateral thigh and can be mistaken for lumbar radiculopathy.[120,121] Because this condition occurs commonly in the elderly, spinal stenosis can be incorrectly implicated as the source of the lateral thigh pain.

Whether or not the source of the pain is diagnosed, the underlying biomechanical cause should be attempted to be established. Treatment must work toward alleviating impairments related to the cause of tissue changes resulting in nociception and the experience of pain, leading to loss of function and participation in meaningful activities. Treatment focused on the underlying cause(s) of tissue inflammation, sprain, strain, or degeneration often relieves symptoms without specific treatment of the source. Several examples of treatment focused on underlying contributing components of the movement system are presented throughout this chapter. Interventions for pain relief can follow the general guidelines illustrated in **Display 19-2**. Treatment of the underlying contributing factors of pain is a more complicated decision-making process and takes into consideration impairments in the subsystems of the movement system (see **Building Block 19-1**).

BUILDING BLOCK 19-1

Consider a 71-year-old female post open reduction internal fixation (ORIF) of the left femur secondary to a fall. She currently is walking with a walker with toe touch weight bearing. The patient can now progress to ambulating weight bearing as tolerated (WBAT), but she has 8/10 pain in the lateral hip and thigh when she places increased weight on her left limb. She presents with significant Trendelenburg pattern upon left weight bearing and fear of falling. Examination reveals 3/5 strength in hip flexion and extension, and 3−/5 of her hip extension and lateral rotation. What subsystems are contributing to her experience of pain? How would you address each subsystem in a therapeutic exercise intervention?

Muscle Performance

The section on kinetics describes the powerful forces required from the musculature surrounding the hip joint for accomplishing ADLs. The force-generating capability of any muscle around the hip joint may be compromised for one of the following reasons:

- Neurologic pathology (e.g., peripheral nerve, nerve root, neuromuscular disease)
- Muscle strain

- Altered length–tension relationships (resulting from either anatomic or physiologic impairments)
- General weakness from disuse, resulting from muscle imbalance, general deconditioning, or reduced muscle torque production for a specific performance level (e.g., high-level athlete in training)
- Pain and inflammation

Endurance impairments at the hip must be thought of in light of the tremendous force-generating requirements of the gluteal musculature during functional activities. Endurance is required to meet the repetitious demands of walking, jogging, running, sprinting, and so on. Proper synergy among all muscles involved in the gait cycle keeps the intensity of muscle action at an aerobic level. When one muscle in a synergy group reduces its function, it imposes greater demands on other muscles, potentially rendering them anaerobic and therefore far less efficient.[131] In addition, loss of muscle function can result in compensatory strategies, such as reliance on the ITB for stability or a compensatory Trendelenburg pattern to reduce the need for muscle force to keep the center of mass within the base of support. Dosage parameters depend on the performance level desired by the individual (e.g., walking 50 feet without pain, running a marathon in the best time possible), with an emphasis on high repetitions instead of maximal force production.

Neurologic Pathology

To develop the appropriate plan of care, it must be determined whether the source of the neurologically induced weakness is a lower or upper motor neuron lesion.

If the clinician has determined that the cause is lower motor neuron in origin, it must then be determined whether the pathology is at the level of the nerve root or in a peripheral nerve. A dysfunction at the level of the lumbar spine can induce nerve root pathology that can manifest as weakness of the muscles innervated by the affected segmental levels.[132] The clinician must thoroughly screen the LP region to confirm or negate the hypothesis of spinal influence on the reduced force-generating capability of muscles surrounding the pelvic girdle.

Numerous peripheral nerves surround the hip. The section on **Nerve Entrapment Syndromes** will discuss the potential peripheral nerve injuries affecting the hip region.

After a thorough examination and evaluation process, the neurologically induced hip joint weakness must be treated. Whether the source of the neurologic involvement is from the nerve root or peripheral nerve, the origin of the problem must be treated appropriately for the affected muscle torque production to improve.

Despite alleviation of neurologic factors, weakness contributing to activity limitation may still exist. The level of weakness depends on the degree and duration of neurologic involvement. **Display 19-3** provides a clinical example to illustrate this point.

Muscle Strain

Force-generating capability may be compromised by an injury to the muscle in the form of muscle strain.

Acute hamstring injuries are one of the most common injuries resulting in loss of time for athletes at all levels of competition.[133–137] Those involved in sports that require high sprinting speeds, such as track, football, and rugby, are especially prone to injury.[138] Previous literature has indicated that nearly one in three hamstring injuries will recur and that many of these would happen within the first 2 weeks on return to sport.[139,140] This high rate of recurrence may be due to a combination of ineffective rehabilitation and inadequate return to sport criteria.

Two specific injury mechanisms have been defined that seem to influence the injury location and rehabilitation requirement: high-speed running and excessive stretching. During high-speed running, the terminal swing phase has been identified as the time of hamstring injury occurrence, most often involving biceps femoris long head.[141,142] During this phase of the running cycle, the hamstring muscles are active while lengthening (eccentric contraction) to absorb energy to slow the advancing limb in preparation for foot contact. At initial contact and loading response, the biceps femoris is thought to decelerate MR that occurs with foot pronation.[131,143–145] These injuries typically

DISPLAY 19-3

Case Example of Neurologic Factors Contributing to Weakness at the Hip

Case Presentation

A 13-year-old gymnast has had a 5-month complaint of posterolateral hip pain. At the time of her initial evaluation, she was diagnosed with a GM strain. Appropriate treatment of her GM strain did not improve her condition after 3 months. At that time, her physician performed a thorough lumbar screen. Radiologic reports indicated a Grade II L5–S1 spondylolisthesis with slight L5 nerve root compression occurring with end range lumbar extension. As a result of the additional diagnosis of spondylolisthesis, she was treated with lumbosacral bracing and exercise to correct impairments related to the spine instability. During the next 3 months, her hip pain began to resolve, although only after a dual program was developed for treatment of the spondylolisthesis and GM strain.

Explanation of Outcome

The L5 nerve root innervates the gluteal musculature. Irritation of the nerve root at the unstable spinal level could interrupt the motor function of the L5 nerve root, resulting in neurologically induced weakness of the GM.[48] Without full afferent input into the GM, it may be vulnerable to strain, especially at the level of this patient's activity. Effective healing could not occur until afferent input into the GM was fully restored, which could not occur until the stability of L5–S1 segmental level was sufficient for her activity level. After the L5–S1 level became more stable and normal afferent input was restored to the affected musculature, a gradual conditioning program for the GM muscle was necessary to restore muscle performance to the functional level desired by this patient.

Sample Exercise Program

An example of a progressive strengthening program for the GM is illustrated in Self-Management 19-4. This progression begins in prone for the muscle with a 3/5 or lower MMT grade[28] and progresses to sidelying with increasing lever arms to increase the load on the muscle. As muscle performance improves, transition to functional positions and movements can be introduced. Self-Management 19-2 can be progressed to a leap, with the focus on controlling frontal and transverse plane forces at the hip on landing.

involve the intramuscular tendon, or aponeurosis, and the surrounding tissues.[146]

The second defined injury mechanism involves an overstretch, which more commonly injures the proximal free tendon of the semimembranosus.[146–148] These injuries are common to dancing and kicking activities, in which a combined hip flexion with knee extension movement occurs. Current evidence indicates that athletes with injuries involving the proximal free tendon take longer to recover.[148]

Sahrmann proposes hamstring overuse as another etiology for hamstring strain.[149] The hamstrings participate in force couples around the LP-hip complex, contributing to posterior pelvic rotation, hip extension, and, indirectly, hip medial and lateral rotation. Because of the multiple roles of the hamstrings, it is quite possible to sustain an overuse injury. **Display 19-4** describes possible mechanisms of hamstring overuse.

The goals of rehabilitation for hamstring injuries are to return the individual to prior level of function. With an athlete, the goal is to return to prior level of performance and participation with minimal risk for reinjury. As such, impairments experienced as a direct result of the injury (e.g., pain, swelling, weakness, reduced ROM) must be addressed throughout the rehabilitation process. In addition to treating the muscle injury, underlying mechanical imbalances may be corrected to reduce the risk of recurrent injuries. Previous research has identified risk factors for initial hamstring injury. Of these, modifiable risk factors include hamstring weakness, fatigue, reduced flexibility,[133,150,151] imbalances in hamstring eccentric and quadriceps concentric strength,[152–154] decreased quadriceps flexibility,[155] and strength and coordination deficits of the pelvis and trunk musculature.[156] It can be speculated that addressing these issues after hamstring injury would also likely decrease reinjury risk.

Treatment of a hamstring strain should follow the guidelines for tissue healing outlined in Chapter 11. After remodeling and repair, the hamstring muscle displays (1) decreased peak torque production,[157] (2) peak force at shorter lengths, which may predispose the muscle to further injury when functioning at a lengthened position, (3) altered firing patterns,[158] and (4) decreased eccentric strength.[159,160] Eccentric exercise can shift the peak force production to longer muscle lengths[161] (see **Fig. 19-9**). This shift in force production may help to restore optimal musculotendon length for tension production to reduce risk of injury. However, for the hamstrings to fully recover, treatment must be focused on the underlying *cause*

DISPLAY 19-4

Mechanisms of Hamstring Overuse

- Subtle imbalances in force or torque production and endurance between the hamstrings and gluteus maximus may lead to excess demand on the hamstrings to decelerate hip flexion during late mid-swing and hip MR at initial contact.
- Significant forefoot varus (see Chapter 21), combined with length–tension alterations and reduced force or torque production of the deep hip lateral rotators, may lead to overuse of the biceps femoris. Without optimal foot mechanics and hip lateral rotator function, the biceps femoris load is exaggerated because of the increased role it must play in decelerating femoral and tibial MR at initial contact through the midstance phase of gait.
- Underuse of the oblique abdominal muscles may lead to overuse of the hamstrings because of the increased role they must play to exert a posterior rotational force on the LP region.

A

B

C

FIGURE 19-9 Eccentric exercise examples. **(A)** Standing windmill; **(B** and **C)** Nordic hamstring.

SELF-MANAGEMENT 19-1
Stomach-Lying Hip Extension

Purpose: To strengthen the gluteal muscles, train to move your hip independent of your pelvis and spine and stretch the muscles on the front of your hip.

Start Position: Lie on your stomach on a firm surface and place ____ pillows under your torso.

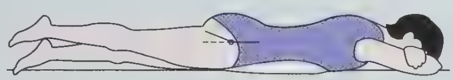
Movement Technique:

- Preset your spine and pelvic position by activating your abdominal wall and gently squeezing your gluteal (seat) muscle. Try to keep your hamstring muscles relaxed.
- Use your abdominal muscles to control the position of the pelvis. Think of keeping your pubic bone rotated upward toward your ribs.
- Use your gluteal muscles to barely lift your thigh off the floor.
- Return your thigh to the floor and repeat the lift with the other leg.

Dosage:

Sets/Repetitions: ______________________

Frequency: ______________________



of the strain and predisposing risk factors. If the cause of the strain is overuse, the load must be reduced on the hamstrings during meaningful functional activities. Improving the muscle performance and neuromuscular control of the *underused synergists* and correcting for any biomechanical factors (e.g., foot progression relative to knee in sagittal plane) constitute a recommended course of action.

Two commonly underused synergists involved in the cause of hamstring overuse strain are the gluteus maximus and deep hip lateral rotators. Examples of therapeutic intervention for progressive strengthening of the gluteus maximus and deep hip lateral rotators are shown in **Self-Management 19-1** and **Figure 19-10.** These exercises illustrated are considered specific, nonfunctional exercises. There are two reasons to prescribe this type of exercise instead of more functionally relevant exercise. First, the force-generating capability of the muscle is inadequate to allow it to fully participate in a functional task. Second (and possibly more importantly), the kinesthetic awareness of the muscle may be such that the patient's ability to selectively recruit it during a functional task may be insufficient.

After force-generating capability and kinesthetic awareness of the proximal posterior hip musculature are improved sufficiently, graded functional activities can be initiated. **Self-Managements 19-2** and **19-3** illustrate functional progressions of specific exercises that use the gluteus maximus, hamstrings, quadriceps, and deep hip lateral rotators in sagittal plane kinetic chain activities. Other functional exercises shown to activate this musculature to at least 40% of maximum voluntary contraction (MVC) include single-limb squat and the lunge (forward, sideways)[162]

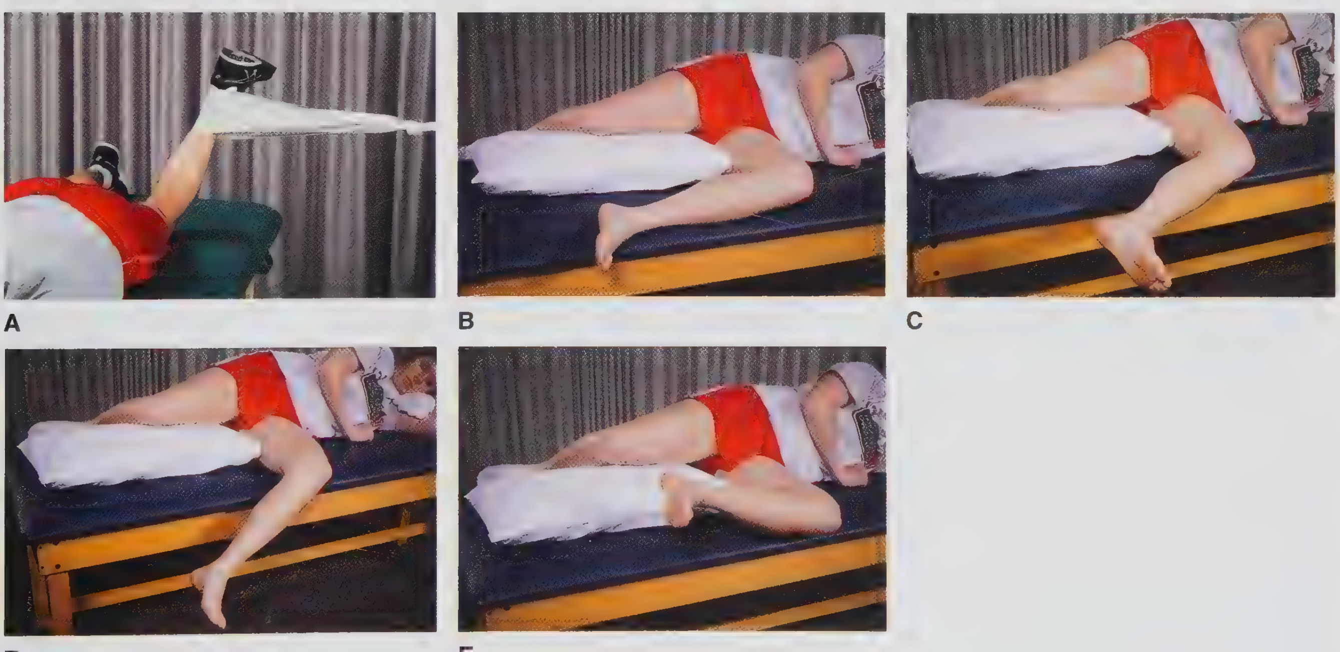


FIGURE 19-10 **(A)** Prone hip LR with elastic. The patient is instructed to stabilize the pelvis in the sagittal and transverse planes with abdominal wall recruitment while rotating the hip from MR to midline or slight lateral rotation. The slow release back to MR emphasizes eccentric control of the lateral rotators. The hip-extended position favors all hip lateral rotators, including lateral hamstrings and gluteus maximus. **(B)** The sidelying position at 90 degrees of hip flexion provides better isolation of the deep hip lateral rotators from the gluteals and hamstrings. **(C)** This illustration shows an isometric contraction by slightly extending the knee so that the hip rotators are holding the tibia against gravity. Be careful of adductor recruitment by ensuring the pelvis is perpendicular to the ground. **(D)** This diagram shows an eccentric contraction. **(E)** This diagram shows a concentric contraction. All types of contractions can be trained for various purposes as they relate to function of the deep hip lateral rotators.

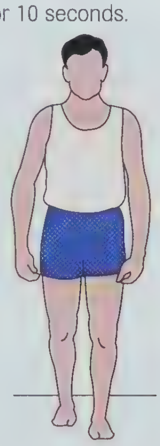
SELF-MANAGEMENT 19-2
Walk Stance Progression

Purpose: To teach the correct pattern to move your body over your hip, teach a good strategy to balance on one leg, and strengthen your hip and other lower extremity muscles to support your lower extremities in good alignment for activities you perform in standing.

Level I

Start Position:
- Stand in a staggered stance position with your involved leg in front of your uninvolved leg.
- Check the position of your feet, knees, hips, and pelvis.
- Feet should be facing straight ahead with arches in neutral.
- Knees should be facing straight ahead without turning in or out excessively (if you have anteverted or retroverted hips, the knee position may be modified).
- Hips and pelvis should be facing forward and level.

Movement Technique:
- Slowly bend your front hip and knee while leaning slightly toward your front leg.
- Pivot at your hips and lean your trunk forward so that it is parallel to the line of your lower leg. Do not round or arch your back.
- Do not bend your knee further than the length of your foot. Hold this position for 10 seconds.
- Activate your abdominal wall. (Note: activate your abdominal wall in preparation for all the levels of this exercise.)
- Turn on your deep hip lateral rotators by keeping your knee centered over your feet (do not let your knee turn inward).
- If your arch drops excessively, hold the arch of your foot up while you keep your big toe down. If your arch remains high and rigid, allow it to roll inward slightly. Your physical therapist will clarify the movement of your foot based on your foot type.



Dosage:

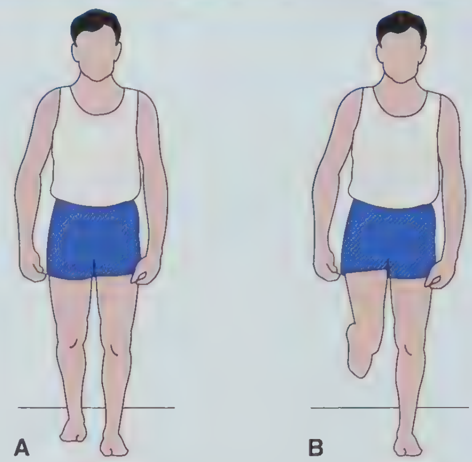
Sets/Repetitions: ______________________

Frequency: ______________________

Level II: Single-Limb Stance

Start Position:
- The start position for this exercise is the end position of Level I.

Movement Technique
- Progress from the walk stance position by lifting your back heel upward as you straighten your front knee and hip (**Fig. A**).



- Be sure your feet, knees, hips, pelvis, and spine are in good alignment.
- Hold this position for 3 seconds.
- Slowly bring your back thigh forward by bending the hip and knee (as if to take a step forward) (**Fig. B**).
- Balance for up to 30 seconds.

Dosage:

Sets/Repetitions: ______________________

Duration: ______________________

Frequency: ______________________

Level III: Split Squat

Start Position:
- Position yourself in a staggered stance with your involved leg forward.
- Lean toward your front limb as in Level I.
- Keeping your spine, pelvis, hips, knees, and ankles steady, slowly lower yourself until you see or feel your pelvis tilting or rotating out of the start position.

SELF-MANAGEMENT 19-2
Walk Stance Progression *(continued)*

- The movement should be occurring at your hip and knee. Your front knee should only bend as far as the length of your foot. (Note: a good rule of thumb is to keep your lower leg bone parallel to your torso throughout the entire maneuver.)
- Most of your weight should be over your front limb; if you feel your back limb straining, shift your weight onto your front limb.
- Slowly rise upward while keeping your weight shifted forward.
- Repeat up and down while remaining in a forward position over your front foot.

Dosage:

Sets/Repetitions: ______________________

Frequency: ______________________

Level IV: Lunge

Start Position: Stand with both feet on the floor and weight equally distributed between both limbs.
Take a step forward and watch your pelvis, hip, knee, ankle, and foot position as in Level I. Do not let your back arch.

This is a ballistic exercise. Be extra careful about your position.

Dosage:

Sets/Repetitions: ______________________

Frequency: ______________________

SELF-MANAGEMENT 19-3
Step-Up, Step-Down

Purpose: To strengthen your spine, hip, knee, ankle, and foot muscles and to improve your balance in single-limb stance.

Step-Up (Fig. A)

Start Position: Stand facing a step.

Movement Technique: Lift your leg onto the step, keeping your thigh in midline and your pelvis level. Do not hike your pelvis while lifting your leg onto the step. This movement should take place only at the hip and knee.
After your foot is on the step, check its position. The arch should be up with the big toe down.
Lean toward the step, being sure that your knee is in line with your foot (Note: this may vary if you have anteverted or retroverted hips) and your pelvis is level.
Looking at your body from the side, a good rule of thumb is to flex your knee no further past the length of your foot and to keep your lower leg bone parallel to your torso throughout the entire step-up and step-down maneuver.
Step up while keeping your pelvis level, knee over toes, and arch up. Be sure to lean into your hip, but do not let your pelvis tilt.

Variation: You can stand to the side of a step and step up sideways. This variation places more stress on your outside hip muscles. Be sure to keep your pelvis level.
Variation: You can step off the back of the step. Do not step down fully, but merely touch your toe on the floor and step back up again so as not to fully unload the weight of your body through the stance leg. This makes the stepping leg work harder. This variation places more stress on your quadriceps.

Dosage:

Sets/Repetitions: ______________________

Resistance (step height): ______________________

Frequency: ______________________

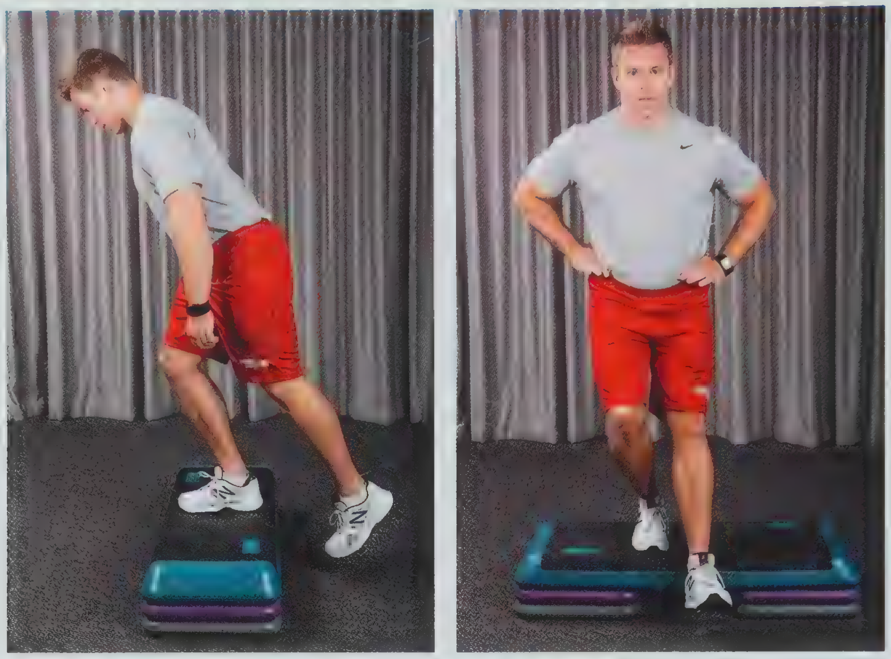
Step-Down (Fig. B)

Start Position: Stand on a step that is higher than you can control during a step-down movement.

Movement:
- Flex the foot of the leg you are stepping down with.
- Bend the hip and knee of the foot remaining on the step as you lower your flexed foot toward the floor.

(*continued*)

SELF-MANAGEMENT 19-3
Step-Up, Step-Down (*continued*)



A B

- Lean forward so as to bend at your hip. Do not let your knee bend further than the length of your foot.
- Do not completely step down, but stop just short of the floor and hold this position for up to 10 seconds.
- Be sure that your pelvis is level, your knee over your toes (Note: this may vary if you have anteverted or retroverted hips), and you arch up as you lower your leg. Do not deviate from this position.
- Variation: You may need to use an external device to assist you in your balance.
  - ___ Hold a ski pole, dowel rod, or upside down broom in each hand.
- ___ Hold a ski pole, dowel rod, or upside down broom in the opposite hand from which you are balancing.
  - ___ Hold a weight in the hand of the hip on which you are balancing.
- Variation: After you can balance well during the lowering phase, you can further challenge your balance by using arm movements. When you have lowered yourself as far as you can control, raise the arm on the same side or opposite side of the leg on which you are balancing.
  - ___ Raise it up and down to the side.
  - ___ Raise it up and down to the front.
  - ___ Raise it toward and away from the midline of your body.

Dosage:

Sets/Repetitions: ____________________

Assistance (amount of weight in hand): ____________________

Resistance (step height): ____________________

Frequency: ____________________

(see **Fig. 19-11**). The clinician must be concerned with the recruitment of the underused synergists during each exercise. Subtle changes in lower quarter kinematics can affect muscle recruitment strategies.[163] For example, keeping the trunk more vertical during a step activity can diminish the use of gluteus maximus relative to the quadriceps (**Fig. 19-12A**), whereas inclination of the trunk toward a more horizontal position can increase the use of gluteus maximus relative to the quadriceps[164] (see Fig. 19-12B). **Display 19-5** describes the role of various muscles during these exercises.

Overstretch can also be a contributing factor to muscle strain. For example, the GM muscle is susceptible to strain resulting

FIGURE 19-11 **(A)** Single-limb squat: ensure the patient/client maintains a sagittal plane alignment during the squat and that tibia and torso remain parallel as the squat progresses in depth. Watch for sagittal, transverse, and frontal plane alignment from thorax to foot. Lunge: similar to the squat, ensure optimal alignment in all planes during **(B)** front and **(C)** side lunges. Cue forward lean in the lunge.

from length-associated changes, which can occur in an individual with an apparent LLD and resulting iliac crest height asymmetry.[149] On the side of the high iliac crest, the hip is adducted, and the GM is in a chronically lengthened position. As a result, this muscle is at risk of strain. Treatment of this type of strain must involve exercises that resolve the contributing factors to the LLD in conjunction with treatment to improve the length–tension properties, muscle performance, and neuromuscular control of the GM. In the early stages of recovery, taping (**Fig. 19-13**) can unload the muscle and support it at an appropriate length, providing a positive environment for healing. Severe strains may require use of a cane in the contralateral hand to unload the muscle

A B

FIGURE 19-12 **(A)** Side view of step-up exercise with vertical trunk orientation, decreased hip flexion, and center of mass posterior to the axis of rotation of the hip and knee. Step-up from this start position promotes use of a hamstring and soleus strategy to pull the hip and knee into extension to raise the center of mass upward. Relative to the quadriceps and gluteus maximus recruitment, this position favors use of the quadriceps primarily because of the lack of hip flexion. **(B)** Side view of step-up exercise with good spine, hip, knee, and ankle–foot relationships. Note the forward inclination of the trunk. A good rule of thumb is to teach the exerciser to keep the trunk parallel to the tibia during the entire phase of vertical to lowering and the return motion. This will best ensure proper balance between the gluteus maximus, hamstrings, and quadriceps during closed chain activities.

DISPLAY 19-5

Role of Lower Extremity Muscles During Closed Chain Exercises

- The gluteus maximus muscle decelerates hip flexion in the lowering phase of the split squat, lunge, and step-down and accelerates hip extension during the rising phase of the split squat, lunge, and step-up.
- The quadriceps muscle decelerates knee flexion during the lowering phase of the split squat, lunge, and the step-down and accelerates knee extension during the rising phase.
- The deep hip lateral rotators are recruited to control hip MR during all phases of each exercise.
- The posterior tibialis and peroneus longus muscles control foot pronation during the stance phase of each exercise, which assists in controlling tibial and femur MR up the kinetic chain.

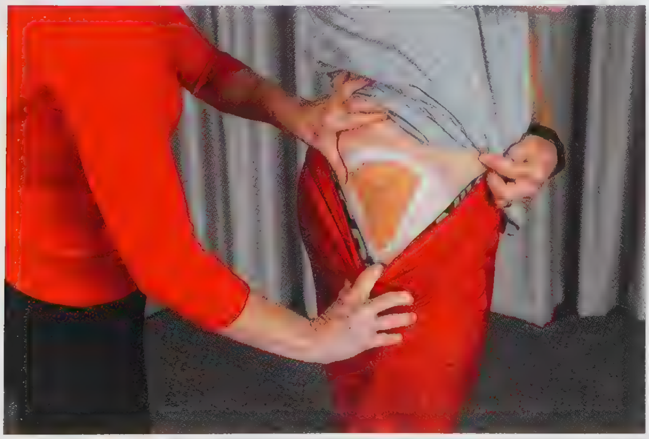


FIGURE 19-13 Taping to support a strained GM. This tape is best applied with the hip and is biased in abduction and LRto prevent strain to the GM.

enough to induce healing. Exercises to progressively strengthen the GM are depicted in **Self-Management 19-4**, and also in Self-Management 19-2. Other exercises shown to activate the GM include the lateral band walk (**Fig. 19-14**), single-limb squat (Fig. 19-11A), single-limb dead lift (Fig. 19-9A), hop (forward, sideways), and lunge (forward and sideways), though these are high-level progressions and require 4 to 4+/5 GM strength.[162] When prescribing closed chain exercises, caution must be taken in ensuring proper kinematics. Of particular concern are pelvic, femur, tibia, ankle–foot alignment and movement patterns to prevent further stretch to the GM (i.e., lateral pelvic tilt, femur adduction, femur MR).

Disuse and Deconditioning

Disuse and deconditioning of the hip joint musculature, particularly of the abductor muscles, is quite common. Disuse or deconditioning can result from injury or pathology affecting the hip and surrounding structures or from acquired movement patterns that promote disuse. For example, weakness in the gluteal musculature in hip joint OA is a common finding, but research has not determined whether it is the cause or the result of hip joint pathology.[165] Atrophy and pain both contribute to the decrease in muscle strength in hip OA.[166] Because hip muscles participate in gait, sit to stand, squatting, and ascending/descending stairs, weakness of hip muscles can affect the performance of basic ADLs.

In addition, hip weakness and decreased ROM has been associated with low back and various lower extremity pathologies. A moderate relationship currently exists between hip dysfunction and low back pathology,[167] whereas a much stronger relationship has been identified between hip dysfunction and knee pathology.[168] Hip abduction and lateral rotation weakness has been associated with patellofemoral pain syndrome (PFPS). Ireland[169] revealed that females with PFPS demonstrated 26%

SELF-MANAGEMENT 19-4
Gluteus Medius Strength Progression

Purpose: To strengthen the hip muscles that keep your hip and pelvis in good alignment when you walk (highest level of this exercise [Level V] helps to stretch the band on the outside of the thigh).

Level I: Prone Hip Lift

Start Position:
- Lie on your stomach on a firm surface. Place ___ pillows under your torso as indicated in the illustration.
- Your legs should be in line with your hips and rotated *slightly* outward.

Movement Technique:
- First you must activate your inner core plus abdominal muscles to stabilize your pelvis. Contract your abdominal muscles so that your pubic bone moves toward your ribs.
- Squeeze your buttock muscle.
- *Slightly* lift your leg and move it sideways through as much range as your hip allows. The indication that your hip has moved through its full available range is that your pelvis begins to tilt sideways and your spine sidebends. Do not move your hip any further after you feel your pelvis or spine move. Hold this position for 10 seconds.
- Return your hip to a start position.

Dosage:

Sets/Repetitions: ______________________

Frequency: ______________________

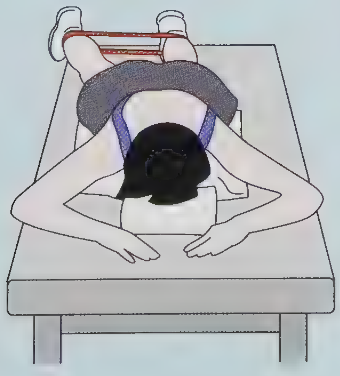
Level II: Prone Hip Lift with Elastic

Perform as in Level I, but attach a ___ piece of elastic around your ankles.

Dosage:

Sets/Repetitions: ______________________

Frequency: ______________________



Level II: Prone hip abduction with elastic

Level III: Sidelying Hip Rotation

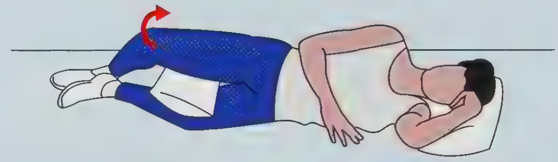
Start Position:
- Lie on your uninvolved side, with your hips in full extension and knees bent to 90 degrees, Place ___ pillows between your knees.
- Be sure you are on your side, with your head and neck in line with your spine and your spine in neutral, not rotated forward or backward. Your physical therapist may instruct you to position yourself against a wall to assist you in proper alignment.

Movement Technique:
- Slightly lift your lateral trunk off the floor by activating your lateral trunk muscles. Maintain this position while you perform the limb motion. Do not allow your pelvis to roll backward, or your waist drop during the limb motion.
- Slowly roll your hip backward (like opening a clamshell). This movement is very small. Your PT will assist you in feeling how subtle this movement is. Hold this position for 10 seconds.
- Slowly return to the start position.

Dosage:

Sets/Repetitions: ______________________

Frequency: ______________________



Level III: Sidelying hip lateral rotation

Level IV: Sidelying Knee Extension

Start Position:
- As in Level III.

Movement Technique:
- Slightly lift your lateral trunk off the floor by activating your lateral trunk muscles. Maintain this position while you perform the limb motion. Do not allow your pelvis to roll backward, or your waist drop during the limb motion.
- Turn out your hip without letting your pelvis or spine tilt backward or forward by activating your inner core and abdominal muscles.
- Extend your knee fully. Hold this position for 10 seconds.
- Keeping your hip turned outward, slowly return your thigh to the start position.
- You can progress this position by using ankle weights.

(continued)

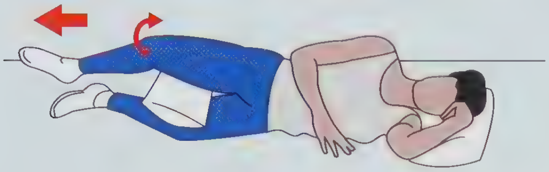
SELF-MANAGEMENT 19-4
Gluteus Medius Strength Progression (*continued*)

Dosage:

Resistance: ______________________

Sets/Repetitions: ______________________

Frequency: ______________________



Level IV: Sidelying leg extension

- Relax your leg onto the pillow before you begin the next repetition.
- *Variation*: You can also perform this level from a fully hip-extended position. It is helpful to lie against a wall, positioning your pelvis such that your pelvis is against the wall and both "cheeks" are touching the wall. In addition, your therapist may ask you to position a small towel behind your upper buttock to ensure your hip is in extension when it slides up the wall. Slide your heel up the wall through a full hip ROM. Do not compensate by tilting your pelvis or sidebending your spine. Hold this position for 10 seconds.
- Keeping your hip turned outward, slowly lower your leg to the start position.

Dosage:

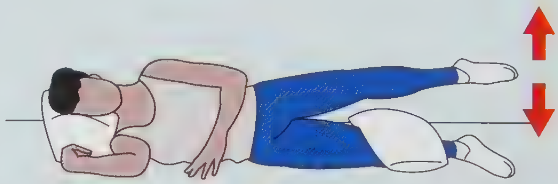
Sets/Repetitions: ______________________

Frequency: ______________________

Level V: Sidelying Concentric/Eccentric Contractions

Start Position:
- You can now begin to work on concentric (shortening) and eccentric (lengthening) contractions.
- As in Level IV, move to fully extended position.

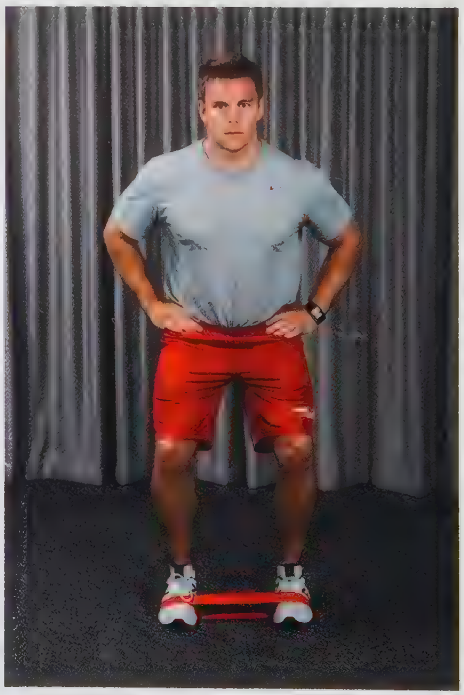
Movement Technique:
- Slightly lift your lateral trunk off the floor by activating your lateral trunk muscles. Maintain this position while you perform the limb motion. Do not allow your pelvis to roll backward, or your waist drop during the limb motion.
- Slowly lift your leg about 10 degrees above neutral, hold top position for 10 seconds.



Level V: Sidelying concentric/eccentric contraction

FIGURE 19-14 Lateral band walk. Traditional placement is at the knee **(A)**. Distal band placement offers a significantly higher activation level of gluteal muscles **(B)**. (From Cambridge ED, Sidorkewicz N, ideda DM, et al. Progressive hip rehabilitation: the effect of resistance band placement on gluteal activation during two common exercises. Clin Biomech 2012;27:719–724.)

A



B

less hip abductor and 36% less hip LRstrength than controls. Others have identified similar trends[170–173] while Powers[174] has theorized that hip abductor and lateral rotator weakness can lead to knee valgus, hip adduction, and hip internal rotation, a position that can place undue stress on lower extremity joints. Ferber[175] found that correcting the hip strength deficits improves lower extremity pain in runners.

Because the hip plays such a critical role in ADLs, instrumental ADLs, and recreational activity, minimizing disuse and deconditioning is imperative. According to Ayotte[73] and Escamilla,[176] moderate electromyographic (EMG) activation (21% to 40% maximum voluntary isometric contraction (MVIC) is best used to facilitate endurance and neuromuscular reeducation, and high activation (41% to 60+% MVIC) to promote strength gains. However, clinicians can also use lower level activation exercises to facilitate neuromuscular activation[73] and progress patients with marked weakness to more demanding tasks (**Evidence and Research 19-6**).

EVIDENCE and RESEARCH 19-6

Gluteal Activation During Common Therapeutic Exercises

Reiman et al.[177] conducted a literature search for experimental studies, RCTs, systematic reviews, narrative reviews, and meta-analyses using the Medline (1966 to 2005/2010), CINAHL (1982 to 2005/2010), and Sports Discus (1975 to 2005/2010) databases. Six studies for the gluteus maximus (GMax)[73,162,178–181] and four studies for the GM (GMed)[73,162,179,182] met the inclusion criteria. To make meaningful comparisons of EMG activation levels between studies, the authors categorized activation into four levels (low-level muscle activation at 0% to 20% MVIC; moderate-level activation at 21% to 40% MVIC; high-level activation at 41% to 60%, and very high-level activation at greater than 60%).[176] Nine exercises met the criteria for inclusion in the category of high-level activation and one for very high level for gluteus maximus and nine exercises met the criteria for inclusion in the category of high-level activation and two for very high-level activation for GM (see **Display 19-6**).

It is reasonable to consider that acquired posture and movement habits can contribute to altered length–tension properties and disuse of the hip musculature. For example, a slightly high iliac crest, as commonly occurs in a handedness pattern on the dominant side, contributes to lengthening of the ipsilateral GM,[69,149] which affects its force-generating capability during function.[183] The muscle tends to function at its relatively lengthened state during gait (with the hip adducted).[184] Eventually, this movement pattern may become more exaggerated, contributing to excessive hip adduction during the stance phase of gait and further reliance on stability from passive tension of the ITB.[185] As the hip increases its use of the ITB for passive stability, GM participation may decrease. Subsequently, the GM is subject to further deconditioning. This imbalance has been demonstrated in distance runners with iliotibial band syndrome (ITBS).[185] Long-distance runners with ITBS have weaker hip abduction strength in the affected leg compared with their

DISPLAY 19-6

High-Level Gluteus Maximus Activation[177]

- Sideways lunge (41% ± 20% MVIC)
- Lateral step-up (41% MVIC; 90% CI)
- Transverse lunge (49% ± 20% MVIC)
- Quadruped with contralateral arm/leg lift (56% ± 22% MVIC)
- Unilateral mini-squat (57% ± 44% MVIC)
- Retro step-up (59% ± 35% MVIC)
- Wall squat (59% MVIC; 90% CI)
- Single-limb squat (59% ± 27% MVIC)
- Single-limb dead lift (59% ± 28% MVIC)

Very High-Level Gluteus Maximus Activation

- Forward step-up (74% ± 43% MVIC)

High-Level Gluteus Medius Activation

- Lateral step-up (41% MVIC; 90% CI)
- Quadruped with contralateral arm and leg lift (42% ± 17% MVIC)
- Forward step-up (44% ± 17% MVIC)
- Unilateral bridge (47% ± 24% MVIC)
- Transverse lunge (48% ± 21% MVIC)
- Wall squat (52% ± 22% MVIC)
- Sidelying hip abduction (56% MVIC; 90% CI)
- Pelvic drop (57% ± 32% MVIC)
- Single-limb dead lift (58% ± 22% MVIC)

Very High-Level Gluteus Medius Activation

- Single-limb squat (64% ± 24% MVIC)
- Side-bridge to neutral spine position (74% ± 30% MVIC)

unaffected leg. After 6 weeks of training with special attention directed to specifically strengthen the GM, hip abductor torque increased from 34% to 51%, and 22 of 24 athletes were pain-free and able to return to running.

The iliopsoas is active in the initial swing phase and terminal stance phase of gait, and presumably in ascending stairs.[186] Its activity is probably related to LRand hip flexion, which accompanies the initial swing phase of gait. Faulty patterns of hip flexion can indicate underuse of the iliopsoas and overuse of another synergist. The following examples describe faulty hip flexion patterns:

- Hip hike during the swing phase of gait or stair-climbing suggests recruitment of lateral trunk musculature to hike the hip instead of using the iliopsoas to flex the hip (**Fig. 19-15**).
- Hip flexion with MR (**Fig. 19-16**) suggests use of TFL as the predominant hip flexor instead of the iliopsoas.

Sahrmann states that repetitive alteration in the optimal path of instant center of rotation of the hip during flexion and the resulting compensatory hip and LP movement patterns predispose the hip and LP region to further impairments and pathologic conditions.[149] Specific exercises to improve the force-generating capability of the iliopsoas (see **Self-Management 19-5**) and gradual movement reeducation

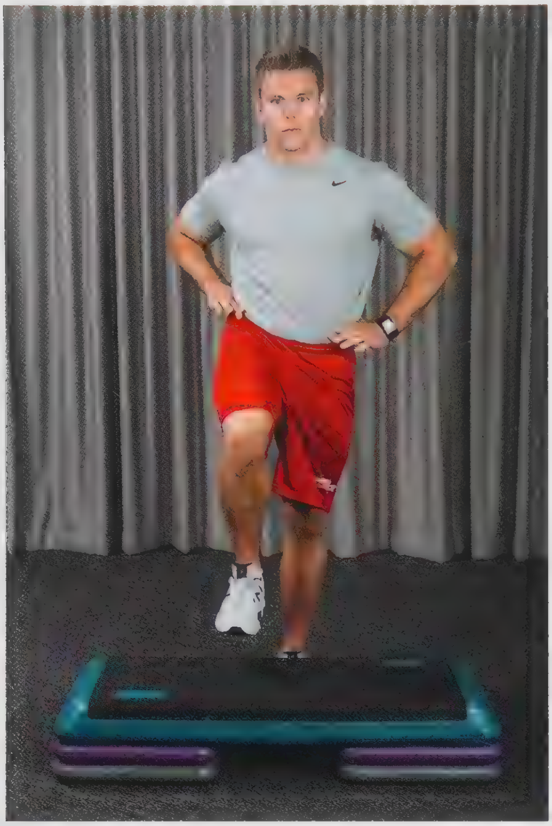


FIGURE 19-15 Use of a hip-hike strategy versus independent hip flexion on the left to ascend the stairs.

FIGURE 19-16 Medial femoral rotation versus neutral hip rotation of the left femur accompanying hip flexion during stair-climbing.

SELF-MANAGEMENT 19-5
Iliopsoas Strengthening

Purpose: To strengthen the muscle deep in the front of your pelvis that lifts your leg and controls the forward rotation of your hip joint.

Start Position: Sit with your feet flat on a firm surface, back straight, pelvis erect, and arms resting at your sides.

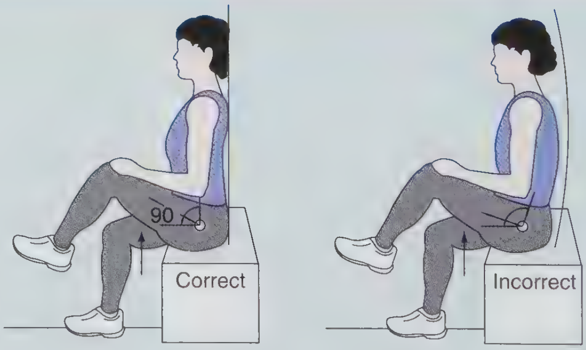
Movement Technique:

Level I—Passive lift, hold, lower

- Use your hands to lift your knee toward your chest as far as possible without letting your lower back round or "slump" backward.
- Hold this position for the prescribed number of seconds.
- Lower your leg to the start position.

Level II—Resisted hip flexion

- Perform as in Level I, but push against your knee in a down and slightly outward direction for the prescribed number of seconds.
- Lower your leg to the start position.



Level II: Resisted hip flexion

Dosage:

Sets/Repetitions: ______________________

Duration: ______________________

Frequency: ______________________

in hip flexion patterns during function (i.e., swing phase of gait and stair-climbing) are indicated to improve iliopsoas muscle performance and participation in the hip flexion force couple.

Reduced participation of the gluteus maximus profoundly affects gait and the ability to ascend stairs.[131] During gait, gluteus maximus activity is related to deceleration of hip flexion at terminal swing and isometric extensor support of the flexed hip at initial contact and during the loading response phases of gait.[131] Squatting, step-ups, step-downs, and sit-to-stand exercises are functional methods for improving the gluteus maximus force-generating capability and its recruitment during functional movement patterns, provided the proper kinematics are promoted (see Display 19-5 and **Fig. 19-17**).

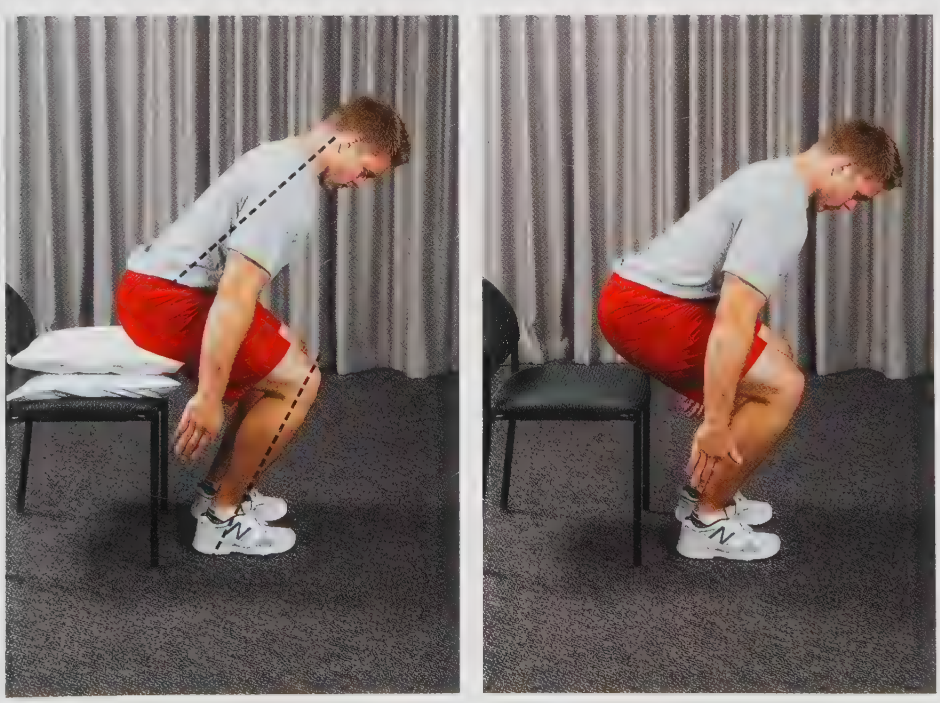
Hip lateral rotators are active from the initial contact to midstance of gait, presumably to decelerate the medial femoral rotation occurring as a result of foot pronation. Signs of excessive hip MR during weight acceptance and the single-limb support phases of gait need to be examined to determine the contributing impairments (e.g., hip anteversion, knee valgus, foot pronation, hip medial rotation). Use of orthotic support as the exclusive remedy for hip MR should be avoided. There is evidence that the kinematic effects of orthotic intervention are small and not systematic.[187] Instead, specific exercise (Fig. 19-10) and functional retraining of the hip lateral rotator control should be emphasized (**Fig. 19-18**; see Self-Management 19-2). Even in the presence of foot and ankle-related impairments and orthotic intervention, isolated hip lateral rotator muscle strengthening is indicated to assist in pronation control (see **Building Block 19-2**).

BUILDING BLOCK 19-2

Consider a 57-year-old female with a positive Trendelenburg sign on the left side and bilateral weakness in the hip abductors and lateral rotators. She shows some mild OA bilaterally but does not want to have surgery. She presents with slow gait speed, poor control of the core musculature, and bilateral pronation. Develop three exercises that would be appropriate for this patient to maximize her function.

ROM, Muscle Length, Joint Mobility, and Integrity Impairments

ROM and joint mobility impairments of the hip can span the continuum of hypomobility to hypermobility. The extreme clinical manifestation of hypomobility is the arthritic hip with a capsular pattern of limitation. The extreme clinical manifestation of hypermobility is congenital dysplasia of the hip, creating chronic instability in the hip joint. Between these extreme conditions, more subtle mobility impairments can affect the function of the hip. Joint stability refers to the resistance that musculoskeletal tissues provide at a joint and is the product of contributions from all the subsystems of the movement system. Joint hypo/hypermobility may result from



A B

FIGURE 19-17 Chair squats. Note the forward inclination of the trunk and parallel lines of the trunk and tibia. **(A)** Chair squats can be made easier with the use of pillows. **(B)** Gradually taking away the pillows can make the exercise more difficult by increasing the depth of the squat. Cue the patient to "hover" just above the seat before completely sitting down into the chair.

A B

FIGURE 19-18 Single-limb balance challenges hip rotators in a more functional position by adding torsional destabilizing stress through resisted movement of the upper extremities into horizontal abduction **(A)** and adduction **(B)**.

an impairment in one or more component of these subsystems and lead to limited or excessive joint translation and subsequent joint overload.[188–193]

Hypermobility

The etiology of hypermobility can be either arthrokinematic or osteokinematic. "Arthrokinematic hypermobility" is defined as linear translation that is excessive, whereas "osteokinematic hypermobility" is angular translation that is considered excessive. "Joint instability" refers to insufficient stabilizing structures and mobility that exceeds the physiologic limits along a continuum. Unfortunately, the term "instability" is used interchangeably with hypermobility in the literature, which causes much confusion. Hip joint instability was previously thought to be rare and usually associated with trauma,[194–196] or developmental bony abnormalities such as acetabular dysplasia. Although the hip joint is considered to be stable because of its bony architecture and strong capsuloligamentous restraints, evidence suggests that deficits in the acetabular labrum and iliofemoral ligaments may lead to increased femoral head translation[197–199] and possibly to early degenerative hip pathology[200] (**Evidence and Research 19-7**).

Capsuloligamentous laxity may be generalized or focal. Generalized laxity is associated with connective tissue disorders, whereas focal laxity results from an acute injury or from repetitive weight-bearing rotational forces overloading specific parts of the capsuloligamentous system. Sporting activities involving repeated axial loading and rotation, such as gymnastics, football, tennis, ballet, martial arts, and golf, may influence the development of focal laxity. Active stability

EVIDENCE and RESEARCH 19-7

Surgical Intervention for Hip Dysplasia

For some patients with acetabular dysplasia, the Bernese periacetabular osteotomy (PAO) can be an effective surgical treatment that reorients the dysplastic acetabulum to stabilize the hip and to improve coverage of the femoral head.[3,201–208] One systematic literature review included 13 studies containing 626 hips with a minimum 2-year follow-up (average 5 years). Overall, 79% of patients experienced a good or excellent clinical result with a low rate of conversion to total hip arthroplasty (THA) (7.3%).[202] This review demonstrated that the clinical benefit of the procedure is optimal in younger patients with no or mild preoperative OA. It is less predictable, and failure rates are higher, when preoperative OA is graded moderate or advanced. The procedure also is associated with decreased postoperative hip ROM. Finally, at short- to midterm follow-up, reduction in pain and enhanced hip function were noted in all studies, yet patients with early failures and/or poor clinical results also were observed. The complication rate is noteworthy with these procedures, as 6% to 37% of patients experienced a major complication. Increased surgeon experience may reduce the complication rate in the future.[209] These studies have not shown long-term survivorship of the reconstruction and have not proven the prevention or delay of secondary OA. Given the lower level of evidence provided by the available studies and the concurrent evolution of surgical techniques, many factors regarding PAO remain unknown. Future studies need to determine optimal selection criteria for surgery, risk factors for clinical failure, optimal deformity correction parameters, the incidence and characteristics of associated complications, and the role of adjunctive surgical procedures.

of the hip joint from tension in hip muscles may augment passive stability in the normal and structurally abnormal hip.[192] Despite this likely important role, little is known about what muscle or muscle synergies are involved or if hip pathology has an influence on hip muscle function. Currently, it is unclear which muscle synergies have the potential to stabilize the femoral head within the acetabulum. This is largely due to the inherent difficulties with measuring joint stability and muscle forces in vivo. It is hypothesized that there is a "cuff" of the hip involving deep hip rotators, iliopsoas, and gluteus minimus[210] (**Display 19-7**; **Figs.** 19-10, **19-19**, **19-20**; Self-Management 19-5). The trail limb on split squat or lunge drills also target the iliopsoas in the hip extension phase (see Self-Management 19-2).

The ability for a muscle to hold the femur centered in the acetabulum is based on the muscle's fiber orientation and size (see **Evidence and Research 19-8**).

DISPLAY 19-7

Rotator Cuff of the Hip

- Deep hip rotators posteriorly
- Iliopsoas anteriorly
- Gluteus minimus laterally

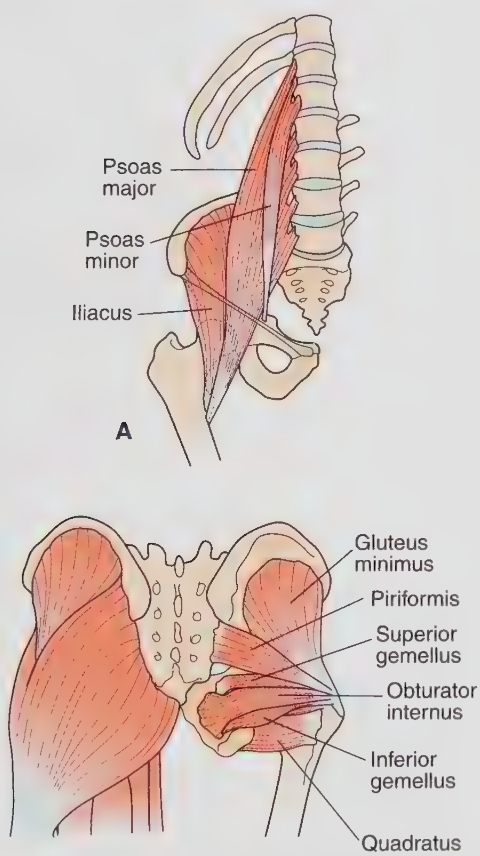


FIGURE 19-19 "Cuff" of the hip. **(A)** Iliacus and psoas. **(B)** Gluteus minimus and deep hip lateral rotators.

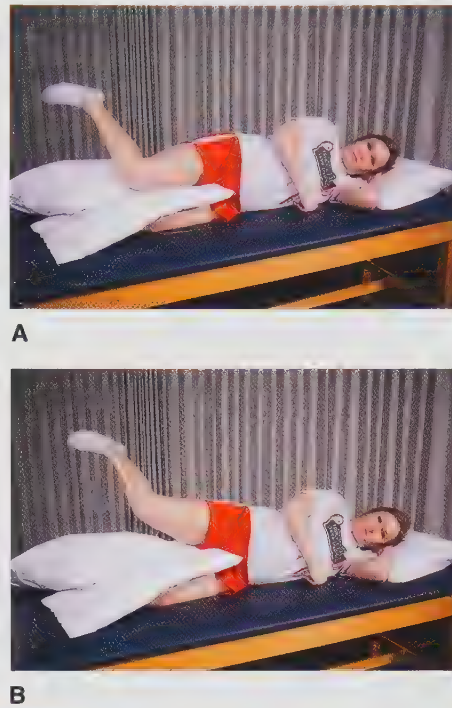


FIGURE 19-20 Gluteus minimus strengthening is also important when stabilizing against adduction moments. **(A)** The patient is positioned in sidelying with hip extended, knees bent to 90 degrees, and one to two pillows between the knees to keep the femur in neutral with respect to the frontal plane. The patient is instructed to turn the knee inward and lift the foot upward (engaging the medial rotators). **(B)** The next step to better isolate the gluteus minimus is to slightly abduct the femur while it remains in extension and medial rotation. To make this exercise more difficult, cuff weights can be added to the ankle.

EVIDENCE and RESEARCH 19-8

Evidence for Cuff of the Hip

Gray[211] defined the **short hip rotators** as "adjustable ligaments" for all hip positions. Cat anatomic and histochemical work supported this notion with evidence of design features considered ideal for hip control: short mean fiber lengths; small fiber pennation angles; small physiologic cross-sectional area; and a high proportion of slow twitch fibers.[212] Human data of short fiber length[213] have been interpreted to imply function in hip joint stabilization rather than torque generation.[214] Hodges et al. demonstrated a viable and valid technique to record obturator internus EMG and provides the first direct evidence of activation in simple functions.[215] Data from this study can be interpreted to suggest that a role as an "adjustable ligament" according to its muscle fiber anatomy would be limited to situations in which torques are applied in specific directions as an abductor, extender, or lateral rotator, rather than a generalized role.

Gluteus minimus, the deepest part of the abductor synergy, is an abductor, rotator, and flexor of the hip.[216] However, its primary function is considered to be as a stabilizer of the hip and pelvis.[216–218] Gluteus minimus fibers run parallel to the neck of the femur,[217] and it has attachments to the superior aspect of the capsule,[219] supporting the contention that gluteus minimus is an important stabilizer of the femoral head in the acetabulum.

(continued)

EVIDENCE and RESEARCH 19-8 (continued)

Gluteus minimus may therefore be important in stabilizing the hip by being able to modulate joint capsule stiffness. A fine wire EMG study has provided support for the role of the gluteus minimus as a stabilizer by demonstrating that the anterior portion of gluteus minimus is active in both prone hip extension and late stance phase, acting presumably to provide anterior support to the joint, rather than as a hip extensor for which it has no moment arm.[220]

A fine wire EMG study by Andersson et al.[221] investigating 11 subjects supports the role of the **iliacus** as a stabilizer of the hip, particularly in the late stance phase of gait. Lewis et al.[222] surmised that the iliacus and **psoas** muscles may play a role similar to that of the rotator cuff muscles at the shoulder by being able to influence joint stability not only by insertion but also by tension in musculotendinous units as they pass over the anterior aspect of the hip joint.

Sahrmann[149] describes a syndrome in the hip (femoral anterior glide syndrome) in which abnormal anterior translation of the hip accompanies hip flexion and excessive anterior translation occurs with hip extension. Correlating impairments may include stiffness in the posterior capsule combined with impaired force couple function of hip flexor torque producers (dominant rectus femoris, TFL) and stabilizers (insufficient iliopsoas and deep hip rotators).[222] Another syndrome (femoral adduction with medial rotation) is described in which excessive hip adduction and MR occur in combination, without the presence of excessive linear translation of the hip joint.[149] Femoral adduction syndrome can become exaggerated to the point that lateral glide mobility becomes excessive, thus involving both osteokinematic and arthrokinematic hypermobility (femoral lateral glide syndrome).[149] A person with femoral adduction or lateral glide syndrome may have a broad pelvis, an apparent LLD (the high side being symptomatic), femur medial rotation, genu valgum, and foot pronation as predisposing risk factors. These alignment faults contribute to chronic stretch of the abductor and lateral rotator muscle groups and lateral capsuloligamentous structures allowing excessive adduction, medial rotation, and lateral glide to occur during ADLs and sports. Patterns of sustained postures and repetitive movements can predispose an individual to a variety of syndromes because of soft tissue extensibility changes in the myofascia or periarticular tissues leading to hypermobility in osteokinematic or arthrokinematic patterns.

Careful examination should distinguish between osteokinematic and arthrokinematic hypermobility; the diagnosis of the latter is more difficult to resolve than the former. The primary objective of any therapeutic exercise intervention for the treatment of hypermobility, regardless of etiology, is to promote joint stability and prevent continued stress on the overstretched or torn tissues (myofascia or periarticular) via posture and movement pattern changes to improve length–tension properties (passive subsystem). Strength dosage can improve muscle performance (active subsystem), and precision practice can improve motor control (neural subsystem) of all muscles involved. For example, if a patient has hypermobility in the frontal plane, correction of postural habits such as sitting with his or her legs crossed, or standing with the affected leg in adduction, is indicated. Protecting the lateral structures from excessive stretch in the sidelying position with pillows between the legs would be recommended. Hip adductor stretching may be indicated to reduce the adductor tension on the hip joint (see **Fig. 19-21**).

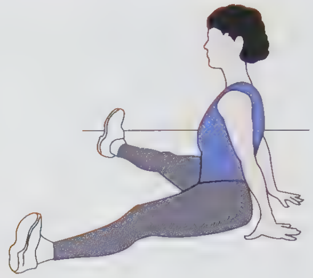


FIGURE 19-21 A method of stretching hip adductors. The patient is instructed in maintaining a neutral pelvis (sitting with the back against the wall can help prevent posterior pelvic tilt) and increasing the range of hip abduction versus trunk forward bend (as is commonly depicted in adductor stretches).

Hip muscle strengthening exercises, particularly hip abductor strengthening, are the most commonly prescribed intervention by physiotherapists in patients with hip pain, but current evidence suggests that joint stability may be enhanced via retraining of deep hip stabilizers in a direction-specific manner. Although current trends advocate the use of functional rehabilitation exercises, there is some evidence to suggest that this alone is inadequate for the effective retraining of normal feed-forward postural activity.[223] Much akin to the current rationale of strengthening the local muscles at the lumbar spine and pelvis, cervical spine, and shoulder joint prior to addressing the more superficial global muscles, it could be argued that effective therapeutic exercise programs for the pathologic hip should initially target local stabilizing muscles using low-load tonic exercises. Specific exercises for retraining the local muscles of the hip are commonly started in positions of low postural load such as prone, supine, or sidelying. The patient can be taught to monitor their motor performance by careful palpation. In the case of a patient presenting with concurrent aberrant LP motor control, cocontraction of the deep hip stabilizers and LP stabilizers can be taught. Clinically, such an approach appears to be effective; however, there is currently no evidence to support its use as it has not been evaluated.

Strengthening both GM (Self-Management 19-4) and gluteus minimus (Fig. 19-20) can be valuable to improve stability against adductor moments. Dosage for strengthening hip abductor and lateral rotators should prioritize muscle hypertrophic changes to enhance joint stiffness.

Whenever excessive MR ROM is measured, care must be taken to screen for anteversion. A common associated finding with hip anteversion is weakness of the hip lateral rotators (i.e., deep hip rotators, gluteus maximus, posterior fibers of GM). In the presence of excessive MR ROM, with or without anteversion, exercise to improve muscle performance of the lateral rotators is indicated. Lateral rotator strengthening exercises, to be most effective, should be coupled with education about altering postural habits (e.g., reduce the incidence of standing

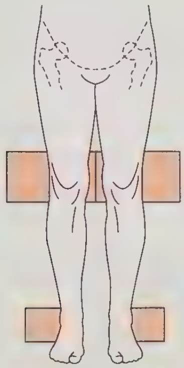
Patient-Related Instruction 19-1

Standing Knees over Toes

Your neutral hip position may vary depending on the structure of your hips. Your physical therapist will instruct you as to your neutral position if you have a structural variation in your hips.

From the Front

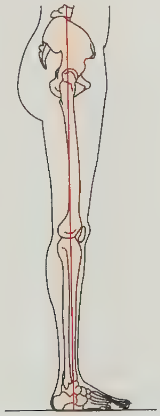
- Your weight should be distributed equally between both feet.
- Your pelvis should be level from side to side.
- The left side of your pelvis should be in line with the right side of your pelvis (i.e., one side of your pelvis should not be in front of the other side).
- Your knees should be in line with your feet; if you bend your knees, your knees would be directed over the midline of your feet.
- Your feet should be hip-width apart and *slightly* turned outward.
- The arch of your foot should be *slightly* elevated, with your big toe down.



Ideal alignment

From the Side

- Your pelvis should be in neutral, with the front pelvis bones in the same plane as your pubic bone.
- Your knees should not be bent or locked.
- Your ankle should fall below your knee, with your lower leg at a 90-degree angle with respect to your foot.



with the femur in excessive medial rotation) and movement training to improve recruitment of lateral rotators during closed chain function (see **Patient-Related Instructions 19-1** and **19-2** for examples of posture and gait education and training). Caution must be taken when strengthening hip lateral rotators in the presence of anteversion so as not to push the individual into too much lateral rotation, which will induce arthrokinematic hypermobility (see the following section for further explanation).

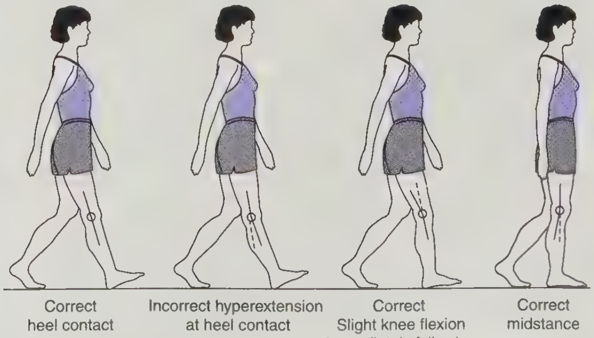
Individuals with hip anteversion can present with two unique hypermobility problems related to attempts to compensate for

Patient-Related Instruction 19-2

Walking with Knees over Toes

When you walk

- Your knee should be fully extended at the instant of heel strike, then immediately bend slightly to absorb shock. Do not let your knee lock back as you bring your weight over your foot. This hyperextension reduces your shock absorption and places undesirable stress on the ligaments and joint surfaces on your knees.
- Though your hip should turn inward slightly at heel strike, think of activating your deep hip lateral rotators to slow down this rotation and prevent your knee from turning in excessively as your body weight moves over your foot.
- Though your arch must drop a slight amount (pronation) at the time of heel strike in order to absorb shock, think of using your foot muscles to prevent your arch from dropping too low or too quickly as your body weight moves over your foot.
- Keep your abdominal muscles activated to prevent your pelvis from tilting forward. This is particularly important as your body weight moves in front of your foot and your hip must extend. If you do not activate your abdominal muscles, your pelvis may tilt or rotate instead of your hip extending.
- Be sure to roll through your foot to a full toe-off phase of gait. If someone were behind you, he or she could see the backs of your toes if you achieve full toe-off phase. This re-supinates your foot and prepares you for the next step.



the anatomic impairment. Persons with hip anteversion may engage in activities that promote extreme hip lateral rotation, such as ballet or soccer. The anteverted hip is forced to function in extreme LR for accurate performance of the activity. The head of the femur can be forced to translate excessively anteriorly and laterally to achieve the laterally rotated femur position,[224] often resulting in anterior groin pain. Hip joint hypermobility subsequently develops in an anterior and lateral direction.[224] Mounting evidence suggests a link between increased anteversion angles and OA.[225–230] It is possible that the anterolateral hypermobility seen in patients with anteversion may be a predisposing factor in the development of OA. To prevent or alleviate this impairment, the patient should be educated about his or her unique lower extremity biomechanics and LR ROM limitations. The therapist may need to counsel the individual to seek a recreational activity that does not require significant LR ROM.

Another common movement impairment that develops in the individual with anteverted hips is to achieve LR ROM by laterally rotating the tibia on the femur (see **Fig. 19-22**).[81] This is to be distinguished from tibial torsion, an anatomic impairment of the tibia bone twisting in an internal or external direction.[231] The person with this compensatory alignment should also be educated about his or her unique lower extremity biomechanics and hip LR ROM limitations to prevent rotational hypermobility problems at the tibiofemoral joint and potential knee joint pathology[225,232,233] (see **Building Block 19-3**).

Once isolated contraction of the deep hip stabilizer and abductor muscles is successfully achieved, progression can be made to the rehabilitation of secondary stabilizers and prime movers of the hip, particularly the gluteus maximus, initially using non–weight-bearing exercises and progressing to weight-bearing exercises once motor control and strength allow. Preactivation of the deep external rotators, iliopsoas, and gluteus minimus may make closed chain functional exercises more effective. Deficits in flexibility and proprioception should also be addressed at this stage with appropriate muscle lengthening and balance exercises. Once adequate hip muscle strength and endurance is achieved, functional and sports-specific exercises can then be implemented.

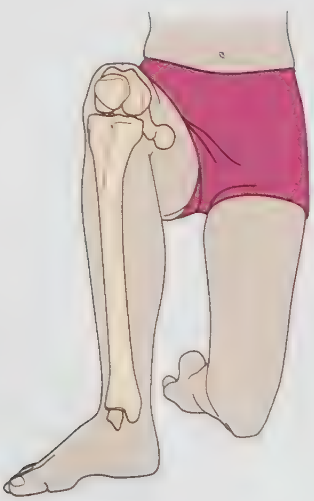


FIGURE 19-22 Excessive tibiofemoral rotation.

BUILDING BLOCK 19-3

Consider the 15-year-old female with generalized hypermobility. The patient is enrolled in ballet and tap dance classes. She complains of anterior and lateral hip pain that gets worse after dance. She presents with weakness of the GM and gluteus minimus, deep hip lateral rotators, poor transverse plane control with a squat, and no evidence of retro/anteversion. Develop three specific exercise interventions (include at least one closed chain exercise)and one taping technique for this patient to decrease her pain and increase her stability.

Hypomobility

Hypomobility impairments, particularly in the direction of flexion and medial rotation, can be found across all age populations. Subtle losses in flexion and MR may indicate early arthritic changes[76] or hypomobility caused by chronic lack of use, as a result of altered movement patterns. A fully established capsular pattern (see Display 19-1) can be a hallmark finding for the arthritic hip.[76] Recent advances in understanding cam morphology associated with FAI (see Fig. 19-4B) link loss of hip IR and adduction with morphologic changes to the head and neck of the femur as well as femoral and acetabular version angles[234] (see **Evidence and Research 19-9**).

EVIDENCE and RESEARCH 19-9

Passive ROM According to the Degree of Femoral Torsion or Acetabular Version

Decreased MR and adduction ROM, as found in FAI, is not solely dependent on the size or even the occurrence of cam morphology but should be interpreted by taking into account the overall hip anatomy, specifically femoral version and acetabular coverage. In a study by Audenaert et al.,[234] MR ROM at a neutral hip position was greatest (mean, 44.2 degrees) in hips with femoral anteversion and concomitant acetabular anteversion; conversely, it was least (20.1 degrees; $P < .001$) in hips with femoral retroversion and concomitant acetabular retroversion. Trends observed for LR ROM were consistently the opposite of those described for MR ROM. Hip flexion ROM was greatest (mean, 113.5 degrees) in hips with femoral anteversion and acetabular anteversion and least (103.8 degrees; $P = .011$) in hips with femoral anteversion and acetabular retroversion. Size of the cam lesion and ROM significantly differed between groups ($P < .05$). The range of MR on impingement testing was found to average 27.9 degrees in the healthy control group compared with 21.1 degrees in the asymptomatic control group with radiographic features specific to FAI ($P < .001$) and 12.3 degrees in the patient group ($P < .001$). Cam size, acetabular coverage, and femoral version appeared to be predictive variables for the range of MR. Seventy-five percent of variance between patients could be attributed to the combined effect of these three variables ($R = 0.86$).

Structural Impairments Contributing to Hypomobility

Mechanistically, hip MR is thought to introduce a mechanical conflict between the anterolateral femoral head–neck junction and the acetabulum, whereas LR results in posterior impingement that occurs extra-articularly between the greater trochanter and the ischium[235] and intra-articularly between the femoral head–neck junction and the posteroinferior aspect of the acetabulum.[236] In support of this view, Ross et al. demonstrated that a 10 degrees increase in anterior pelvic tilt (acetabular retroversion) caused mechanical conflict between the femur and acetabulum, reducing MR ROM.[237] PTs must consider the ramification of pelvic position on hip ROM limitations as well as structural impairments that might limit motion. In these instances, ROM exercises or mobilization would be contraindicated. However, every attempt should be made to improve 3D pelvic positioning, both at the total pelvic level and at the intrapelvic alignment levels (i.e., anterior pelvic tilt, lateral pelvic tilt, total pelvic rotation, intrapelvic torsion) (see Fig. 19-6).

Hypomobility Secondary to Degenerative Changes

Pain need not be an essential component of early arthritic changes and hypomobility findings. For example, OA (confirmed radiologically) leading to considerable restriction of range in the capsular pattern may not cause pain, even when the capsule is stretched quite hard.[76] This is a typical finding in middle-age men with a capsular pattern of restriction at the hip. Commonly, they have no complaints of hip pain or related activity limitation, but they may complain of LBP because of increased movement imposed on the back as a result of decreased hip mobility.

Emphasis has been placed on hip flexion and MR hypomobility impairments, but loss of hip extension ROM is another common finding, particularly in patients with end-stage hip arthritis. With myofascial or periarticular stiffness across the anterior hip, the pelvis may rest in a relative anterior tilt in relaxed standing. This posture may contribute to a relative increase in anterior pelvic tilt and lumbar extension to achieve an upright position (see **Fig. 19-23A**). On return from the forward bend, the patient leads with lumbar extension versus hip extension (Fig. 19-23B), the pelvis does not achieve a neutral position, and the anterior pelvic tilt imposes excessive lumbar extension to achieve an upright position (Fig. 19-23C).

A common finding associated with loss of hip extension ROM is positional weakness in the external oblique muscles, lower rectus abdominis, and transversus abdominis because of the chronically anterior tilted pelvis. Treatment of this impairment requires careful stretching of the affected hip flexor muscles concurrent with positional strengthening of the appropriate abdominal muscle groups (see Chapter 18).

Specific muscle length tests reveal which hip flexor muscles are contributing to the lack of hip extension ROM. Often, the diarthrodial hip flexors (i.e., rectus femoris and TFL/ITB, and sartorius) are stiff or short. Traditional stretches for the diarthrodial hip flexors do not follow the basic guidelines for optimal stretching because proximal stability is often not maintained (**Fig. 19-24**). Alternative stretches are recommended for optimal results. **Self-Management 19-6** illustrates an isolated passive diarthrodial hip flexor stretch. For maximal efficiency with this stretch, it is critical to maintain the stability of the pelvis and spine while maintaining the femur and tibia in a neutral position during knee flexion. To isolate the stretch to the TFL, slight LR and adduction of the femur at end range is suggested. Compensatory tibia LR may occur as the ITB is stretched. The patient must be cautioned to maintain tibiofemoral alignment by medially rotating the tibia during the stretch.

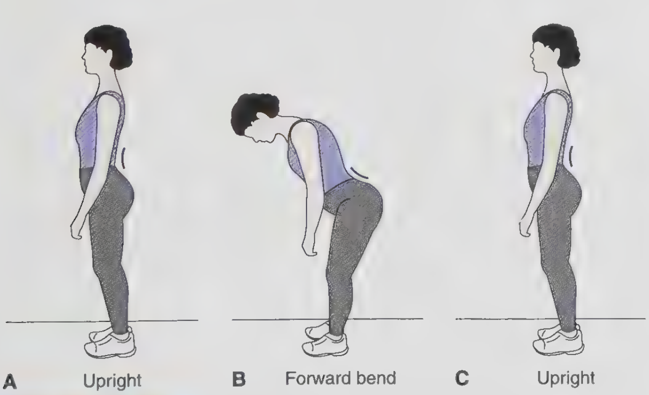


FIGURE 19-23 **(A)** Anterior pelvic tilt and lumbar lordosis. **(B)** On the return from forward bend the patient leads with lumbar extension versus pelvic extension. **(C)** If the pelvis stops rotating posterior before it reaches a neutral position, excessive lumbar extension is imposed on the spine to achieve an upright posture.

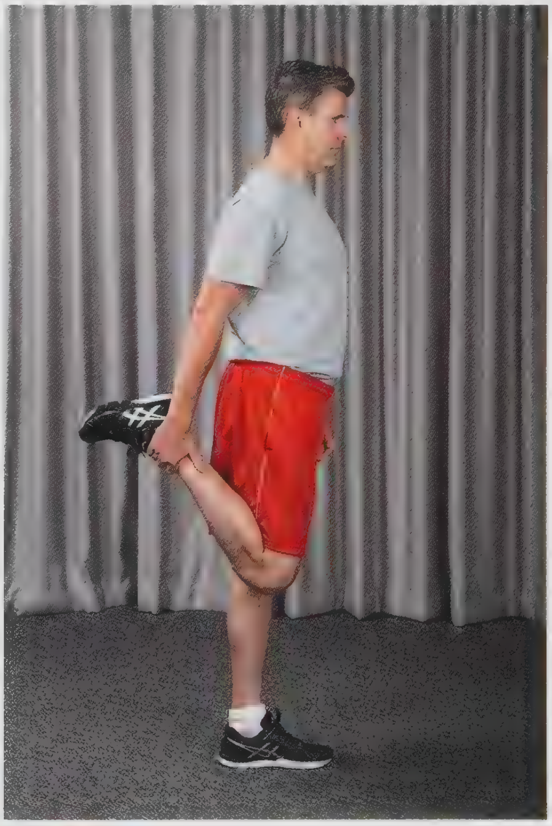


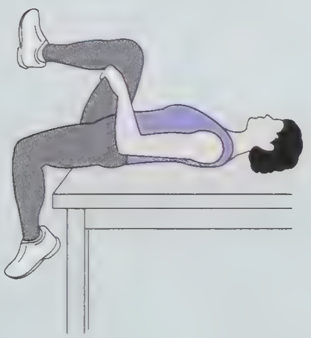
FIGURE 19-24 Traditional standing hip flexor stretches do not effectively stabilize the spine and pelvis. Note the anterior pelvic tilt and hip flexion in this individual attempting to perform this commonly used hip flexor stretch.

SELF-MANAGEMENT 19-6
Hip Flexor Stretch

Purpose: To stretch the front thigh muscles.

Start Position:
- Sit on the edge of a table so that your thigh is halfway off.
- Lie back while bringing both knees toward your chest.
- Pull your knees toward your chest until your low back just touches the tabletop surface.

Movement Technique:
- While grasping behind your knee, lower your other leg toward the floor, keeping your knee bent to 90 degrees. Your low back should maintain contact with the surface.
- Keep your thigh in the midline; do not let it drift out to the side.
- Do not let your thigh rotate inward.
- Variation: Let your thigh drop out to the side instead. Turn your lower leg inward. Gently pull your thigh toward midline until you feel slight tension in your iliotibial band.
- Hold for 15 to 30 seconds.



Dosage:

Sets/Repetitions: Repeat up to four times each limb

Frequency: ____________________

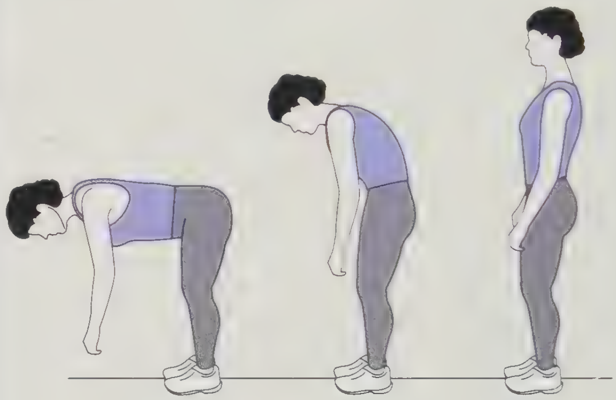
Self-Management 17-5 in Chapter 17 illustrates an active diarthrodial hip flexor stretch. This stretch uses active movement of knee flexion in an extended hip position to place repeated stretch on the diarthrodial hip flexors while contracting the abdominal muscles to stabilize the pelvis. As the abdominal muscles are recruited to stabilize the pelvis in this stretch, simultaneous elongation of the diarthrodial hip flexors and abdominal strengthening in the shortened range occur.

To ensure that gains in hip extension mobility are used in a functional context, the clinician must confirm that proper movement patterns are being used during functional activities. Optimal performance of functional movement patterns requires hip extension mobility and abdominal control to prevent anterior pelvic rotation and to achieve full hip joint extension.

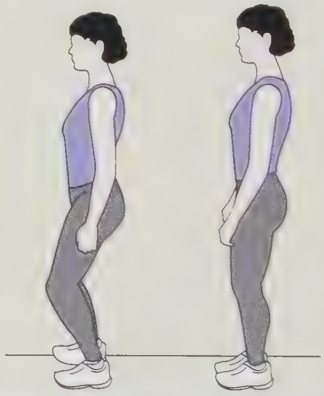
Patient-Related Instruction 19-3

Return from Forward Bending with a Neutral Pelvis

When You Come Up from Bending Forward
- Lead with your hips by activating your seat muscles.
- Do not arch your back. Avoid this by activating your inner core and gently pulling your belly button toward your spine.
- Complete the motion by bringing your pelvis back to neutral before finishing the spine movement.
- At the bottom of the motion, be sure your spine, buttock, and thigh muscles are fully relaxed before you reverse the motion.



When You Rise Upward from a Squatting Motion
- Be sure to complete the motion by fully extending your hips until your pelvis reaches neutral. Finish the motion with spine extension.
- Activate your inner core and abdominal muscles as you rise to ensure your pelvis remains in neutral. Your back extensors finish the motion.



Achieving control over hip extension and pelvic position during functional activities such as the late stance phase of gait (see Patient-Related Instruction 19-2), sit to stand, hip extension phase of squatting, and the return from forward bending (see **Patient-Related Instruction 19-3**) is necessary to ensure the specific ROM improvements are carried into ADLs.

Hypomobility Secondary to Altered Lumbopelvic Rhythm

Hip joint hypomobility may result from altered LP movement patterns because of a combination of anthropometric (e.g., high center of mass), occupational, and environmental (e.g., sports, recreation, hobbies) factors. It is hypothesized that, ultimately, as hip mobility decreases, lumbar and intrapelvic mobility increases. This finding has been demonstrated in measuring LP rhythm during forward bending,[238–242] particularly in the early phase of forward bending. The investigators of these studies found a significant relationship between a relative loss of hip flexion mobility and relative increased lumbar flexion mobility. Knowledge of this relationship is critical for the clinician prescribing exercise and retraining movement patterns. Functional activities such as bending forward to brush one's teeth, making the bed, and reaching into the refrigerator involve moderate amounts of hip and lumbar flexion. Hip stiffness resulting from reduced extensibility in capsule, ligament, or myofascial structures may impose excessive motion on the lumbar spine during forward-bending activities, which may ultimately lead to pathologic changes in the lumbar spine. Exercises to increase hip flexion mobility and lumbar stability, combined with retraining LP rhythm during forward-bending activities, are important to mitigate impairments associated with the cause of LBP in this particular patient subset. A useful exercise to retrain hip and lumbar movement is illustrated in **Self-Management 19-7**.

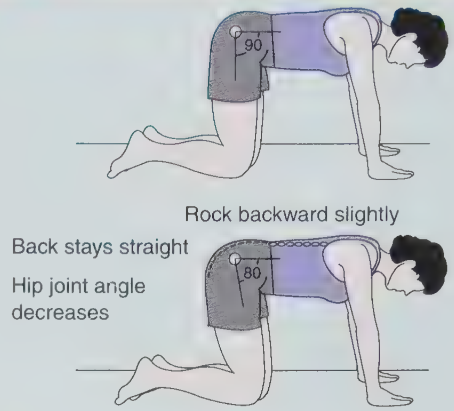
Hamstring Length as a Source of Hip Hypomobility

The hamstrings have been implicated as a potential source of hip stiffness.[242] A common stretch for the hamstrings is illustrated in **Figure 19-25**. A selective medial or lateral hamstring stretch can be induced by rotating the hip in the medial direction to stretch the lateral hamstrings and lateral direction to stretch the medial hamstrings. Because the hamstrings are a diarthrodial muscle, knee extension must be maintained while the hip flexes to ensure optimal stretch stimulus. After the hamstrings have been stretched passively, an active exercise should be performed to ensure the new length is used during function. One exercise that uses hamstring length during an active movement pattern is illustrated in **Self-Management 19-8**.

Sequelae to Hip Hypomobility

Other regions in the kinetic chain that may become stressed because of a relative loss of mobility in the hip joint are the lumbar spine and the knee. During squatting movements, loss of hip flexion ROM may impose increased motion on the lumbar spine in the direction of flexion (**Fig. 19-26A**) and/or the knee joint via excessive knee flexion (Fig. 19-26B). Loss of hip joint mobility is a common finding in persons complaining of overuse-related knee conditions such as patellofemoral dysfunction and patellar tendinopathy. Improved hip joint ROM and muscle performance of the gluteus maximus coupled with improved squatting movement patterns can reduce the stress on the knee joint. Progressive squatting exercises with optimal kinematics at the hip and knee are recommended to decrease excessive forces at the low back and knee (see **Self-Management 19-9**).

SELF-MANAGEMENT 19-7
Hand-Knee Rocking



Purpose: To improve the ROM of your hips, stretch the posterior hip muscles, and train independent movement between your hips, pelvis, and spine.

Start Position:
- Position yourself on your hands and knees so that your hips are directly over your knees and hands are directly under your shoulders.
- Knees and ankles should be hip-width apart with feet pointing straight back.
- Your spine should be flat with a slight curve downward in your low back and your pelvis tilted so that your hip joint is at a 90-degree angle.

Movement Technique:
- Rock backward at the hip joint only. Stop at any sensation of movement in your back.
- Variation: Your physical therapist may ask you to gently squeeze a ball or towel roll between your heels to activate your deep hip lateral rotators. This will help to stabilize your hip in the socket and prevent excessive flexion at the hip joint.

Dosage:

Sets/Repetitions: ______________________

Frequency: ______________________

Balance

Approximately 25% to 35% of persons older than 65 years experience one or more falls each year.[243–245] Falls are a leading cause of morbidity and mortality of persons older than 65 years,[246,247] and many of the falls result in hip fractures.[248] Hip fracture is an international public health problem. Worldwide, approximately 1.5 million hip fractures occur per year, with roughly 340,000 in the United States in individuals older than 65 years.[249] In 2050, there will be an estimated 3.9 million fractures worldwide, with more than 700,000 in the United

SELF-MANAGEMENT 19-9

Progressive Squat *(continued)*

A B C

States.[249] The hip fracture rate in the United States is about twice as high for women as for men,[250,251] and residents of nursing homes have been reported to have a 3 to 11 times greater risk than non–nursing home residents of hip fracture in the United States,[252] Netherlands,[253] France,[254] and Finland.[255] Hip fracture has a high impact on patients' health and medical costs. A high risk for hip fracture is predicted by low bone density, calcium, and vitamin D levels,[256] prior fragility fractures, and a high risk of falling.[257–259] Benzodiazepine treatment is also known to increase the risk of hip fracture in older populations by 50%.[260] Improved postural stability during functional activities is complex and multifaceted involving not only balance but also other internal factors such as strength, proprioception, integrity of the neuromuscular system, **pain**, vision, and in some instances fear of falling[261,262] (**Evidence and Research 19-10**).

T'ai chi has been valuable in promoting posture stability and balance control in the well elderly.[264–267] The T'ai chi progression (i.e., bipedal weight shifting to uniped positions) focuses less on centering the center of mass within the base of support and more on learning corrective strategies for instability. The advanced forms serve the purposes of destabilizing the individual in a controlled fashion, engaging new movement strategies and facilitating the confidence level of the participant.

Force-platform biofeedback systems can also be used to train posture stability and balance control. However, the focus of force-platform biofeedback systems is different than that of T'ai chi balance training. The former is typically concerned

EVIDENCE and RESEARCH 19-10

Exercise Intervention for Balance

A 2011 Cochrane Review presented the best evidence for effectiveness of exercise interventions designed to improve balance in older people living in the community or in institutional care.[263]

The general direction of findings presented a positive effect of exercise on balance immediately post intervention, but typically not maintained on cessation of the intervention. A cautious interpretation of the available evidence is necessary, particularly given the extent of the missing data for primary outcomes. From the data available, this systematic review provides some evidence that some exercise types compared with usual activity are moderately effective, at least immediately post intervention, in improving clinical balance outcomes in older people. These data show that exercise programs involving gait, balance, coordination and functional exercises, strengthening exercise appear to improve at least some "indirect" quantifiable measures of balance such as the Timed Up and Go test, single-leg stance, walking speed and a global subjective measure of balance, the Berg Balance Score. Although the duration and frequency of these exercise programs vary, in general, the effective programs ran three times a week for 3 months and involved standing, challenging balance exercises. Where studies provided data following cessation of exercise, there was no evidence of differences between exercise and control groups, probably indicating that the positive effects on balance are only evident while the patient is engaged in programs.

with learning to enhance center of mass or center of pressure movement within the limits of stability, and the latter is concerned with learning controlled motions as those limits are passed. Furthermore, the force-platform–based systems utilize visual feedback to the patient, which may not be as effective as other types of intrinsic feedback, such as proprioception.[268] Controlled clinical studies have not demonstrated a reduction in falls or delays in fall occurrences among older persons using force-platform biofeedback systems.[269] This may be because the ability to control the center of pressure during quiet standing or with the added provision of random but moderate perturbations, used during typical machine-based postural training, may not translate well into functional situations.

The ability to effectively treat patients with balance disorders can be enhanced by a clearer understanding of the problems underlying balance. Treatment of impaired balance must focus on the intrinsic and extrinsic factors related to the balance disorder. This requires extensive examination and evaluation of muscle performance, ROM, joint mobility, vestibular function, balance reactions, and environmental factors. Clinicians trained in balance-related rehabilitation have shown that compliance with a multidimensional, individualized exercise program that addresses the impairments and activity limitations associated with balance deficits can improve balance and mobility function and reduce the likelihood of falls.[67]

Display 19-8 lists general guidelines that can assist the practitioner in developing balance training activities for the hip, and **Display 19-9** describes a sample progression of balance tasks (see **Building Block 19-4**).

DISPLAY 19-8
Guidelines for Balance Training Activities

- In treating balance impairments with training programs, including T'ai chi, progressive drills, and computerized balance devices, the specific demands of compensatory stepping or grasping reactions that are found to cause difficulty (e.g., lateral weight transfer, rapid foot or arm movement, crossover steps) should be addressed. These skills can be addressed through unpredictable exercise conditions, such as the use of dense foam or having an outside perturbation such as a partner pushing or pulling the patient off balance. Cautious progression toward uniped motions is indicated, especially because this position is experienced by most older persons before falling.
- When training balance control, stepping and grasping reactions are not just strategies of last resort. These strategies can be initiated very early, well before the center of mass is near the stability limits of the base of support.[269] One goal of balance training may be to reduce the incidence of stepping and grasping strategies as posture stability and balance are increasingly challenged. Display 19-9 provides examples of progressive uniped balance tasks. The goal of the exercise would be to balance on one limb, with the progressive self-induced perturbations (e.g., arm movements), without using a grasping or stepping strategy to prevent a fall.
- For anteroposterior perturbations, the fixed-support ankle strategy (i.e., ankle muscular response to arrest the motion of the center of mass) may provide an early defense against destabilization, followed by a stepping or grasping strategy.[269] When using an anteroposterior destabilizing force (e.g., uniped with sagittal arm movements), we expect the ankles to provide the stabilizing force to maintain postural stability.
- A fixed-support hip strategy (i.e., hip muscular response to arrest the motion of the center of mass) may be limited to a special task condition that precludes the option of stepping or grasping.[269] Use of a fixed-support hip strategy would be inappropriate under normal conditions.
- Lateral destabilization complicates the control of compensatory stepping because of anatomic or physiologic restrictions on the lateral lower extremity movement and the associated prolonged uniped balance demand. Aging appears to be associated with increased difficulty in controlling lateral postural stability, which may be of specific relevance to the problem of lateral falls associated with hip fractures.[270] Exercises designed to provide frontal plane destabilizing forces (e.g., uniped with frontal plane arm movements) would especially be indicated in the aging population. Side-stepping strategies for recovery to prevent a fall are important skills for this population to learn.
- Assistive devices can aid the individual in balance control before developing functional balance control through a comprehensive training program. Use of a cane in the nondominant hand has reduced the rate of falls by up to fourfold.[271] Cutaneous information from fingertip contact, through a cane, and from a stable surface is more powerful than vision in stabilizing sway in stance.[271]

DISPLAY 19-9
Examples of Progressive Balance Tasks

- Balance on one leg on a firm surface is progressed to an unstable surface such as dense foam.
- Balance on one leg while rotating the head on a firm surface is progressed to dense foam.
- Balance on one leg with frontal, sagittal, or transverse plane arm movements on a firm surface is progressed to dense foam.
- Perform the previous balance task, but follow the arm movements with the eyes and head.
- Balance on one leg and move the trunk and upper body into contralateral flexion and rotation (i.e., reach for inside of ipsilateral ankle and foot) and ipsilateral extension and rotation (i.e., reach for object superior, lateral, and posterior to the head), and follow the arm movements with the eyes and head.
- Perform the previous three exercises while holding a weighted ball.

BUILDING BLOCK 19-4

An 81-year-old male is referred to you with a diagnosis of "poor balance" and orders to "evaluate and treat." The patient ambulates very slowly, with short step length, flexed, rigid posture, and no assistive device. The patient can only stand on one leg for 1 to 2 seconds and presents with increased sway even during quiet standing. The patient also presents with decreased flexibility of the hip flexors and adductors. Develop three interventions to improve this patient's safety and maximize his function.

Posture and Movement Impairment

Posture and movement training of the hip is used to optimize kinetics and kinematics at the hip joint as well as to positively affect the kinetics and kinematics of other joints in the kinetic chain. Similarly, posture and movement training of other joints in the kinetic chain can influence the kinetics and kinematics of the hip. Intervention focusing on posture and movement is pivotal to all therapeutic exercise interventions. Exercise should be taught with careful attention to details of posture and movement. All patients should be provided with instruction in avoiding posture and movement habits that contribute to the cause of symptoms and in developing alternative habits that will reduce or eliminate symptoms.

With respect to hip alignment, it is important to understand that pelvic tilt is not the only factor contributing to hip joint angle in the sagittal plane. Knee joint angle can also affect hip joint angle. For example, when the knees are flexed, the hips are flexed, even if the pelvic tilt is near neutral, and when the knees are hyperextended, the hips will be extended, even if the pelvic tilt is slightly anterior (**Fig. 19-27**). Be sure to correct for pelvic tilt *and* knee joint angle when treating posture impairments at the hip. This holds true for transverse and frontal plane posture impairments as well.

Movement impairments at the hip, as with posture impairments, can be affected by impairments at other segments. The cause of any given hip movement impairment must be diagnosed from the data collected during the examination of the patient. For example, limited hip flexion during a step-up activity may result from a loss of hip flexion ROM, reduced joint mobility, weakness in the hip flexors, or poor trunk stabilization. Only a thorough examination can reveal the cause of the movement impairment. Once the underlying cause(s) are established, an appropriate intervention can be developed to manage the associated impairments.

To affect a posture or movement change, mobility, length–tension properties, and muscle performance must be at functional levels, and kinesthetic awareness about joint position, joint motion, or a specific muscle recruitment pattern must be developed.

The initial focus of any intervention should be on improving impairments of body functions to a functional level. After these impairments have achieved a functional level of capacity, gradual transition from specific exercises, addressing physiologic impairments to greater emphasis on posture and movement patterns used during functional exercise, and activities should occur until the primary emphasis is on functional retraining. Examples of exercises to improve posture and movement of the hip joint are presented throughout this chapter.

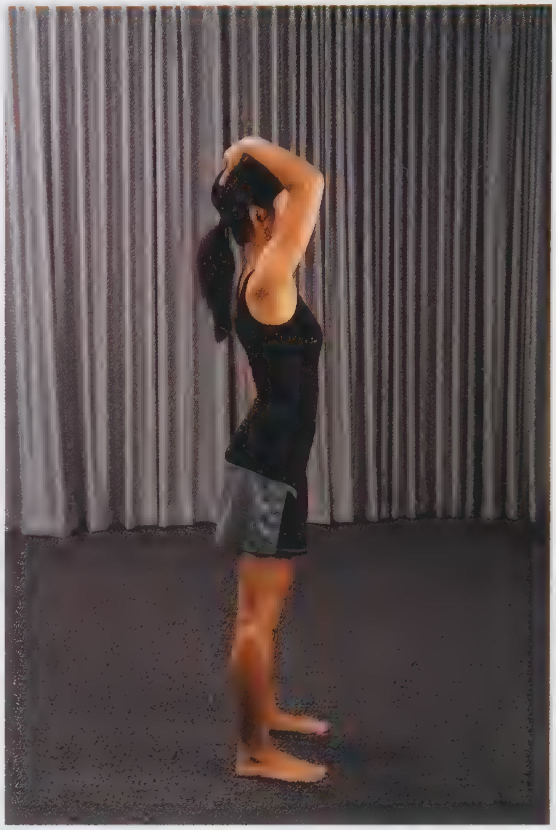


FIGURE 19-27 Note the anterior pelvic tilt. When the knees are hyperextended, the hips will be extended, even if the pelvic tilt is anterior.

Limb Length Discrepancy

Although limb length discrepancy (LLD) is not considered a postural impairment isolated to the hip, it is discussed here because of its functional implication at the hip as the transmitter of forces from the ground and lower extremities to the trunk and upper extremities. FLLD is the most difficult form to diagnose and treat. Nearly any movement of an osseous segment out of its normal plane of reference in relation to other bones can create a shorter or longer distance between proximal and distal reference points. Altered osseous positions can occur about any axis of motion and in any segment. Minor alterations in position in any one segment, when added to minor alterations in position of other segments, can lead to a substantial LLD.

To further complicate matters, FLLD can coexist with SLLD—sometimes exaggerating the LLD and sometimes compensating for the LLD. For example, a structurally longer limb may compensate for its length with lateral pelvic tilt, knee flexion, or foot pronation. After the type of LLD and the segments involved are accurately diagnosed as functional, structural, or combined LLD, appropriate intervention must be determined.

Treatment of LLD ranges from posture and movement training to shoe inserts to various surgical techniques including limb lengthening and shortening and epiphysiodesis. After it has been determined that the LLD is not completely amenable to posture and movement training, other nonsurgical or surgical interventions are indicated. There is disagreement regarding the correct treatment in regard to magnitude of LLD (**Evidence and Research 19-11**).

EVIDENCE and RESEARCH 19-11

Limb Length Discrepancy

Reid and Smith[272] suggest dividing LLD into three categories: mild (0 to 30 mm), moderate (30 to 60 mm), and severe (>60 mm), in which mild cases should go either untreated or treated nonsurgically, moderate cases should be dealt with on a case-by-case basis and some should be dealt with surgically, and severe cases should be corrected surgically. Moseley suggests a similar breakdown: 0 to 20 mm requiring no treatment, 20 to 60 mm requiring a shoe lift, epiphysiodesis, or shortening, 60 to 200 mm requiring lengthening that may or may not be combined with other procedures, and >200 mm prosthetic fitting.[273]

Structural Leg Length Discrepancy The most common treatment for mild SLLD is the use of shoe lifts, which consists of a heel lift, shoe insert, or building up the sole of the shoe on the shorter leg. In general, up to 20 mm of correction can be made with an insert, whereas further corrections should be done on the sole of the shoe.[274–275] If an equinus anatomic impairment exists, a heel lift is more appropriate than a full-sole lift. The amount of lift prescribed depends on the limb length difference and the patient's physiologic tolerance to change. Individuals with long-standing, significant structural discrepancies generally do not tolerate significant, rapid change because of the osseous and soft tissue adaptations that have developed over time. Minimal height adjustments at infrequent intervals should be made until the maximal necessary change has occurred.

Functional Limb Length Discrepancy Treatment of FLLD should consider the physiologic impairments at each involved segment and the interactions between levels. For example, a functionally short limb caused by femoral and tibial MR and by foot pronation could have associated impairments of the following:

- Lengthened or weak posterior GM and deep hip lateral rotators
- Lengthened or weak foot supinators
- Forefoot or rearfoot varus

Appropriate exercises combined with posture and movement training are necessary to alleviate the related impairments. Biomechanical support can be supplemented if necessary.

Patients with FLLD related to lower extremity kinetic chain pronation (i.e., femur MR, genu valgum, and foot pronation) may benefit from temporary or permanent foot orthotics to assist in controlling pronation throughout the kinetic chain. However, caution must be used in prescribing orthotics to remedy physiologic impairments up the kinetic chain. Exercises to alleviate impairments of body functions contributing to pronation should be attempted first. If performance demands exceed the ability to control pronation, use of orthotics may be a useful adjunct.

Cautious use of sole or heel lifts to compensate for an FLLD is recommended. The faulty strategy of displacing the center of mass over the base of support used by a patient with an FLLD does not necessarily alter with a lift. The more common scenario is for the individual to continue with the same faulty strategy, thereby enhancing the FLLD. For example, during the initial contact phase of gait, the short limb may be functionally short as a result of positioning the hip in adduction with minimal displacement of the center of mass over the base of support. After adding a lift, a similar gait strategy may continue to be used, causing further exaggeration of the LLD. Often, training the patient to properly position the hip and accurately displace the center of mass over the base of support alleviates the LLD without the need for orthotic correction (see Self-Management 19-2, Levels I and II).

THERAPEUTIC EXERCISE INTERVENTIONS FOR COMMON DIAGNOSES

Although it is beyond the scope of this text to present a comprehensive description and intervention plan for all diagnoses affecting the hip joint, a few selected diagnostic categories are presented. A brief overview of the etiology, examination/evaluation findings, and proposed intervention, with emphasis on therapeutic exercise, is presented for each diagnosis.

Osteoarthritis

OA is the most common form of arthritis, affecting ~27 million adults in the United States.[276] Among US adults 30 years of age or older, symptomatic disease in the hip occurs in approximately 3%.[274] OA increases with age, and sex-specific differences are evident.[277–280] Other risk factors for hip OA include developmental disorders (Legg–Calvé–Perthes disease, congenital hip dislocation, slipped capital femoral epiphysis), genetics, previous injury, sports exposure, and leg length disparity.[57] Because OA is a disease whose prevalence increases with age, it will become even more prevalent in the future as the bulging cohort of baby boomers grows older.

OA is a complex disease whose etiology bridges biomechanics and biochemistry. Evidence is growing for the role of systemic factors (such as genetics, dietary intake, estrogen use, and bone density) and of local biomechanical factors (muscle weakness, obesity, and joint laxity). These risk factors are particularly important in weight-bearing joints, and modifying them may present opportunities for prevention of OA-related pain and disability. The reader is referred to Chapter 12 for an in-depth discussion of the etiology of OA (**Evidence and Research 19-12**).

EVIDENCE and RESEARCH 19-12

Hip Osteoarthritis

OA is a common and disabling disease. Because of improved treatment of chronic diseases and lower mortality from infectious diseases, the US population is aging, and older Americans are living with disabling conditions, including hip OA. The projected number of older adults with arthritis or other chronic musculoskeletal joint symptoms is expected to nearly double, from 21.4 million in 2005 to 41.1 million by 2030.[281] The burden of hip OA is increasing due to the aging population and the obesity crisis; as a result, the need for THA is expected to grow 174%, to 572,000 primary THAs per year by 2030 in the United States.[281] Genetic factors play a role in both the incidence and, very likely, the outcome of OA. It has been proposed that generalized OA (involvement of at least three joints) may be a distinct disease in which systemic (genetic) predisposition (nodal OA, associated with Heberden's or Bouchard's nodes) is more important than local environmental (e.g., mechanical) factors. It is possible that bilateral THA and younger age at surgery is also associated with genetic traits. However, it is complicated by coexisting local morphologic characteristics resulting from biomechanical stress. For example, mild acetabular dysplasia, nonspherical femoral head shape, neck-shaft angle may lead to abutment of the femoral head–neck junction against the anterior rim of the acetabulum during flexion of the hip, leading initially to labrochondral damage and ultimately to early degeneration of the joint.[282] Additional theories are proposed for developmental risk factors such as stress across the growth plate during late childhood and early adolescence predispose patients to develop morphology that may contribute to early OA.[283] If this is the case, closer attention should be paid to the stresses across the hips of children and adolescents during development, particularly with those individuals at risk of a genetic predisposition.

Diagnosis

Proper diagnosis of a patient with hip OA requires a careful history, physical examination, and review of appropriate radiographic and laboratory studies. The presence of radiographic changes (e.g., joint space narrowing, moderate malalignment, osteophytes at the marginal aspects of the joint) should correlate with positive examination findings at the hip joint to arrive at a diagnosis of hip OA. A positive radiographic finding alone does not indicate that the hip OA is the source of symptoms, because many other musculoskeletal and nonmusculoskeletal sources can mimic hip joint pain. Hip OA is a common sequelae of aging and is not always symptomatic. Many people with pathologic and radiographic evidence of OA have no symptoms.[284]

Gradual, progressive, chronic pain can be associated with hip OA. Intra-articular pain is usually described as deep, aching pain and can be experienced in the groin, around the greater trochanter, medial knee, and posterior buttock. Long periods of rest may result in joint stiffness. The stiffness of OA is not as severe as that of rheumatoid arthritis. Mild activity usually dissipates the stiffness. A clinical prediction rule for the diagnosis of hip OA is described in **Display 19-10.**

DISPLAY 19-10

Clinical Prediction Rule for Diagnosing Hip Osteoarthritis

If at least four of five variables were present, the positive likelihood ratio was equal to 24.3 (95% CI 4.4 to 142.1), increasing the probability of hip OA to 91%.

Variables

- Self-reported squatting as an aggravating factor
- Active hip flexion causing lateral hip pain
- Scour test with adduction causing lateral hip or groin pain
- Active hip extension causing pain
- Passive MR of less than or equal to 25 degrees

Sutlive TG, Lopez HP, Schnitker DE, et al. Development of a clinical prediction rule for diagnosing hip osteoarthritis in individuals with unilateral hip pain. J Orthop Sports Phys Ther 2008;38(9):542–550.

Treatment

Major advances in management of OA to reduce pain and disability are yielding an impressive array of available treatments ranging from acupuncture to chondrocyte transplantation, new oral anti-inflammatory medications, and patient-related instruction. Evidence for the efficacy of commonly used oral therapies, alternative therapies, biomechanical interventions, such as exercise, and behavioral interventions directed toward enhancing self-efficacy and self-management is mounting (see **Display 19-11**). In the vast majority of cases, surgical treatment of OA is considered only after failure of nonsurgical treatments.[125] Recently, biologic approaches to the surgical treatment of OA have been explored.[275,306] Over the last decades, more than 50 modalities of nonpharmacologic, pharmacologic, and surgical interventions for hip and knee OA have been described in the medical literature and integrated into international, monodisciplinary, and interdisciplinary clinical guidelines[307–309] (see **Table 19-4**)

The following sections will review concepts related to therapeutic exercise intervention for the treatment of impairments related to hip OA. These concepts are introduced to assist in the prevention of surgical intervention. However, if surgery is necessary, many of these concepts can be implemented in postsurgical care as well. Many impairments preceding THA

DISPLAY 19-11

Nonoperative Treatment of OA

- Systemic and topical treatments (i.e., nonopioid analgesics, nonsteroidal anti-inflammatory drugs [NSAIDs], opioid analgesics, chondroitin and glucosamine, and topical analgesics)[285–292]
- Acupuncture[293,294]
- Intra-articular injection of corticosteroids[295,296]
- Intra-articular injection of hyaluronic acid[297]
- Assistive devices[124,298]
- Patient education[299–301]
- Exercise[302–304]
- Manual therapy[305]

TABLE 19-4

Management of Osteoarthritis (OA)

General

1. Optimal management of OA requires a combination of nonpharmacologic and pharmacologic modalities

Nonpharmacologic Modalities of Treatment

2. All patients with hip and knee OA should be given information access and education about the objectives of treatment and the importance of changes in lifestyle, exercise, pacing of activities, weight reduction, and other measures to unload the damaged joint(s). The initial focus should be on self-help and patient-driven treatments rather than on passive therapies delivered by health professionals. Subsequently emphasis should be placed on encouraging adherence to the regimen of nonpharmacologic therapy.
3. The clinical status of patients with hip or knee OA can be improved if patients are contacted regularly by phone.
4. Patients with symptomatic hip and knee OA may benefit from referral to a physical therapist for evaluation and instruction in appropriate exercises to reduce pain and improve functional capacity. This evaluation may result in provision of assistive devices such as canes and walkers, as appropriate.
5. Patients with hip and knee OA should be encouraged to undertake, and continue to undertake, regular aerobic, muscle strengthening and ROM exercises. For patients with symptomatic hip OA, exercises in water can be effective.
6. Patients with hip and knee OA, who are overweight, should be encouraged to lose weight and maintain their weight at a lower level.
7. Walking aids can reduce pain in patients with hip and knee OA. Patients should be given instruction in the optimal use of a cane or crutch in the contralateral hand. Frames or wheeled walkers are often preferable for those with bilateral disease.
8. In patients with knee OA and mild/moderate varus or valgus instability, a knee brace can reduce pain, improve stability, and diminish the risk of falling.
9. Every patient with hip or knee OA should receive advice concerning appropriate footwear. In patients with knee OA, insoles can reduce pain and improve ambulation. Lateral wedged insoles can be of symptomatic benefit for some patients with medial tibiofemoral compartment OA.
10. Some thermal modalities may be effective for relieving symptoms in hip and knee OA.
11. Transcutaneous electrical nerve stimulation (TENS) can help with short-term pain control in some patients with hip or knee OA.
12. Acupuncture may be of symptomatic benefit in patients with knee OA.

Pharmacologic Modalities of Treatment

13. Acetaminophen (paracetamol) (up to 4 g/d) can be an effective initial oral analgesic for treatment of mild to moderate pain in patients with knee or hip OA. In the absence of an adequate response, or in the presence of severe pain and/or inflammation, alternative pharmacologic therapy should be considered based on relative efficacy and safety, as well as concomitant medications and comorbidities.
14. In patients with symptomatic hip or knee OA, NSAIDs should be used at the lowest effective dose but their long-term use should be avoided if possible. In patients with increased gastrointestinal risk, either a COX-2 selective agent or a nonselective NSAID with co-prescription of a proton pump inhibitor or misoprostol for gastroprotection may be considered, but NSAIDs, including both nonselective and COX-2 selective agents, should be used with caution in patients with cardiovascular (CV) risk factors.
15. Topical NSAIDs and capsaicin can be effective as adjunctives and alternatives to oral analgesic/anti-inflammatory agents in knee OA.
16. Intra-articular (IA) injections with corticosteroids can be used in the treatment of hip or knee OA, and should be considered particularly when patients have moderate to severe pain not responding satisfactorily to oral analgesic/anti-inflammatory agents and in patients with symptomatic knee OA with effusions or other physical signs of local inflammation.
17. Injections of IA hyaluronate may be useful in patients with knee or hip OA. They are characterized by delayed onset, but prolonged duration, of symptomatic benefit when compared to IA injections of corticosteroids.
18. Treatment with glucosamine and/or chondroitin sulfate may provide symptomatic benefit in patients with knee OA. If no response is apparent within 6 months, treatment should be discontinued.

(continued)

TABLE 19-4 (continued)

Management of Osteoarthritis (OA)

19. In patients with symptomatic knee OA, glucosamine sulfate and chondroitin sulfate may have structure-modifying effects while diacerein may have structure-modifying effects in patients with symptomatic OA of the hip.

20. The use of weak opioids and narcotic analgesics can be considered for the treatment of refractory pain in patients with hip or knee OA, where other pharmacologic agents have been ineffective, or are contraindicated. Stronger opioids should only be used for the management of severe pain in exceptional circumstances. Nonpharmacologic therapies should be continued in such patients and surgical treatments should be considered.

Surgical Intervention

21. Patients with hip or knee OA who are not obtaining adequate pain relief and functional improvement from a combination of nonpharmacologic and pharmacologic treatment should be considered for joint replacement surgery. Despite best practice in conservative therapy, if significant symptoms persist and functional limitations are associated with reduced health-related quality of life, replacement arthroplasties can be effective and cost-effective interventions for patients.

22. Osteotomy and joint preserving surgical procedures should be considered in young adults with symptomatic hip OA, especially in the presence of dysplasia.

do not disappear as a result of the surgery and often need to be dealt with postoperatively.

Pain and Inflammation Management of pain and inflammation for hip OA can follow the general guidelines discussed in a previous section (see Display 19-2). Activity modification may be one of the most significant aspects of treatment for pain and inflammation. The changes may include modification of basic and instrumental ADLs. The patient should be instructed in joint protection techniques during prolonged postures (i.e., standing with equal weight bearing on both feet, or, if necessary, using an assistive device) and common movement patterns (i.e., carrying heavy loads in the hand on the involved side or in both hands equally).[122,124] The patient canmoderate vigorous weight-bearing activities (e.g., walking vs. running or doubles vs. singles tennis) and add non–weight-bearing activities (e.g., biking, swimming, water aerobics) to provide ample exercise stimulus required to lower or maintain BMI.

Specific to hip OA, treatment addressing the mechanical nociceptive trigger should focus on altering the biomechanics of the hip. The degeneration in OA is caused by a breakdown of chondrocytes, which are an essential element of articular cartilage. This breakdown may be initiated by biomechanical stress. A primary goal of the intervention should be to alter biomechanical forces acting on the joint. Restoring joint ROM, tissue extensibility, and motor control in flexion, extension, MR, and abduction and restoring dynamic muscle performance of GM, minimus, maximus, deep hip lateral rotators, and iliopsoas enables the joint to function with improved femoroacetabular congruence and more diffuse load-bearing surfaces. Focus on reducing maladaptive movement patterns can lessen the biomechanical stress to the focal area of degenerative joint disease and result in decreased pain.

Range of Motion and Joint Mobility Exercises aimed at ROM and joint mobility may include passive (**Figs. 19-28** and **19-29**) and active stretching (Self-Management 197), and mobilization in the affected directions (see Chapter 7). When performing passive stretching, care must be taken to stabilize the pelvis, SIJ, and lumbar region and guide the hip in the acetabulum to prevent impingement. Active exercises should be employed whenever possible. Active exercises improve ROM and joint mobility with the added bonus of recruitment of the muscles necessary to move the joint in the desired direction during function. Examples of active exercises to improve hip mobility in persons with hip OA are shown in Self-Management 19-7 and Self-Management 19-9. Another useful technique to teach the patient with OA in the hip is self-traction (**Fig. 19-30**).

Muscle Performance The patient can be instructed in specific exercises to improve muscle performance (see Self-Managements 19-1, 19-4, and 19-5). Whenever possible, functional exercises should be employed. For example, chair squats or standing on the involved hip in neutral hip joint alignment and lifting the uninvolved hip onto a step can stimulate hip abductor recruitment on the weight-bearing side. However, weight-bearing exercises on a hip with OA may exacerbate symptoms, particularly if the alignment is faulty or muscle recruitment is maladaptive. Adjunctive use of a cane, walking stick, ski pole, or dowel rod in the contralateral hand during weight-bearing exercise can reduce the amount of work necessary for the ipsilateral hip abductors. This approach reduces the joint reaction force and joint pain and increases tolerance to weight-bearing exercise (**Evidence and Research 19-13**).

Another method to reduce the joint reaction force enough to allow weight-bearing exercise is to hold a weight in the hand on the involved side.[122–124] Biomechanically, holding a weight on the involved side will move the center of mass laterally, toward the affected hip, thereby decreasing the length of the lever arm and decreasing the force generation needed by the hip abductors. The amount of weight can be graded to use the least amount necessary to reduce pain and allow optimal alignment during the step-up activity.

Regardless of the method used to unload the hip, the appropriate strategy for unilateral balance must be reinforced. A healthy joint is dependent on the neuromuscular system to provide movement, joint stability, shock absorption, and proprioception. The results of Sims and Richardson's study[313] (**Evidence and Research 19-14**) suggest that at least part of the muscle dysfunction associated with hip OA may be a loss of precision rather than strength. Rehabilitation programs for patients in whom pain and disability are not severe should therefore include an emphasis

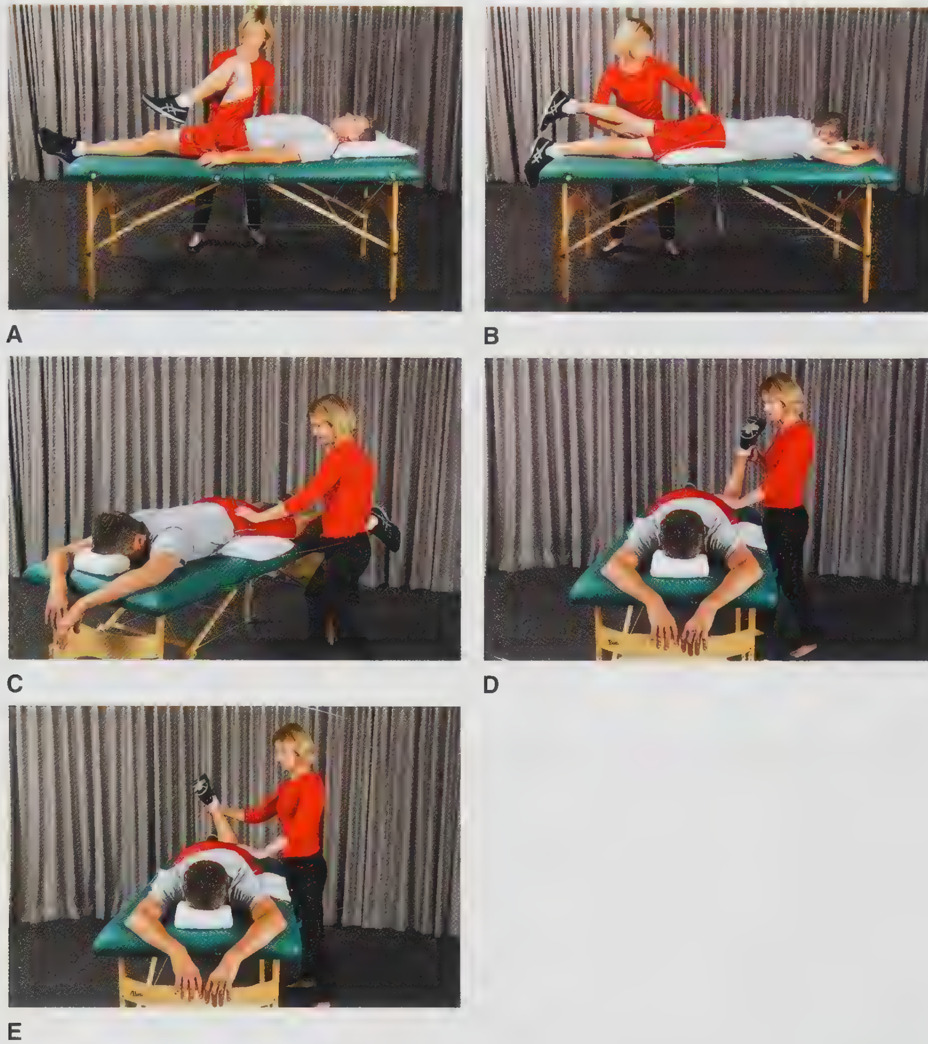


FIGURE 19-28 Passive ROM to the hip in **(A)** flexion, **(B)** extension, **(C)** abduction, **(D)** medial rotation, and **(E)** lateral rotation. Note the stabilization of the pelvis to make certain that movement occurs at the hip in isolation. In the case of hip flexion, a simultaneous posterior-inferior glide of the head of the femur can reduce anterior hip impingement that occurs with a stiff posterior joint.

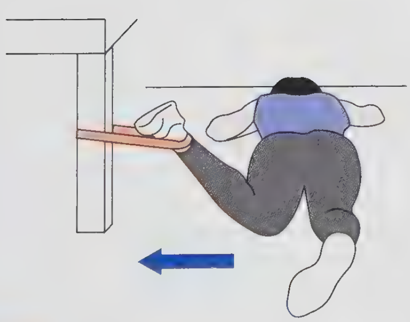


FIGURE 19-29 Prone hip MR stretch with elastic. The patient is instructed to stabilize the pelvis in sagittal and transverse planes via inner core contraction. It is important to keep the femur in contact with the floor to ensure a precise rotational stretch. If the hip flexors are short, use of a pillow under the hips can allow the knee to flex 90 degrees with minimal compensatory hip flexion. This exercise is contraindicated in the presence of knee pathology.

FIGURE 19-30 Self-traction of the hip. The involved limb is given traction by the use of a belt or other stiff material around the ankle which is secured in a door jam, whereas the contralateral limb pushes off a surface as shown. This technique can provide a decompression stress to the joint and stretch the joint capsule.

EVIDENCE and RESEARCH 19-13

Use of a Cane

By using a cane, subjects decreased vertical and shear ground reaction forces on the affected limb. The peak landing and push off vertical ground reaction forces were reduced by 7% and 9%, respectively, with the use of a cane.[310] Those decreases were expected because the cane transmitted load during the stance phase of the affected limb, thereby reducing the load on the limb.[311] The cane also significantly reduced the braking shear (anterior) and propulsive shear (posterior) ground reaction forces for the affected limb, possibly by transmitting some of those forces as well. The lateral shear was 15% smaller for both limbs during the cane trials. The cane may have decreased the lateral oscillation of the center of mass, which could have reduced the lateral shear force. Ely and Smidt[311] reported that for patients with a limp because of a hip disability, 15% body weight applied to a cane in the contralateral hand reduced the maximal vertical reaction forces from 100% to 89% body weight. Although speed remained the same for gait with or without a cane, cane-assisted gait had a longer stride length and decreased cadence. Long[165] and Kleissen[312] have reported a 25% decrease in GM EMG amplitude during cane trials.

Evidence and Research 19-14

Control Versus Strength in Hip OA

A link has been reported between abnormal muscular activity and hip OA. In all cases a dysfunction has been found in the TFL or GM, which work together to maintain the level of the pelvis in single-leg stance.[217,314] The GM also provides joint stability[217] and is active when postural stability is challenged in the mediolateral direction.[315,316] One gait study found continuous activity in the TFL and inhibition of the GM of some subjects with hip OA.[315] In contrast, another found continuous activity in the GM of subjects with severe hip OA.[316] One study found that the group with hip OA had greater GM activation than the healthy older adults.[313] The magnitude of activation of the TFL did not differ between groups or sides. The findings of increased GM activation and lack of change in TFL were contrary to traditional beliefs that their activation would reduce and increase, respectively. One possible explanation is that the increased level of GM EMG activation may reflect a failure of the central nervous system to grade the degree of muscular force required in the performance of the stepping task in subjects with hip OA. An increased level of hip abductor activity is of clinical relevance because it has the potential to cause large compressive forces on the hip. Research has shown substantial acetabular loading before heel strike, and peak acetabular pressures in midstance before peak ground reaction force, suggesting the influence of muscle contraction on the internal joint forces.[317] The challenge to the practitioner will be to balance the ideal activation of the GM and TFL during gait to optimize joint loading. This may require more focus on control over limb and pelvic position to minimize internal joint forces during muscle contractions required for the gait sequence.

on the fine control of pelvic position during single-leg stance. This would require improving the ability of the GM to activate appropriately rather than general strengthening. Appropriate rehabilitation is crucial both as a preventive measure and as a critical part of pre- and postoperative care of hip OA. The GM and TFL are synergist hip abductors. It is common for the TFL to dominate the stance recruitment pattern, particularly if the hip is in flexion or medial rotation. If a patient has decreased mobility in hip extension, the hip will rest in an anterior pelvic tilt, making it more difficult to recruit the GM, resulting in increased firing of the TFL. As such, mobility might need to be addressed prior to instruction in neuromuscular reeducation. Education regarding the neutral position of the hip and GM recruitment is critical to the optimal outcome of this exercise. This may require additional activity from the abdominal and hip extensor muscles to control anterior pelvic tilt.

Step-up activities stimulate hip extensor recruitment of the stance limb[165] and facilitate hip flexion mobility, particularly if emphasis is placed on hip flexion during the step-up (Fig. 19-12B), and step-down activities stimulate GM recruitment.[165] Care must be taken during stepping activities to prevent Trendelenburg patterns and to reinforce proper length–tension properties of the GM (i.e., hip should not adduct more than 5 to 8 degrees, and femoral MR should be kept to a minimum). All stepping activities can be graded by altering the step height or adding weight. A handheld load of 15% of body weight held ipsilateral to the hip produces an external torque in the same rotary direction as that required by the right hip abductor muscles[318] (see **Fig. 19-31**).

Joint angles and moments showed a relatively low but significant dependency on the inclination (height) of the step.[319] This can be related to the varying amount of potential energy that has to be produced (during ascent) or absorbed (during descent) by the muscles. Using this evidence, it would stand to reason that a small step height (4 inches) and carrying a weight in the involved side hand reduces the force-generating requirements of the hip extensors and abductors. Conversely, larger step heights (8 to 12 inches) and carrying a weight in the contralateral hand increase the force-generating requirements.

Dosage parameters regarding repetition for these exercises depend on whether the goal is to improve force/torque or endurance capabilities. Higher repetitions with a decreased load focus on endurance, and lower repetitions with a higher load focus on force production.

Balance Injury to a joint and musculotendinous structures, as in hip OA, probably results in altered somatosensory information that can adversely affect motor control.[320] Progressive balance training can have a positive effect on function of the arthritic hip. Self-Management 19-2, Levels I and II, can be useful in training an individual to balance on one limb with correct form. After the patient is able to stand on one limb with appropriate muscle recruitment and joint loading strategies with reduced pain, balance activities can be added to the program. Progression should be taken slowly to prevent an inflammatory reaction in the hip, which would be counterproductive to improved function.

Posture and Movement Patient-related instructions regarding improved weight-bearing habits are critical to the long-term effectiveness of therapeutic exercise. The person with hip OA must be cautioned to avoid prolonged positioning of the involved limb in the capsular pattern (i.e., hip flexion and lateral rotation). Instruction in use of the deep trunk and pelvic muscles (i.e., diaphragm, abdominal wall, deep erector spinae, pelvic diaphragm) should not be overlooked because of its effect on improving LP and thereby, acetabular position. Small ROM wall squats can be useful to provide a stretch to the anterior myofascial structures simultaneous with abdominal wall strengthening (see Fig. 13-4). During function, use of assistive devices such as canes, crutches,

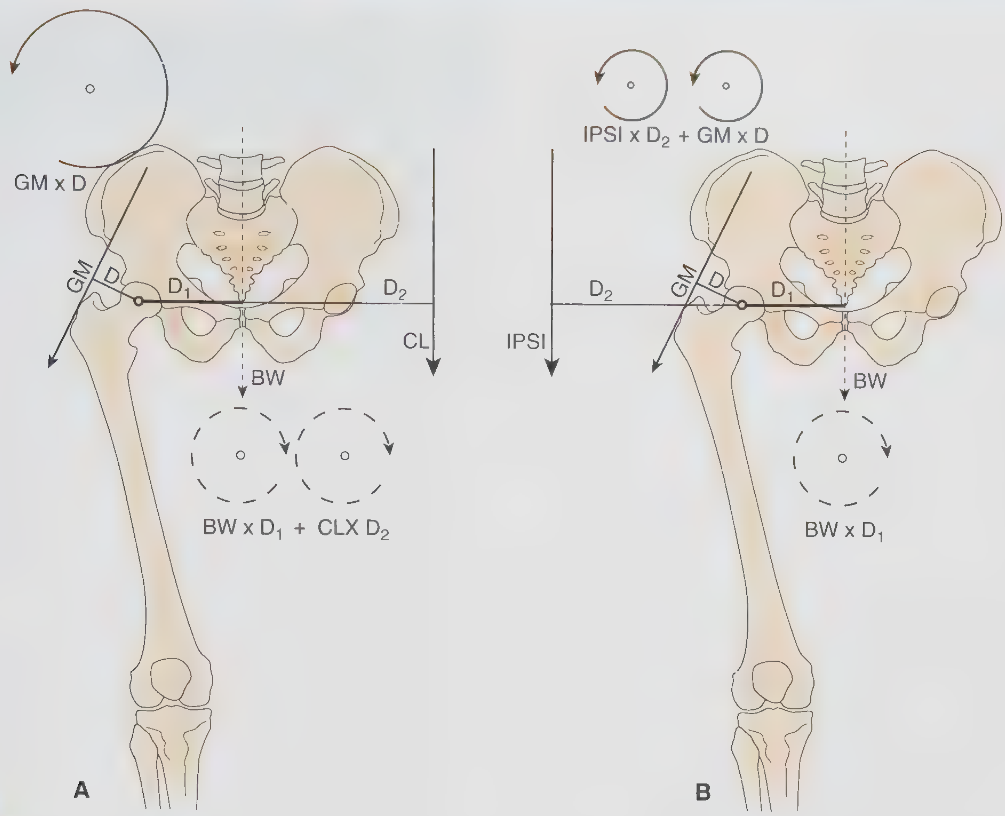


FIGURE 19-31 Diagram representing the moments that contribute to static rotatory equilibrium about the right stance hip when a load is carried (assuming negligible frontal plane accelerations about the stance hip). **(A)** Contralateral carry: The gluteus medius (GM) muscle force times its moment arm (D) must produce an internal moment (counterclockwise moment; solid arrows) large enough to neutralize the combined external moments (clockwise moments; broken arrows) of BW times its moment arm (D1) plus the contralateral load (CL) times its moment arm (D2). **(B)** Ipsilateral carry: The ipsilateral load (IPSI), by passing lateral to the stance hip and thus acting through its moment arm (D2), produces a counterclockwise moment (solid arrows) that is additive to that produced by the gluteus medius (GM) muscle. Fewer demands are therefore placed on the gluteus medius (GM) muscle to neutralize the clockwise moment produced by BW times D1. (Reprinted and modified from Neumann DA, Cook TM. Effect of load and carry position on the electromyographic activity of the gluteus medius muscle during walking. Phys Ther 1985;65:305–331, with permission of the American Physical Therapy Association.)

or walkers can be quite effective in reducing joint stress during ambulation, and consequently decrease antalgic gait patterns. Problem-solving to develop improved posture and movement patterns to allow continued participation in social and occupational activities is time well spent with a patient.

Adjunctive Interventions Because the hip is a weight-bearing joint, it is important that the individual maintains optimal body weight through proper nutrition and aerobic activity. Moderate weight-bearing or non–weight-bearing aerobic activities are recommended for persons with hip OA.[292]

Use of a stationary bike with the seat relatively high can serve as a means of maintaining aerobic activity with minimal weight-bearing stress on the joint. Aquatic exercise programs have been shown to be effective for the treatment of OA of the knee and hip, with 75% of subjects reporting improvement in pain and function after a 6-week bout of aquatic PT.[321,322] Swimming, non–weight-bearing exercise with inflatable supports, or weight-bearing exercises in a pool (see Chapter 16) minimize stress on the hip joint.

Manual therapy has been used to improve hip ROM and decrease OA pain, especially in patients without signs of severe OA. Manual therapy, consisting of stretching, manual traction, and long axis manipulation, was found to be superior to exercise in some studies. The combination of manual therapy and exercise yielded improvement in six of seven patients with hip OA.[305]

Iliotibial Band–Related Diagnoses

The extensive deep fascia that covers the gluteal region and the thigh like a sleeve is called the fascia lata. It is attached proximally to the external lip of the iliac crest, the sacrum and coccyx, the sacrotuberous ligament, the ischial tuberosity, the ischiopubic rami, and the inguinal ligament. Distally, it is attached to the patella, the tibial condyles, and the head of the fibula. The dense portion of the fascia lata situated laterally is designated the ITB. The TFL and three-fourths of the gluteus maximus insert into the ITB so that its distal attachment serves as a conjoint tendon of these muscles.[120] The TFL can be functionally differentiated into anteromedial (**Fig. 19-32A**) and posterolateral fibers (Fig. 19-32B and C). The anteromedial fibers have a greater mechanical advantage for hip flexion (Fig. 19-32A), and the posterolateral fibers have a greater mechanical advantage for hip abduction (Fig. 19-32B) and MR (Fig. 19-32C).[323]

During normal walking, the anteromedial fibers generally are quiet, whereas the posterolateral fibers are active near initial contact.[323] With sequentially increased locomotor velocity, anteromedial fiber activity increases near preswing and initial swing, presumably to decelerate the extending hip and accelerate flexion of the thigh, and posterolateral activity increases at initial contact, presumably to decelerate the adduction moment.[323] The anteromedial fibers are active during the hip flexion phase of

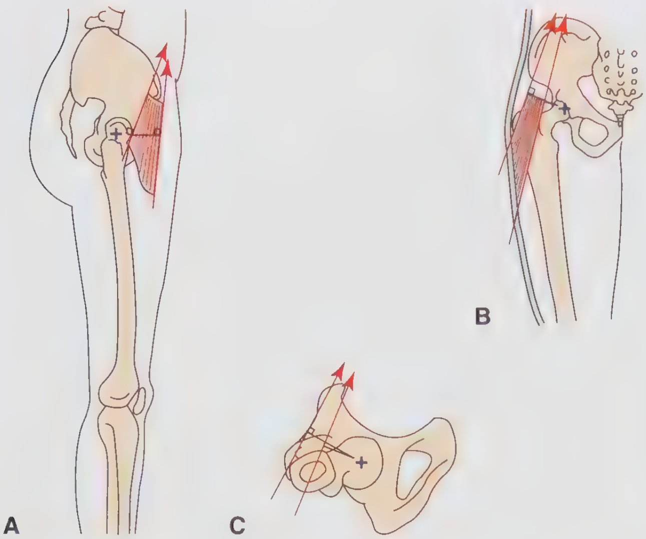


FIGURE 19-32 **(A)** The anteromedial fibers of the TFL have a greater mechanical advantage for hip flexion. **(B)** The posterolateral fibers of the TFL have a greater mechanical advantage for hip abduction and **(C)** medial rotation. (From Pare EB, Stern JT, Schwartz JM. Functional differentiation within the tensor fascia latae. J Bone Joint Surg Am 1981;63A:1457.)

the step-up, and the posterolateral fibers are active during the loading phase of the step-up. The ITB is traditionally considered to function as a "strut" during walking, stabilizing the hip in the frontal plane.[184] However, the high compliance of the ITB,[324–326] the fact that it crosses both the hip and knee, and the presence of in-series muscles suggest that the ITB may play other roles. If the ITB stretches substantially while transmitting muscle forces, storing elastic energy, then it may decrease the metabolic cost of locomotion (see **Evidence and Research 19-15**).

EVIDENCE and RESEARCH 19-15

ITB and Energy Storage

Enga et al.[327] created a model that characterizes the geometry and active and passive muscle force and fiber length properties of the ITB, TFL, and GMax to test the hypothesis that forces generated by TFL and GMax stretch the ITB during running, storing elastic energy. Analysis of the model revealed that the ITB has the capacity to store 7 J per stride during running at 5 m per second. The posterior ITB stores substantially more energy than the anterior ITB because it transmits larger muscle forces. To provide additional context, they reported that the hip extensors do 40 J of work per stride during stance, while the hip flexors do 6 J of work during swing. Recovery of 2 J from glut max/ITB during slow running could account for 5% of the work done by hip extensors in stance, while recovery of 0.3 J from TFL/ITB could contribute 5% of the work done by hip flexors in swing. Furthermore, the human ITB is stretched substantially just before swing, when the TFL is active and the hip is extending. Subsequent recoil of the ITB may help accelerate the swing limb. Although the energetic cost of running is primarily determined by muscle forces that support the body during stance,[328] the cost of accelerating the swing limb may be as much as 27% of the total metabolic cost.[329,330] The assistance of energy recovery from the ITB can significantly assist in running economy. These data provide evidence to consider when prescribing stretching or foam roller work on the ITB in the running population. The ITB appears critical in the stretch-shortening cycle and economy of running.

DISPLAY 19-12

ITB-Related Diagnoses

- *ITB fasciitis*: Inflammation of the ITB resulting from overuse of ITB for stability.
- *Trochanteric bursitis*: In trochanter bursitis, the bursa becomes inflamed because of the pressure exerted by a short ITB moving back and forth over the greater trochanter during movement.
- *ITB friction syndrome (also known as ITB syndrome)*: In ITB friction syndrome, pain and tenderness are localized to the lateral femoral condyle because of a short ITB exerting pressure over the lateral femoral condyle.
- *Patellofemoral dysfunction*: Shortness of the ITB can contribute to patellofemoral dysfunction because of its insertion into the lateral retinaculum of the patellofemoral joint and its tendency to dominate over the quadriceps for knee stability (see Chapter 20).
- *TFL strain*: TFL strain can occur from overuse of a short TFL/ITB or a stretched TFL/ITB complex. The former is more common, but there are instances of strain of the stretched TFL/ITB. The TFL/ITB on the side of the adducted hip (usually the high iliac crest), if there are no associated hip MR or hip flexion alignment or movement faults, is subject to continuous tension and therefore strain.
- *Faulty movement patterns at the hip and tibiofemoral joints*: Faulty movement patterns of the hip and tibiofemoral joints related to the TFL/ITB are critical to understanding the effect of muscle imbalance on the function of these joints. Sahrmann provides more information on this subject.[54]

Because of the vast functional roles of the TFL/ITB complex, it is prone to overuse injuries (see **Display 19-12**).[149] The following sections provide etiologic and treatment information for the most common ITB-related diagnoses.

Iliotibial Band Fasciitis/Fasciosis

A condition, sometimes mistakenly diagnosed as sciatica, is that of pain associated with inflammation or degeneration of the fascial band from overuse of the TFL, commonly called ITB fasciitis,[149] though pain may be due to degenerative changes to the ITB and edema from associated tissues.[120] Pain may be limited to the area covered by the fascia along the lateral surface of the thigh or may extend upward over the buttocks and involve the gluteal fascia. Painful symptoms may extend below the knee, with associated symptoms of paresthesia in the region of the lateral calf.

A review of the anatomy of the lateral aspect of the knee demonstrates the relationship of the peroneal nerve to the muscles and fascia in this area. Peroneal nerve irritation can result from pressure from rigid bands of fascia in a short ITB or from the effect of traction from taut bands of fascia in an overstretched ITB. Peroneal nerve irritation can manifest as symptoms in the lateral calf.[69]

Symptoms are similar to plantar fasciitis; often worse in the morning and improve with minimal weight bearing, but they then worsen with continued weight-bearing. Tests to differentiate ITB fasciitis from sciatica are summarized in **Display 19-13**. Presumably, this condition results from overuse of the TFL/ITB.

DISPLAY 19-13

Key Tests for Differential Diagnosis of Iliotibial Band Fasciitis from Sciatica

Key Tests

- Palpation over the length of the fascia lata may elicit tenderness, especially over the greater trochanter or near the point of insertion lateral to the patella.
- Hip flexion, abduction, and MR (TFL manual muscle test) may test painful.
- The Ober test (test for ITB length) reveals shortness of the TFL/ITB, and further stretch may elicit pain. Paresthesias along the peroneal nerve distribution may worsen with ankle inversion and dorsiflexion.
- Lumbar spine clearing test results are negative for reproduction of the patient's symptoms.

Associated Findings

- Hip rotation ROM may reveal excessive MR relative to LRROM.
- Positional weakness of the synergistic muscles of the GM, gluteus maximus, iliopsoas, and quadriceps.
- Hip anteversion.
- Excessive medial rotation, positive Trendelenburg sign, or limited hip extension in gait.

Concurrent with any overuse syndrome is underuse of the related synergists about any axis of motion in which the affected muscle functions. The more deconditioned the underused synergists become, the greater the force-producing requirements become for the TFL/ITB complex, until finally the force-producing requirements exceed the muscle and fascial capability, and inflammation (fasciitis)[149] or degenerative changes (fasciosis)[121] result. **Display 19-14** summarizes the synergist relationships that may become imbalanced, leading to TFL/ITB overuse.

Iliotibial Band Friction Syndrome

Although iliotibial band friction syndrome (also known as ITBS) manifests at the knee, it is presented here because therapeutic exercise intervention is focused at the imbalances in flexibility and muscle performance at the hip. ITB syndrome is an overuse syndrome first described by Olson and Armour.[331] The ITB lies anterior to the lateral femoral condyle with the knee in extension and moves posterior to the lateral epicondylar prominence with knee flexion. Biomechanical research of ITB syndrome has demonstrated that friction occurs near foot strike, predominantly in the foot contact phase, between the posterior edge of the ITB and the underlying lateral femoral epicondyle.[332] The posterior fibers of the ITB are more problematic in this syndrome than the anterior fibers. This is supported by the surgically known fact that the posterior fibers of the ITB are tighter against the lateral epicondyle than the anterior fibers.[333] Repetitive knee flexion and extension causes the posterior edge of the ITB to rub across the lateral epicondyle, which, theoretically, gives rise to an inflammatory reaction in the tissue deep to the ITB.

The ITB syndrome is quite common in long-distance runners, cited as the second most common injury, with a sex discrepancy prevalence of 38% male and 62% female.[334] ITB syndrome in runners results from a complex of training errors, muscle imbalances in performance and flexibility, inappropriate surface and terrain, lower extremity alignment, and inappropriate footwear.

The clinical symptoms of ITB syndrome include lateral knee pain and occasional snapping on the lateral side of the knee as the knee moves from extension into flexion and then returns to extension. The area is tender over the lateral femoral condyle and pain can be provoked be exerting pressure over the lateral epicondyle during active knee flexion, particularly at 30-degree flexion.[335] It is not uncommon for this syndrome to be misdiagnosed as another condition that causes lateral knee pain such as lateral meniscal tear, lateral collateral ligament sprain, or popliteal tendinitis.[333,334] Coronal MRI can be useful to determine a differential diagnosis.[333]

DISPLAY 19-14

Potential Synergist Relationships with TFL/ITB Overuse

- The anteromedial TFL can dominate the hip flexion force couple, contributing to underuse of the iliopsoas.
- The posterolateral TFL can dominate the hip abduction and MR force couples, contributing to underuse of the GM, upper fibers of the gluteus maximus, and gluteus minimus.
- Because the ITB can provide stability to the knee, overuse of the ITB may contribute to underuse of the quadriceps.
- The hip tends to function in MR patterns, thereby contributing to underuse of the hip lateral rotator force couple, including the deep hip rotators, posterior fibers of the GM, and lower fibers of the gluteus maximus.

Other ITB-Related Syndromes

Similar causes exist for the remaining ITB diagnoses, although with slightly different symptoms. Although some of these diagnoses manifest at the knee, treatment must focus on the cause of the condition, which is TFL/ITB overuse at the hip.

Treatment

Therapeutic exercise intervention for each of the ITB-related diagnoses should take into consideration the biomechanical factors causing the syndrome and the related anatomic and physiologic impairments.

Pain and Inflammation In the acute phase, treatment should be directed toward alleviating the pain and inflammation with medication (i.e., NSAIDs), physical agents (i.e., cryotherapy), and unloading (e.g., use of a cane, taping, proper positioning at night with pillows between knees if sidelying).[149,335] As acute symptoms subside, succeeding treatments should be directed toward resolving the impairments and activity limitations associated with the condition.

Range of Motion ROM impairments are most often associated with a stiff or short TFL/ITB complex.[336] Stretching the TFL/ITB complex may be indicated but can pose a challenge to the clinician and patient. Furthermore, the practitioner must consider the metabolic utility of an appropriately stiff ITB as discussed in Evidence and Research 19-15.

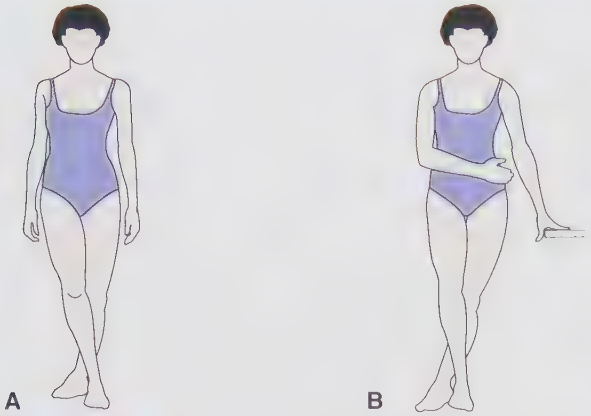


FIGURE 19-33 Commonly prescribed TFL/ITB stretch that does not stretch the TFL/ITB in all directions opposite its actions. **(A)** Crossing the legs commonly places the hip joint in medial rotation. **(B)** Swaying laterally, with the hip medially rotated, stretches the GM and lateral capsule more than the TFL/ITB.

If it is determined that the ITB is too stiff, to appropriately elongate the ITB, its multiple actions must be considered. For an optimal stretch, the TFL/ITB must be elongated simultaneously in all directions opposite its actions. It is critical that the stretching be specifically directed to the area in need of stretch, and some commonly prescribed TFL/ITB stretches do not meet these criteria (**Fig. 19-33**).

An assisted stretch emphasizing the posterolateral fibers is shown in **Figure 19-34**. This stretch ensures the most precise positioning for the best outcome. The obvious disadvantage of this stretch is that rarely can an individual self-stretch in this position. Over time, he or she may be able to master the control required after a series of hip abduction exercises with the emphasis on eccentric control of the GM (see Self-Management 19-4). This exercise also emphasizes improving the force-generating capability and kinesthetic awareness of the GM—a critical, underused synergist. A self-stretch exercise for the TFL/ITB is shown in **Figure 19-35**. This stretch is directed more toward the anterolateral fibers and is considered an active stretch because of the activation of the abdominal muscle group and gluteus maximus to rotate the pelvis posteriorly.

FIGURE 19-34 Assisted Ober stretch position. The hip must be in concurrent hip extension, lateral rotation, and adduction without lateral pelvic tilt. This is difficult to perform without assistance.

FIGURE 19-35 ITB stretch to the extended hip. In the half-kneel stretch position, the patient is asked to maximally drop the contralateral pelvis to adduct the ipsilateral hip. The patient also is asked to extend the hip by means of posterior pelvic tilt (using the gluteus maximus and abdominal muscles). A slight hip LR can be added to stretch the posterolateral fibers. This technique is best used for hip conditions as weight bearing on the knee can be uncomfortable in patients with knee conditions.

Two important issues to be mindful of with respect to stretching any structure:

1. Be cautious of overstretch. Know the goal is to restore normal ROM, not excessive. Recall the ITB is critical to energy storage and overstretch will compromise this function (Evidence and Research 19-15).
2. Stretching should not be used in isolation with the hope that the stretch will permanently improve the length. The clinician must seek the related impairments and activity limitations that perpetuate the shortness. For example, short posterolateral fibers of the TFL/ITB do not remain stretched if the person stands and moves with the hip in excessive medial rotation. Improvements in muscle performance of the underused synergists coupled with education regarding postural habits and neuromuscular training of new movement patterns are essential to restoring length to the ITB on a more permanent basis.

Muscle Performance Correction of muscle performance deficits of the hip abductor muscles has been shown to be correlated with recovery from ITB syndrome.[186] Progressive strengthening of both concentric and eccentric roles of additional underused synergists such as the iliopsoas, gluteus maximus, and quadriceps can further assist in reducing the physiologic and biomechanical requirements of the TFL/ITB. After functional muscle performance is achieved, attention to biomechanical elements to ensure recruitment of these synergists/antagonists during function is essential to full recovery.

The initial exercise prescription depends on the positional strength of these muscles. For example, the iliopsoas may require active assistance exercise initially, progressing to active holding, resistive holding, and finally functional exercises (see Self-Management 19-5 and the swing phase of Self-Management 19-3). The emphasis initially is on end range isometrics, followed by eccentric, and finally concentric, contractions to ensure the improvement of the positional strength of the iliopsoas at end range. The goal with this approach is to improve the length–tension relationships of the relatively lengthened, weaker synergist to the TFL/ITB in hip flexion. An example of a functional movement recruiting the iliopsoas may include repeated swing phase of a step-up with avoidance of hip MR or hip hike accompanying the hip flexion pattern. Additionally, eccentric control is introduced with functional movements focusing on the trail limb during lunges controlling extension forces.

Adjunctive Intervention For a strained TFL/ITB due to continuous tension, use of taping as illustrated by Kendall et al.[69] (**Fig. 19-36A**) can unload the strained structure. Because the femur must not function in excessive medial rotation, taping the hip in a slight amount of LRmay be indicated. An alternative taping technique is illustrated in Figure 19-36B. Applying firm pressure over the TFL while applying tape over this area may unload the TFL and therefore encourage more GM participation during functional activities (see **Building Block 19-5**).

BUILDING BLOCK 19-5

Consider a 19-year-old female track runner who presents with pain 6/10 on the lateral aspect of the right hip, worse with running. The patient presents with weakness of the GM and deep hip lateral rotators. You analyze her running mechanics and notice pronation at initial contact with subsequent excessive femoral adduction and MRwith knee valgus during loading response. Develop a prioritized treatment plan for this patient to return to running with less pain.

Nerve Entrapment Syndromes

Although nerve entrapment syndromes represent a relatively small group of conditions causing hip, groin, or buttock pain, an understanding of the etiology of these syndromes can facilitate a precise diagnosis and promote efficient management of the condition. **Display 19-15** lists the possible nerve entrapment syndromes that can be a source of hip, groin, or buttock pain.

The anatomic possibilities for nerve entrapment syndromes in this region arise from the lumbosacral plexus and its branches (**Fig. 19-37**). Unless nerve entrapment syndromes produce "hard" neurologic signs of motor weakness, sensory loss, or change in tendon reflexes, specific diagnosis may be difficult. This is particularly true of nerve entrapments around the pelvis

FIGURE 19-36 Taping techniques to unload the ITB. **(A)** Unloading the TFL/ITB with lateral longitudinal taping using a technique developed by Florence Kendall. **(B)** Unloading the TFL/ITB with anterior to posterior strips positioned proximally over the TFL and placed every 2 to 3 in distally. The patellofemoral joint may need to be taped medially to prevent lateral displacement from the stretch placed on the ITB distally.

DISPLAY 19-15

Specific Nerve Entrapment Syndromes as a Cause of Pain in the Hip, Groin, and Buttock

- Iliohypogastric nerve
- Ilioinguinal nerve
- Genitofemoral nerve
- Obturator nerve
- Lateral cutaneous nerve of the thigh
- Femoral nerve
- Pudendal nerve.

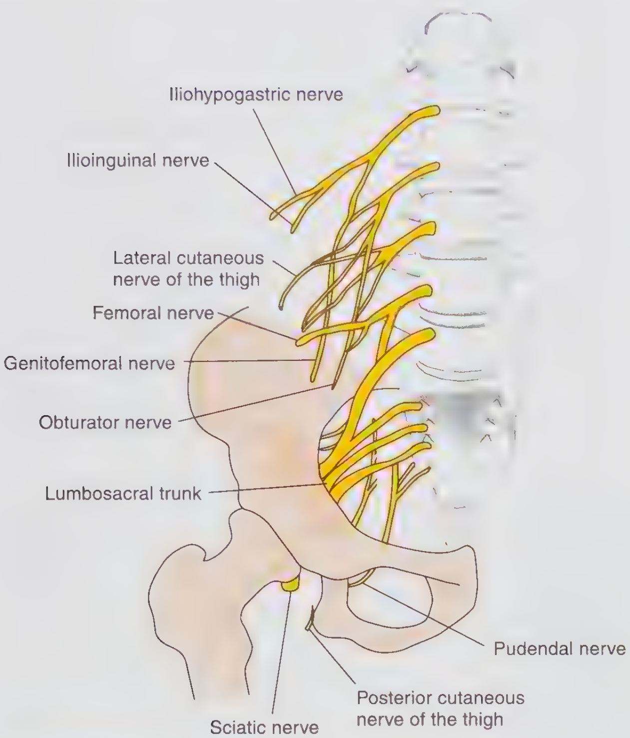


FIGURE 19-37 Anatomy of the lumbosacral plexus.

where the cutaneous sensory dermatomes overlap considerably and many of the nerves have no motor innervation that can be easily tested, resulting in nonspecific and poorly localized pain or paresthesia complaints. A thorough knowledge of the anatomy of the region is necessary to diagnose nerve entrapment syndromes at the hip. Table 19-2 assists the reader with differential diagnosis by providing a regional approach to the diagnosis of nerve entrapment syndromes.

For the purposes of this text, the discussion of entrapment syndromes will be focused on symptoms in the region of the buttock and posterior thigh. The piriformis syndrome has been described as a form of sciatic nerve entrapment causing buttock and posterior thigh pain and the piriformis muscle has been implicated as a potential source of sciatica symptoms.[337] The original description of this condition dates from 1928 when Yeoman[338] stated that insufficient attention had been paid to the piriformis muscle as a potential cause of sciatica.

Although there may be numerous cases in which sciatic pain is associated with a short piriformis, Kendall[69] and Sahrmann[149] describe a variation of this syndrome in which the piriformis is lengthened.

The length of the piriformis must be carefully assessed before planning an intervention for this syndrome. For example, in a faulty standing position with the femur in adduction and MR and the pelvis in anterior pelvic tilt, the piriformis muscle is placed on stretch. The piriformis muscle is pulled taut, potentially entrapping the sciatic nerve. Pressure on the sciatic nerve may result from tension from the adjacent taut piriformis muscle. If the nerve pierces through the piriformis, an injurious tension may be imposed on the sciatic nerve along with the stretched muscle. Because the piriformis is actively used during gait, abnormal gait patterns can impose stress on the piriformis and related sciatic nerve. With an overstretched piriformis, repetitive movements of the hip in MR and adduction and movements of the pelvis in anterior pelvic tilt can impose friction on the nerve, resulting in inflammation of the neural tissue. Strain of the piriformis can ensue because of the muscle functioning in a chronically stretched position.

Diagnosis

Differential diagnosis of buttock and posterior thigh pain can be quite complex. One should consider the potential causes of symptoms including piriformis (lengthened, shortened, strained, or hypertrophied), obturator internus/gemelli complex, lumbosacral radiculopathy, or referred pain. Given the anatomic relationship of the piriformis to the various nerves in the deep gluteal region, it is possible that the buttock pain represents entrapment of the gluteal nerves. Pain caused by piriformis strain can also be felt deep in the buttock. Posterior thigh pain can be caused by the posterior cutaneous nerve of the thigh, which would explain the absence of distal sciatic neurologic signs in some cases. It is possible that the obturator internus/gemelli complex is an alternative cause of neural compression. For this reason, "deep gluteal syndrome" may be a more appropriate term for symptoms isolated to the buttock.[339] Symptoms of sciatica related to a stretched, short, or hypertrophied piriformis can be experienced from the posterior buttock extending inferiorly as far as the toes. Symptoms of pain or tingling may appear in the cutaneous areas below the knee supplied by branches of the peroneal or posterior tibial nerve before symptoms of numbness or signs of weakness become apparent.

Key tests used in making a differential diagnosis that includes a stretched piriformis, a shortened piriformis, lumbar radiculopathy, or referred pain are summarized in **Table 19-5**.

Treatment

For the purposes of this text, this discussion will be isolated to the piriformis syndrome. Therapeutic exercise intervention is based on the physiologic and morphologic status of the piriformis. Careful differential diagnosis of whether the muscle is strained, lengthened, shortened, or hypertrophied is necessary to develop the appropriate therapeutic exercise intervention. For example, a short piriformis must be stretched, whereas this would aggravate a lengthened piriformis syndrome. Periodic ROM measures combined with positional strength testing and dynamic functional testing can indicate the status of recovery of the strain and length–tension properties. The following sections

TABLE 19-5

Differential Diagnosis of Stretched Piriformis Syndrome

Key Tests
Standing alignment
Selective tissue tension tests
Range of motion
Palpation
Positional strength
Functional tests
Lumbar clearing examination
Signs
Lordosis and anterior pelvic tilt
Hip flexion and medial rotation
High iliac crest on involved side
<90 degrees of hip flexion, with adduction and MR reproduces symptoms
Passive or active LR and abduction reduces symptoms
Resisted knee flexion is negative
Excessive hip MR relative to LR within the involved side
Excessive MR of the involved side relative to the uninvolved side
Tenderness elicited in region of the sciatic notch
Weakness in hip lateral rotators and posterior gluteus medius
Tendency to function in hip MR, hip adduction, and anterior pelvic tilt during functional activities
Repetitive movements in MR and/or adduction, with the pelvis in anterior tilt, reproduce symptoms
Lateral rotation, abduction, and neutral pelvic alignment relieves symptoms
Symptoms diminish or disappear when not bearing weight

provide guidelines for the therapeutic exercise intervention for all forms of the piriformis syndrome.

Pain Patients should be instructed in positions that relieve nerve pain and which positions to avoid to prevent further nerve irritation. Regardless of the length of the piriformis, relief may be achieved by placing the involved leg in LR and abduction in lying and standing positions. Sitting with the hips in LR (i.e., legs crossed at the ankles), avoiding extreme hip flexion, or sitting on a firm surface to support the femoral head in the acetabulum can alleviate symptoms while sitting. Sitting in bucket seats forces the hips into medial rotation. So, if your pelvis is too wide for the seat, add a pillow or foam to level the seat to reduce the force into medial rotation.

Posture and Movement Permanent changes with respect to postural habits are encouraged to help alter the length–tension properties of the muscle. The patient should be instructed to position the limb to take the muscle off stretch (i.e., hip adduction, medial rotation, or extreme flexion). Limb position should be monitored during ADLs such as transitioning from sit to stand, squatting, and during the stance phase of gait. Cues to maintain neutral transverse and frontal plane alignment can reduce repetitive stretch to the piriformis.

Muscle Performance In the case of a strained or lengthened piriformis, gradual progressive strengthening is indicated. Often the muscle is quite weak initially due to the strain or shifted length–tension properties. Caution must be used with dosage

FIGURE 19-38 Prone foot pushes strengthen the piriformis isometrically in the short range. The patient positions the hip in abduction and lateral rotation. The patient pushes the heels together with a submaximal contraction. Submaximal contraction is desired over maximal to reduce the amount of accessory muscle recruitment (i.e., lateral hamstrings and adductors). Duration and repetitions are determined based upon the goal of the exercise (i.e., strength vs. endurance).

parameters so as not to exceed the muscle's physiologic capabilities. Exercise in the short range is indicated for the lengthened piriformis. Strengthening exercises should be avoided for the short or hypertrophied piriformis. Exercises that can target hip lateral rotator strength and length–tension properties include prone foot pushes (**Fig. 19-38**), prone hip extension with pelvic stabilization (Self-Management 19-1), sidelying hip abduction with emphasis on LR (Self-Management 19-4), and hip lateral rotator strengthening in the short range (Fig. 19-10).

Strengthening the abdominal muscles (see Chapter 18) in the short range may be necessary to address an associated anterior pelvic tilt in the strained or lengthened piriformis syndrome. Strengthening the ipsilateral GM (Self-Management 19-4) may be necessary to reduce adduction patterns that will add further stress to a strained or lengthened piriformis.

After the muscle performance of the piriformis has improved to maintain the femur in neutral while bearing weight, exercises can be progressed to standing. In the lengthened or strained piriformis, the focus is to train the femur to function in less MR and adduction and the pelvis in less anterior tilt, without promoting excessive hip flexion. In the short or hypertrophied piriformis syndrome, the focus is to train the femur to function in less LR and abduction and encourage the hip to function in more flexion (see Self-Managements 19-2, 19-3, and 19-8; and Fig. 19-12).

Range of Motion Stretching the piriformis is contraindicated for the strained or lengthened piriformis. However, stretching the opposing medial rotators may be necessary if the stiffness or shortness contributes to the hip functioning in medial rotation, imposing undue tension on the lengthened piriformis. Stretching the medial rotators (e.g., posterolateral fibers of the TFL, gluteus minimus, anterior GM) can be difficult to perform unassisted. Assisted stretching with the patient in a prone position into lateral rotation, with careful stabilization of the pelvis and the tibia, ensures optimal stretch to the medial rotators (see Fig. 19-27E). The pelvis must be stabilized actively or passively to prevent anterior pelvic tilt and lumbar extension while stretching the TFL/ITB complex.

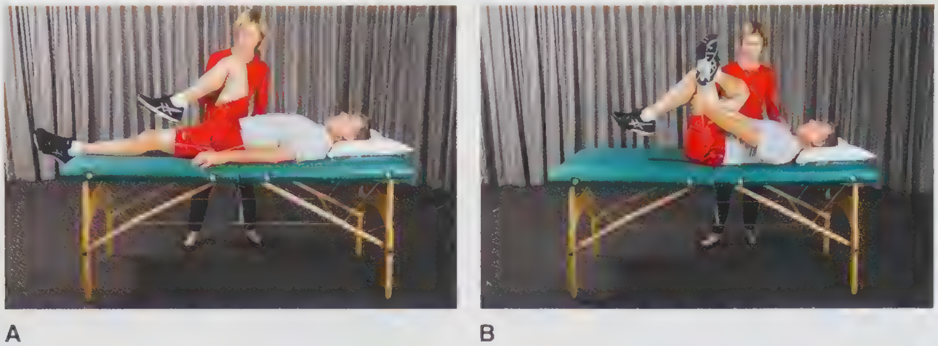


FIGURE 19-39 Piriformis stretch. **(A)** Passive stretch for the piriformis muscle. With the patient lying supine, the lower extremity is grasped at the flexed knee. The lateral aspect of the iliac crest and the ASIS are stabilized by the cranial hand while the caudal hand flexes the femur to 60 degrees and guides the femur into adduction. Self-stretch of the piriformis and other deep hip rotators. **(B)** After 60-degree hip flexion, the piriformis medially rotates the femur. To stretch the right deep hip lateral rotators, the patient lies supine and the right femur is flexed and laterally rotated such that the right ankle rests on the posterior aspect of the distal left thigh. From this position, the left hip is flexed until tension is perceived in the right buttock.

Stretching the piriformis is indicated in the short or hypertrophied piriformis syndrome. Passive stretches for the piriformis are shown in **Figure 19-39**. Caution must be taken to ensure stabilization of the sacrum when stretching by moving the femur.

Stretching the low back muscles (see Self-Management 19-7 may be necessary to reduce forces contributing to anterior pelvic tilt. This same stretch can be used to stretch the piriformis. Caution must be heeded when stretching the low back muscles in the lengthened piriformis syndrome so as not to place further tension on the sciatic nerve. While moving into hip flexion, the emphasis should be on achieving a flat low back and not on hip flexion.

Stretching the ipsilateral hip adductors (Fig. 19-21) or abductors (Figs. 19-31 and 19-32) may be necessary to improve frontal plane alignment of the hip depending on the initial length of the piriformis.

Adjunctive Interventions Support to a strained piriformis is indicated for rapid recovery. The lengthened piriformis should also be supported to relieve tension and allow for length–tension changes to occur. The combination of taping, posture, and exercise providing this support can be determined on a case-by-case basis, but it must be addressed in some fashion and for a period sufficient to allow recovery.

Taping techniques to support the limb in more neutral positions and provide feedback to avoid MR and adduction are indicated for the stretched or strained piriformis. McConnell[340] has developed a taping technique for the buttock that can support a strained piriformis and assist in unloading neural tissues. Taping behind the knee can serve as "biofeedback" to prevent excessive MR tendencies during standing exercises and function (**Fig. 19-40B**; see **Building Block 19-6**).

FIGURE 19-40 Excessive MR of the femur in standing as shown by **(A)** tape on the hamstring tendons. **(B)** Corrective taping posterior to the knee. To encourage hip LR and tibia MR, the tape is applied from the lateral femur distally to the medial tibia and from the medial tibia proximally toward the lateral femur. *Note*: Because this taping procedure does not anchor the tape to any bony prominence, its ability to prevent unwanted tibiofemoral movement is questionable. At best, it can provide temporary feedback to the patient until the tape has sufficiently stretched.

BUILDING BLOCK 19-6

Consider a patient presenting with left-sided gluteal pain that radiates down the posterior aspect of the left leg. The patient demonstrates decreased tolerance to sitting, weakness in the deep hip lateral rotators, increased MR ROM of the left hip, and increased adduction and MR patterns with sit to stand/stand to sit, step-ups/downs, and during the loading phase of gait. Develop a treatment plan for this patient to address her pain.

KEY POINTS

- The structure of the hip joint is designed for stability and to withstand high kinetic forces.
- The angles of inclination and torsion are critical to ideal functioning of the hip joint.
- The ligaments of the hip provide significant stability to the hip, particularly in hip extension, adduction, and medial rotation.
- The tension of the ligaments corresponds to positions of stability and instability of the hip.
- Hip osteokinematic ROM is closely linked to the LP region. Limitation in hip mobility may manifest in compensatory LP mobility and at the knee, ankle, and foot, although to a lesser degree.
- Hip arthrokinematic motions follow convex moving on concave rules with rolling and translation (minimal as it may be) moving opposite in direction to the distal end of the femur.
- It is important to understand the function of the muscles that cross the hip and the relationships they have with the LP region and the knee joint.
- In vivo loads acting at the hip joint have demonstrated the average patient loads the hip joint with 238% body weight (BW) when walking at about 4 km per hour, while climbing upstairs increases joint contact force to 251% BW going downstairs to 260% BW.
- A thorough hip examination is necessary to understand the anatomic and physiologic impairments in the hip and those in related regions that affect the patient's activity limitations and disability.
- Impairments in muscle performance, gait and balance, posture and movement, ROM, and joint mobility commonly occur together in hip-related conditions. Treatment must focus on the impairments most related to the presenting activity limitations and participation restrictions. The initial focus should be on restoring functional capacity of each relevant impairment and gradual progression toward functional activity.
- FAI is of unknown etiology, but there is a strong case that mechanical stress in the developing hip can contribute to cam morphology.
- 3D orientation of the acetabulum and femur can have an impact on mechanical hip pain and impingement.
- PTs can contribute to both prevention and nonsurgical management of FAI through properly prescribed therapeutic exercise.
- The primary focus of treatment of hip OA is to improve joint loading by increasing the contact area for loading. Restoring proper joint mobility and soft tissue extensibility are prerequisite to building force or torque related to optimal joint loading. Improving posture and movement patterns are critical to transition improved physiologic impairments into function. Balance skills are the final element to restoring more optimal movement patterns and joint loading.
- Numerous ITB-related syndromes exist. The focus of treatment is to improve the force or torque and functional recruitment of the underused synergists in meaningful functional movement patterns.
- The stretched piriformis syndrome can mimic lumbar radiculopathy. Correct differential diagnosis from lumbar radiculopathy, short piriformis syndrome, and hamstrings strain is mandatory for a successful outcome. Treatment focuses on improving the movement patterns and associated physiologic impairments that contribute to femur MR and adduction and on anterior pelvic tilt, all of which can contribute to stress on the piriformis and the sciatic nerve.

LAB ACTIVITIES

1. How would you progress a patient with OA in standing exercises to improve weight acceptance and single-limb support phases of gait? Would you use any assistive devices?
2. With respect to Critical Thinking Question 3, what isometric contractions can normalize orientation of each of a retroverted or anteverted acetabulum?
3. With respect to Critical Thinking Question 4, develop a program of exercises that improve the mobility and associated force or torque impairment for each scenario. Teach this program to your partner. Assume that all manual muscle test grades are 3+/5. Progress specific nonfunctional exercises to functional exercises.
4. With respect to Critical Thinking Question 6, how would you begin to improve the force or torque production of a GM underused synergist with a positional strength grade of 3−/5. How would you progress this exercise as the positional strength improved? Teach your partner these exercises. Can you feel the TFL trying to dominate the exercise movement pattern? What is the associated pattern of movement with TFL dominance? Progress this exercise to standing functional exercises. How does the foot alignment contribute to the hip position in closed chain positions and movements?
5. Your partner has been diagnosed with ITBS. List synergists that may be underused and therefore contribute to this diagnosis. Develop an exercise to improve muscle performance for each underused synergist. Consider each underused synergist has a 3+/5 muscle test grade.
6. Practice the balance progression described in Display 19-8. What type of balance strategy are you using? Develop balance drills that stress the frontal plane and crossover stepping strategies.
7. With respect to Critical Thinking Question 7, progress hip lateral rotator exercises from specific, nonfunctional exercises to functional exercises. How would you stress the lateral rotators in a single-limb balance drill (be creative)?
8. Refer to Case Study No. #9 in Unit 7. Develop a complete therapeutic exercise intervention plan using the intervention model developed in Chapter 2.
9. Refer to Case Study No. #10 in Unit 7. Develop a complete therapeutic exercise intervention plan using the intervention model developed in Chapter 2.

CRITICAL THINKING QUESTIONS

1. To which type of knee alignment does coxa vara and coxa valga contribute?
2. What direction are the femoral condyles oriented in femoral anteversion versus retroversion? If a patient with femoral anteversion participates in ballet, what type of mobility problem could he or she develop? If a patient with femoral anteversion participates in soccer, what type of mobility could he or she develop? What are your recommendations for the alignment of the anteverted femur during sport activities?
3. What 3D orientation is the acetabulum in acetabular retroversion? Anteversion? Does retroversion provide increased or decreased femoral head coverage? How would this contribute to positional FAI?
4. What would be the compensatory lumbar motions and what phases of the gait cycle would be involved if right hip mobility were restricted in (a) flexion, (b) extension, or (c) medial rotation?
5. If the hip were restricted in flexion, what are the postural patterns at the pelvis and lumbar spine contributing to this hip flexion restriction? What movement patterns would you retrain to improve hip flexion mobility? What muscle force or torque impairments at the LP region would you be concerned about that could help perpetuate the hip flexion restriction? Answer these same questions with respect to restrictions in hip extension and medial rotation. What is this pattern of restriction (i.e., restricted hip flexion, medial rotation, extension) called?
6. Describe the Trendelenburg pattern of gait. Can you describe other hip joint movement patterns that could indicate hip abductor weakness?
7. In TFL/ITB overuse diagnoses, why is the hip the focus of treatment? What are the common underused synergists that contribute to TFL/ITB overuse?
8. How would you differentially diagnose a stretched piriformis syndrome from a short piriformis syndrome, lumbar radiculopathy, or strained hamstrings?

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CHAPTER 20

The Knee

JILL THEIN-NISSENBAUM • LORI THEIN BRODY

The knee is one of the most frequently injured joints in the body. The vast quadriceps muscle spans the anterior thigh and crosses the tibiofemoral joint, producing knee extension when contracted. The role of the patella is to enhance quadriceps performance across the longest lever arm of the body. Impairments at the knee joint can produce significant activity limitations and performance restrictions. The closed chain demands of daily activities such as walking, standing, and rising from a chair require smooth, coordinated action of the lower extremity neuromuscular system.[1,2] When considering impairments around the knee joint, the impact of these impairments on the related joints in the kinetic chain also must be addressed.

REVIEW OF ANATOMY AND KINESIOLOGY

A thorough understanding of the anatomy and kinesiology of the knee joint is necessary to comprehend the impact of impairments on function of the kinetic chain. The unique kinematic relationships of lower extremity joints depend on local anatomic structures. A brief review of key aspects follows, with further information available on the website.

Anatomy

The osteology of the knee joint consists of the convex medial and lateral femoral condyles articulating with the concave proximal tibial plateau.[3] The medial femoral condyle extends further distally and is wider than the lateral condyle, contributing to the quadriceps angle (Q-angle) and knee valgus posture commonly observed.[3,4] The triangular shaped patella, with its concave undersurface, articulates with the convex femoral condyles (**Fig. 20-1**).

Key aspects of the knee osteology include:

- Condylar asymmetry that contributes to the screw home mechanism (femoral internal rotation coupled with tibial external rotation during terminal extension)[3]
- Lateral tibial plateau that is small, more circular, and concave compared with the oval-shaped, flatter medial tibial plateau
- The undersurface of the patella that is covered with articular cartilage up to 5 mm thick, and has two concave facets and an additional "odd" facet[3,5]

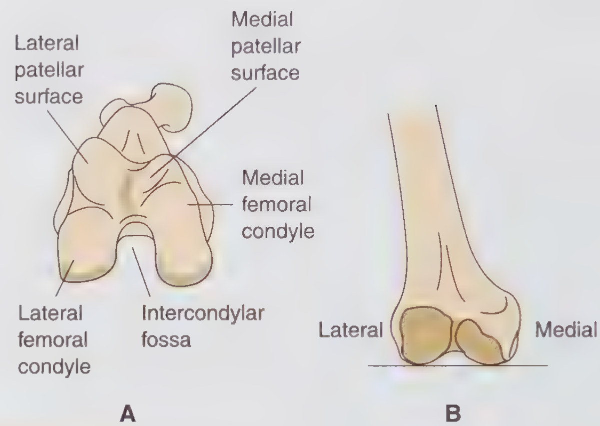


FIGURE 20-1 **(A)** View of the femoral surface from the inferior articulating surface. Note the more anterior prominence of the lateral femoral condyle. **(B)** The medial femoral condyle is longer than the lateral, and the lateral femoral condyle lies more directly in line with the shaft of the femur as compared to the medial. (Adapted from Norkin CC, Levangie PK. Joint Structure and Function: A Comprehensive Analysis. 2nd Ed. Philadelphia, PA: FA Davis, 1992:340.)

The tibiofemoral joint is housed in a fibrous capsule; the internal surface of the capsule is lined with a synovial membrane.[3] The capsule is supported by several ligaments including the medial (MCL) and lateral collateral ligaments (LCL), the oblique popliteal ligament and the arcuate complex. The primary anterior-posterior stability is provided by the anterior (ACL) and posterior (PCL) cruciate ligaments.[4] The patella is stabilized by the quadriceps muscles and the multiple fascial layers surrounding and enveloping this sesamoid bone[3,6] (**Fig. 20-2**). The medial and lateral menisci are crescent-shaped fibrocartilaginous structures interposed between the tibia and femur, adding congruity to seemingly incompatible surfaces. The medial meniscus is semilunar, attaches to the coronary ligament peripherally, and occupies ~60% of the articular cartilage contact area of the medial compartment.[7] In contrast, the lateral meniscus is almost uniformly circular, is more mobile than the medial meniscus, and occupies ~80% of the articular cartilage contact area of the lateral compartment[7] (see **Table 20-1**).

The complex interaction among joints, including the pelvis, hips, distally through the ankle mortis and foot make discussion of myology at the knee more complicated. For the purposes of

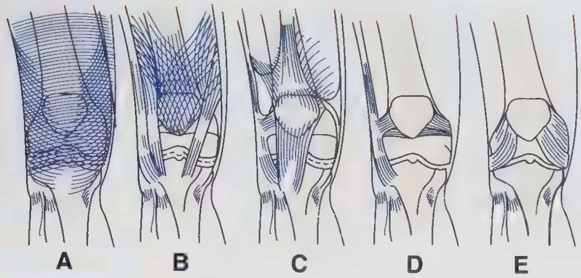


FIGURE 20-2 The multiple soft tissue layers affect the patellofemoral joint: **(A)** the superficial arciform layers with transverse fibers over patella and patellar tendon; **(B)** the intermediate oblique layer with chevron-oriented fibers from the rectus femoris, VL, and VM; **(C)** the deep longitudinal layers, which are extremely adherent to the anterior surface of the patella; **(D)** the deep transverse layer blending with fibers of the ITB; and **(E)** the deep capsular layer composed of the medial and lateral patellomeniscal ligaments. (Adapted from Dye SF. Patellofemoral anatomy. In: Fox JM, Del Pizzo W, eds. The Patellofemoral Joint. New York, NY: McGraw-Hill, 1993:5.)

TABLE 20-1

Arthrology Key Concepts at the Knee

- Posteriorly, the capsule is reinforced by the oblique popliteal ligament
- Medially, the capsule reinforced by three layers of the medial collateral ligament (superficial, middle, and deep layers)
- Laterally, the capsule extends to tibial margin and fibular head, and is reinforced by lateral collateral ligament
- Anteriorly, the capsule blends with expansion of vastus lateralis and vastus medialis muscles to attach to patella and patellar tendon
- Anterior expansion continues medially and laterally to the collateral ligaments and tibial condyles
  - This expansion is known as medial and lateral patellar retinacula or extensor retinaculum
  - Multiple layers implicated in patellofemoral pathology (Fig. 20-2)
- The capsule is reinforced by the patellar tendon
- Synovial plicae are embryonic remnants of synovial septa remaining into adulthood that may cause symptoms

anatomy, only the muscles crossing the knee joint proper will be discussed. Reviews of muscles at adjacent joints can be found in their respective chapters (Chapters 19 and 21). The primary anterior muscles are the quadriceps femoris, consisting of the rectus femoris, vastus lateralis (VL), vastus intermedius, and vastus medialis (VM). These muscles serve as the primary knee extensors. The posteriorly located hamstring muscles are comprised of the biceps femoris, semimembranosus, and semitendinosus, and serve as the primary knee flexors, besides assisting in hip extension and rotation. In addition, the popliteus, which flexes and internally rotates the tibia on the femur, plays a key role in unlocking the knee joint from the screw home position. As such, the popliteus is often termed the "key to the knee".[3] Medially, the gracilis, adductor magnus, and adductor brevis function to adduct the hip but also serve to stabilize the medial aspect of the knee joint. The lateral musculature (gluteus maximus, tensor fasciae latae, and iliotibial tract) functions primarily at the hip but can be symptomatic at the knee as well.[8]

Kinematics

Although the knee joint is classified as a simple hinge joint, the kinematics of this joint are the result of the complex interplay of bony and soft tissue anatomy. Key aspects of tibiofemoral kinematics are as follows, and further information can be found on the website:

- The tibiofemoral has two degrees of freedom, including flexion and extension in the sagittal plane and internal and external rotation in the transverse plane (provided the knee is slightly flexed).[3]
- Varus and valgus motion occur in the frontal plane.
- Shearing or translation can occur in both the anterior and posterior direction and medial and lateral direction.
- The joint experiences both distraction and compression.
- Normal range of motion (ROM) is from 0 degrees (full extension) to 140 degrees of flexion.[8]
- Flexion is limited by the cruciate ligaments and posterior horns of the menisci.[7]
- Extension is limited by the cruciate ligaments, posterior capsule, and anterior horns of the menisci.[3]
- The screw home mechanism, also called conjunct rotation, is driven by the shape of the femoral condyles, the passive tension of the ACL, and the lateral pull of the quadriceps muscle.[3]
- Varus or valgus stress is likely to damage respective collateral ligaments and, if significant, the cruciate ligaments.
- The instant center of rotation changes throughout the ROM. Alterations in the instant center of rotation following injury can produce areas of increased loading on articular cartilage[9] (see **Fig. 20-3**).

Understanding the kinematics of the patellofemoral joint helps guide intervention choices for problems such as patellofemoral pain (PFP), discussed in detail later in the chapter. At full extension, in the screw home position, there is no contact between the patella and the femur. As the knee starts to flex, the inferior patellar pole first contacts the femur at approximately 20 degrees of flexion. As flexion proceeds to 90 degrees, the contact area on the patella moves proximally, toward the central portion of the patella. The "odd" facet does not come into contact with the medial femoral condyle until the knee is flexed 135 degrees. Even with maximal contact of the femur and the patella, which occurs somewhere between 60 and 90 degrees, only approximately one-third of the patellar undersurface is in contact with the femur[3] (see **Fig. 20-4**).

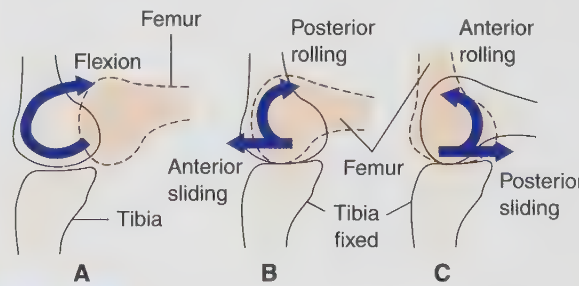


FIGURE 20-3 **(A)** Pure rolling of the femur on the tibia. The femur would roll off the tibia if no gliding occurred. **(B)** Posterior rolling and anterior gliding occur with flexion, while **(C)** anterior rolling and posterior gliding occur with extension. (Adapted from Norkin CC, Levangie PK. Joint Structure and Function: A Comprehensive Analysis. 2nd Ed. Philadelphia, PA: FA Davis, 1992:355.)

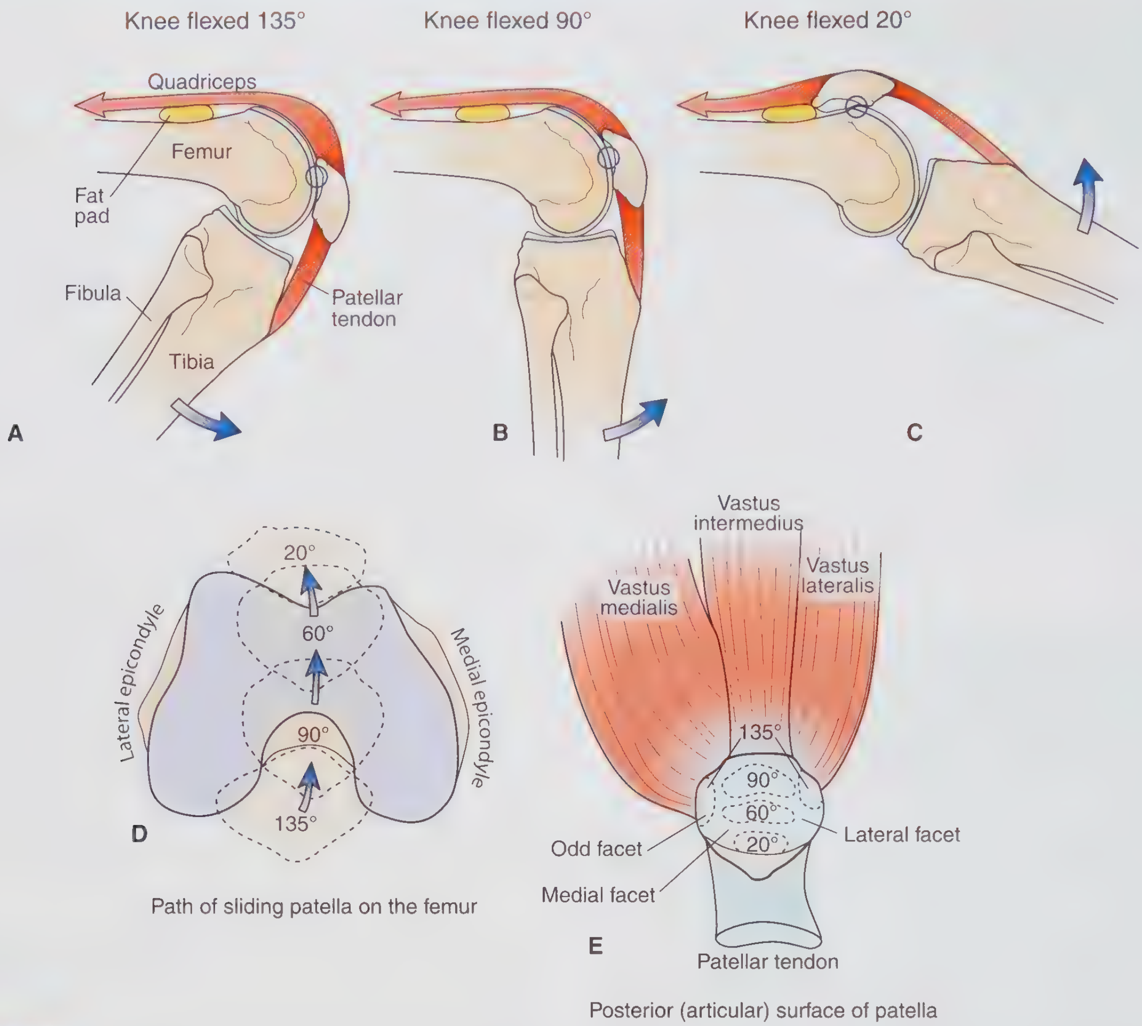


FIGURE 20-4 The kinematics at the patellofemoral joint during active tibial-on-femoral extension. The circle depicted in **(A)** to **(C)** indicates the point of maximal contact between the patella and the femur. As the knee extends, the contact point on the patella migrates from its superior pole to its inferior pole. Note the suprapatellar fat pad deep to the quadriceps. **(D)** and **(E)** show the path and contact areas of the patella on the intercondylar groove of the femur. The values 135, 90, 60, and 20 degrees indicate the flexed position of the knee. (From Neumann DA. Kinesiology of the Musculoskeletal System. 2nd Ed. St. Louis, MO: Elsevier, 2010; used with permission.)

In ideal static alignment, the patella is situated slightly laterally because of the screw home mechanism that lateralizes the tibial tubercle. As the knee flexes and the tibia derotates, the patella is drawn into the trochlear groove. The patella remains in the trochlear groove from approximately 20 to 90 degrees of flexion. With continued flexion, the patella moves laterally and completes a lateral C-shaped curve. This motion is passive when the knee is flexing. However, the tracking changes during active knee extension, and the patella moves superiorly along the line of the femur if the vastus medialis obliquus (VMO) and the VL are in balance.

Kinematics of Gait

Range of motion from 0 to 60 degrees at the knee is necessary for normal gait. However, this presumes normal mobility at the pelvis, hip, ankle, and foot. Any limitations at adjacent joints may require additional motion at the knee. When the foot makes initial contact with the ground, the knee is fully extended. The knee then flexes to 15 degrees during the loading response of gait. After this initial flexion, the knee begins to extend until it reaches full extension at midstance. As the body weight passes over the limb, the knee passively flexes to 40 degrees. As the knee moves into the initial swing phase, the knee further flexes to 60 degrees to assist the foot clearing the floor. The knee then continues to extend through the midswing and terminal swing phases, achieving full extension before initial contact (**Table 20-2**).

Kinetics

Tibiofemoral Joint

Ground reaction forces and muscle activation combine to create significant forces about the knee joint. Malalignment in any plane can result in considerable focal increases in force. Motions occurring in the sagittal plane result primarily in activation of the knee flexors and extensors. During different phases of the

TABLE 20-2

Kinetics and Kinematics of the Gait Cycle at the Knee

PHASE OF THE GAIT CYCLE	ROM (DEGREES)	MOMENT	MUSCLE ACTIVITY	MUSCLE CONTRACTION TYPE
Initial contact	0	Flexion	Quadriceps	Isometric
			Hamstrings	At hip, isometric
Loading response	Flexes 0–15	Flexion	Quadriceps	Eccentric
Midstance	Extends to 5 flexion	Flexion moving toward extension	Quadriceps	Concentric
Terminal stance	Extends to 0	Extension	Minimal	
Preswing	Flexes to 40	Flexion	Minimal	
Initial swing	Flexes from 40 to 60		Hamstrings	Concentric
Midswing	Extends from 60 to 30		Mostly passive with some hamstrings	Eccentric
Terminal swing	Extends from 30 to 0		Hamstrings	Eccentric
			Quadriceps	Concentric

gait cycle, the quadriceps and hamstrings contract in response to the moments created with walking. The muscles contract concentrically, eccentrically, or isometrically during the gait cycle. This information is summarized in Table 20-2.[3]

Ground reaction forces, muscular forces, and the normal lower extremity alignment combine to produce important loads in the frontal plane. During the stance phase, the varus moment at the tibiofemoral joint produces a relative compression in the medial compartment and distraction in the lateral compartment of the knee. This puts greater loads on the medial articular structures (e.g., articular cartilage, meniscus) and on the lateral stabilizing structures (e.g., LCL, joint capsule). Force plate analysis demonstrates that ground reaction vertical force rarely exceeds 115% to 120% of body weight during normal ambulation. However, during jogging and running, ground reaction forces approach three times the body weight.[9]

Patellofemoral Joint

In addition to ground reaction forces, joint reaction forces are created at the patellofemoral joint by tension in the quadriceps and the patellar tendon. As the knee flexes in a weight-bearing position, greater quadriceps torque is required, and joint reaction force increases. For example, the quadriceps torque during level walking is one-half of the body weight, stair-climbing is three to four times the body weight, and squatting is seven to eight times the body weight. These compressive forces can be minimized by a properly aligned patella, which disperses the force over a large surface area. Patellar subchondral bone with a strong, well-organized trabecular arrangement also minimizes joint reaction forces. Pathology, such as degeneration of patellar or femoral chondral surfaces, further reduces the ability of the patellofemoral joint to respond to load.

The balance between the VMO and VL appears to be important for maintaining normal patellar tracking, although the precise recommendations are unclear. Results of surface electromyography (EMG) have suggested an approximately 1:1 ratio of VMO to VL input in normal individuals and <1:1 in those with PFP.[10,11] This issue will be discussed further in the "Patellofemoral Pain Syndrome" section. In addition, small amounts of swelling (as little as 20 mL fluid) may inhibit the VMO.[12]

IMPAIRMENTS OF BODY STRUCTURES

The primary anatomic impairments at the knee occur in the frontal plane. Alignments of the hip, knee, and ankle combine to form an integrated kinetic chain, which must be considered in its entirety. The position of the hip affects the position of the knee, and the position of the knee dictates foot position. The anatomic impairments at the knee must be evaluated in light of the posture of the lumbopelvic, hip, ankle, and foot joints.

Genu Valgum

The femur descends obliquely from the hip in a distal and medial direction. This medial angulation with a vertical tibia results in a valgus angle at the knee, or genu valgum (**Fig. 20-5A**). This medial angle is 5 to 10 degrees. Any angle greater than this is considered to be excessive genu valgum. This valgus position places greater load on the lateral compartment of the knee and creates a tensile and unloading force at the medial compartment. Over time, development of degenerative joint disease in the lateral compartment produces physiologic lengthening of the MCL as the lateral compartment collapses and the medial compartment is unloaded. Increased knee valgum increases the lateral pull of the quadriceps, placing excessive loads on the patellofemoral joint and increasing the risk of patellar dislocation. Genu valgus is associated with coxa varum at the hip and excessive pronation at the subtalar joint.[3]

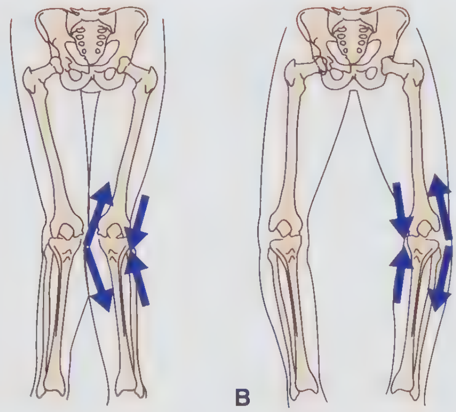


FIGURE 20-5 **(A)** Decreased tibiofemoral angle associated with coxa vara results in genu valgum. **(B)** Increased tibiofemoral angle associated with coxa valga results in genu varum. (Adapted from Norkin CC, Levangie PK. Joint Structure and Function: A Comprehensive Analysis. 2nd Ed. Philadelphia, PA: FA Davis, 1992:344.)

Genu Varum

When the angulation of the femur and tibia is vertical (0 degrees) or laterally oriented, the condition is referred to as genu varum (Fig. 20-5B). Genu varum increases the loads in the medial compartment of the knee and relatively unloads the lateral compartment. Genu varum is associated with coxa valgum, and because the heel contact occurs in a calcaneal varus position, excessive pronation occurs to orient the calcaneus vertically.

EXAMINATION AND EVALUATION

As with all the joints of the lower extremity, a comprehensive knee examination includes the adjacent joints and the lumbopelvic region. The choice of specific tests and measures for the examination depend on the situation. The following sections discuss key aspects of knee joint examination.

Patient/Client History

The most important data to be gathered first are subjective information, which subsequently guides the objective examination and provides the clinician with important information about activity limitations and participation restriction. Key questions focus on which symptoms are most disabling for the patient. Patients may report pain, instability, mobility loss, weakness, or catching as their chief complaint. From this information, the clinician selects tests and measures to match the patient's symptoms and designs a treatment program to address impairments directly related to the activity limitations and participation restrictions described by the patient. The examination must clarify the source of symptoms through thorough questioning and appropriate test and measure choices. For example, a history of a deceleration injury along with complaints of the knee giving way would lead the clinician to tests such as a Lachman's test or a pivot shift test to assess the integrity of the ACL. Refer to Chapter 2 for detailed subjective interviewing information including *History* (Display 2-1) and *Systems Review*.

Tests and Measures

The objective examination should begin with observation of posture and position of the lower extremity. Clearing tests for the lumbopelvic and hip regions should be performed. Any of these areas may refer pain to the thigh, knee, or calf; as such, the clinician needs to be certain the source of symptoms is not an adjacent joint. See Magee's *Orthopedic Physical Assessment*[13] for a more complete description of examination techniques.

THERAPEUTIC EXERCISE INTERVENTION FOR BODY FUNCTION IMPAIRMENTS

After a thorough examination and determination of the diagnosis and prognosis, the treatment plan is implemented. Any impairments identified must be correlated with an activity limitation or participation restriction, with this aspect of the patient's care treated concurrently. However, some impairments must be improved before their associated activity limitation or participation restriction can be addressed.

Mobility Impairment

The first step in treating decreased mobility of the knee is determining the cause. Decreased mobility can be caused by connective tissue (i.e., musculotendinous, capsular) shortening. Mobility can also be diminished by iatrogenic or pathologic abnormalities such as an incorrectly placed ligament graft, a hypertrophic fat pad, or disuse. Examining the pattern of limitation and the patient's location of pain can clarify the cause of mobility impairment. Hypomobility at the knee joint results in compensation at adjacent joints. For example, squatting down with limited knee motion requires additional motion at the hip, ankle, and low back, which puts these joints at risk of injury from the excessive demands placed on them. Thus, adjacent joints must be examined simultaneously.

Mobilization Techniques

Capsular restriction is common after total knee arthroplasties, surgical intervention, or immobilization. Capsular limitations can occur at the tibiofemoral joint, patellofemoral joint, or both, and the source of the limitation must be ascertained. Full knee extension requires superior glide of the patella and anterior glide of the tibia on the femur. Knee flexion requires inferior glide of the patella along with posterior glide of the tibia on the femur. Capsular restrictions are treated with the respective glides and joint distraction techniques. Distraction mobilizations are often helpful for increasing general knee ROM. To increase knee flexion ROM, the therapist can apply distraction to the tibiofemoral joint with the knee flexed while concurrently performing a posterior glide of the tibia on the femur, gently moving the knee into further flexion (**Fig. 20-6**). Manual therapy to increase knee extension can be performed with the patient in prone, with the tibia off the end of the table. The therapist can apply long-axis distraction and combine this with an anterior glide of the tibia. Additionally, if the therapist wants to focus on enhancing the screw home mechanism, the therapist can perform the anterior glide by biasing the medial side of the tibia, creating external

FIGURE 20-6 Joint distraction and posterior glide of the tibia on the femur can be performed simultaneously to increase knee joint flexion mobility.

rotation of the tibia on the femur (**Fig. 20-7**). In addition, a cable weight system works well for applying traction to increase knee extension ROM, and the patient can perform this intervention independently. Using a figure-of-eight strapping technique around the foot and ankle, attach the strap to the cable of a weight stack. A small bolster or towel roll should be placed under the ankle. The patient moves away from the weight stack enough to lift it, applying longitudinal traction to the leg. Additional weight can be placed on top of the knee to push it into further extension (**Fig. 20-8**). If the patient is irritable, treatment can begin in the loose packed or resting position of the knee, which is 25 degrees of flexion.[13] As the joint becomes less irritable, the knee can be positioned closer to full extension.

Self-stretching exercises can be performed to increase knee flexion ROM. A gravity-assisted supine wall slide will facilitate knee flexion. Starting with the buttocks approximately 18 inches from the wall, place the feet up on the wall. Slowly slide the affected knee down until a stretch is felt. The position can be modified by bringing the buttocks closer or further from the wall (**Fig. 20-9**). In addition, the knee can be easily stretched while sitting in a chair at work or school. Slide the foot of the involved knee as far back as possible, then slide forward in the chair, keeping the foot planted, further flexing the knee. Self stretching is also effective in prone, using a strap or, if at least 90 degrees of flexion is available, a weight can be used. If a strap is used, the patient can be instructed in the proprioceptive neuromuscular facilitation technique of hold-relax. The patient pulls the knee into flexion via a strap until a stretch

FIGURE 20-7 Knee distraction combines with an anterior glide of the tibia on the femur with an external rotation bias to encourage the screw home mechanism.

FIGURE 20-8 Knee extension with longitudinal distraction applied by a stack weight.

is felt in the quadriceps. The patient then tries to extend the knee against the resistance of the strap by firing the quadriceps. This mild, isometric contraction is held for 5 seconds, followed by a relaxation of the quadriceps with a concurrent pull of the strap into more knee flexion.[14] This stretching strategy may be


A


B

FIGURE 20-9 Wall slide for knee flexion ROM. **(A)** Starting position. **(B)** Slide the foot down the wall until a gentle stretch is felt.

beneficial when the patient demonstrates muscle guarding and it is necessary to inhibit the muscle.

Self stretching to increase knee extension proves to be more challenging. Prone hangs, where the patient lies prone with the knee at the edge of the table and the leg hanging off the end, may be beneficial. An ankle weight can be added to increase the force into extension. A similar activity can be performed in supine with a small bolster under the ankle, letting gravity and/or additional weight on the distal femur press the knee into extension.

Quadriceps setting is an excellent exercise to increase and maintain superior patellar glide (see **Self-Management 20-1**). However, if adhesions in the suprapatellar pouch limit the excursion of patellar glide, these exercises may increase patellar pain. Patellar mobilization in the direction of limitation can be performed by the therapist or by the patient in a home program (see **Self-Management 20-2**).

SELF-MANAGEMENT 20-1
Quadriceps Setting Exercise

Purpose: To strengthen quadriceps muscle, mobilize patella superiorly, stretch tight tissues behind the knee, and reeducate the quadriceps how to work

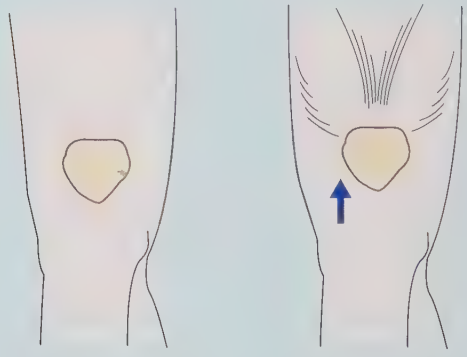
Position: Sitting with the legs straight out, toes pointed up to the ceiling; a small towel may be placed behind the knee

Movement Technique: Level 1: Tighten the quadriceps muscle on top of your thigh. You should see your kneecap move up toward your hip. Your knee may push down toward the floor, and your foot may come up off the floor. You should be unable to manually move your kneecap when doing a quadriceps set correctly. If you are having difficulty, try doing a quadriceps set on the other leg at the same time. Be sure your hip muscles stay relaxed.

Level 2: Perform the same quadriceps set in a standing position.

Dosage:

Repetitions: ______________________ times



SELF-MANAGEMENT 20-2
Patellar Mobilization Performed by the Patient

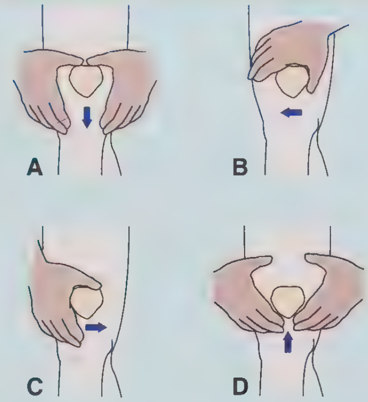
Purpose: To increase the mobility of the kneecap in all directions

Position: Sitting with the legs straight out, toes pointed up to the ceiling

Movement Technique: Using your fingers or the heel of your hand, push your kneecap (**Fig. A**) down toward your foot, (**Fig. B**) toward the outside, (**Fig. C**) toward the inside, and (**Fig. D**) up toward your hip. Hold each position for a count of five. These movements should not be painful; do not push the patella down as you move the patella.

Dosage:

Repetitions: ________________________ times



Stretching Techniques

Muscles that cross the knee joint may be identified as having decreased length. Limitations caused by muscle shortening usually are treated with stretching exercises. The quadriceps and hamstring muscles may be lengthened in several positions, but care must be taken to ensure proper positioning of the spine, pelvis, and hip. Incorrect positioning can increase the stress in these areas and decrease the effectiveness of the stretch. The quadriceps may be stretched across the knee only or, with the addition of rectus femoris stretching, across the hip (**Fig. 20-10**). The pelvis must be prevented from tilting anteriorly, increasing lumbar extension during this stretch (see **Self-Management 20-3**). Stretching the quadriceps at the knee may also be performed in prone with an abdominal support to prevent excessive lumbar extension.

The hamstrings are easily stretched in a sitting position with the knee extended and the lumbar spine held in neutral. Avoid posteriorly tilting the pelvis or flexing the lumbar spine. This exercise can be performed throughout the day at a variety of

FIGURE 20-10 Quadriceps stretching while standing. **(A)** Across the knee only. **(B)** Across the hip and knee.

SELF-MANAGEMENT 20-3

Quadriceps Stretching While Avoiding Lumbar Extension

Purpose: To increase flexibility of the quadriceps muscles

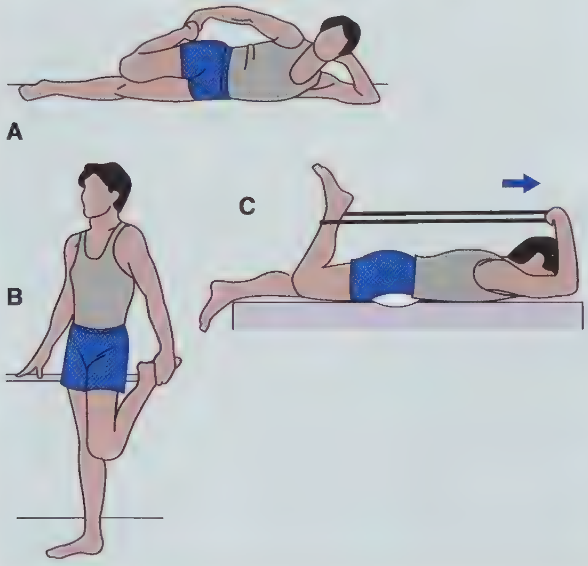
Position: This exercise can be performed in several positions. Pick a position that is comfortable or convenient for you, but avoid arching your back when stretching; tighten your abdominal muscles to keep your back steady.

1. In a sidelying position, with abdominal muscles tightened (**Fig. A**)
2. In a standing position, with some support, abdominal muscles tightened, and knees close together (**Fig. B**)
3. On your stomach, with a small pillow or towel under your hips and abdominal muscles tightened (**Fig. C**)

Movement Technique: Grasp your ankle or a strap attached to your ankle, pull it toward your buttocks until you feel a gentle stretch in the front of your thigh. Hold each stretch for 15 to 30 seconds.

Dosage:

Repetitions: ______________________ times



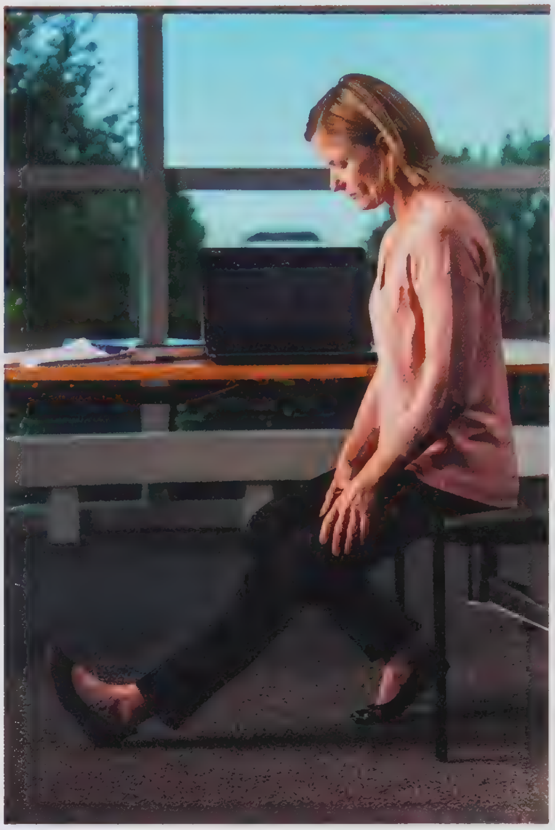


FIGURE 20-11 Hamstring stretch while seated at a workstation. Avoid lumbar flexion or a posterior pelvic tilt.

FIGURE 20-12 Lateral hip and leg stretch. Close observation prevents trunk rotation substitution for hip adduction.

workstations (**Fig. 20-11**). The medial hamstrings may be emphasized by laterally rotating the leg, and the lateral hamstrings may be emphasized by medially rotating the leg. Horizontally adducting the hip with internal rotation of the hip enhances stretching of the iliotibial band (ITB) and its associated lateral structures (**Fig. 20-12**).

In addition to the major muscle groups acting at the knee, the closed chain nature of the lower extremity necessitates assessment at adjacent joints. For example, shortening of the medial rotators of the hip or the gastroc-soleus can contribute to PFP at the knee. These tissues must be examined and treated as necessary. The reader is referred to Chapters 19 and 21 for discussions of hip and ankle flexibility.

Stability of Joint Functions

Issues with lack of stability at the joint level can result in instability. At the knee joint, stability is related to patellar instability and tibiofemoral instability. Instability is associated with clinical signs such as knee recurvatum and subtalar joint pronation. This combination may predispose individuals to PFP at the knee.

Treatment of instability at the knee joint requires postural education and retraining. This education is focused at all lower extremity joints and the lumbopelvic area. Good posture requires an integrated approach throughout the entire kinetic chain. Any further training must be superimposed on correct postural mechanics. After this posture is achieved, closed chain activities emphasizing cocontraction of lower extremity musculature enhance postural stability (**Fig. 20-13**). High-repetition, low-resistance activity is used to enhance stability (**Display 20-1**).


A B

FIGURE 20-13 Lower extremity strengthening exercise using tubing and with a focus on posture and utilization of all lower extremity musculature, including frontal plane muscles. This is a closed chain exercise on the weight-bearing side, and an open chain exercise on the non–weight-bearing side. It requires considerable balance and postural control. **(A)** Start position. **(B)** End position.

DISPLAY 20-1

Impaired Muscle Performance Associated with Neurologic Condition

Patient Case Study No. 1: The patient is a 54-year-old woman diagnosed with post anoxic Parkinsonism 10 years earlier. She has managed well until the past year when she experienced a progressive increase in her symptoms. She notes a decrease in her walking ability as well as lower extremity weakness. The patient reports three falls in the last 6 months, each time landing on her knees. This resulted in her changing her assistive device from a wide-based quad cane to a walker. However, her falls resulted in constant knee pain which compounds her gait dysfunction. Her pain is rated at 5 on a 0 to 10 scale, located in her knees and low back.

PMH: A medication error during hospitalization produced an anoxic brain injury 12 years earlier. One year after the injury, the patient began developing symptoms of Parkinsonism. The patient also has a history of chronic low back pain. The patient has a history of meniscectomy in the left knee.

Obs: The patient has resting tremor B with low amplitude; no rigidity in upper extremity (UE) with cogwheeling in right arm; finger tapping movements markedly bradykinetic; gait markedly impaired with the following characteristics: difficulty initiating gait; small shuffling steps; marked bradykinesia during attempts to turn; significant and prolonged freezing; the patient displays 1+ effusion in the left knee.

Examination

MMT: Strength testing limited by parkinsonism; quadriceps and hip flexor muscle strength grossly 4/5; hip abductor and hip extensor 4/5

ROM: Decreased mobility in hip rotation; decreased trunk ROM in all directions 25% to 30%. Knee flexion ROM from 5 to 110 degrees because of decreased use.

Flexibility: Decreased flexibility in hamstring muscles, quadriceps, and hip flexor muscles

Activity Limitations:

1. Unable to walk more than ¼ mi; requires use of walker
2. Unable to do most household chores
3. Unable to walk a full flight of stairs
4. Unable to squat ¼ normal distance
5. Unable to stand for more than 20 minutes

Participation Restrictions:

1. Unable to work outside the home or participate in usual volunteer activities.
2. Limited socialization secondary to inability to walk any distance or to stand for more than 20 minutes

Muscle Performance Impairments

Impaired muscle performance about the knee includes decreases in strength, power, and endurance of major muscle groups such as the quadriceps and hamstrings. The quadriceps are essential for controlling the motion and joint reaction forces across the knee joint, and as such, are critical for maintaining the long-term health of the joint surfaces. The muscles controlling the knee joint require, at a minimum, both strength and endurance. For many activities, power is a critical component as well. Strength is necessary to many functional activities such as rising from a chair or ascending stairs. Endurance is necessary for walking any distance, such as grocery shopping. Common non–weight-bearing exercises for increasing quadriceps and hamstring strength can be found in **Table 20-3**. These exercises isolate or bias the muscle of interest (quadriceps or hamstrings).

TABLE 20-3

Quadriceps and Hamstring Strengthening in Non–Weight-Bearing Positions

EXERCISE	GOAL	POSITION	PATIENT CUES	KEY POINTS
Quadriceps setting	1. Quadriceps strength 2. Dynamic knee control 3. Patellar mobility 4. Muscle reeducation	Any position with knee extended	"Tighten the quadriceps, push knee down, push from front of thigh, lock kneecap"	Ensure that quadriceps are firing and that the patient is not substituting with hip extension. Patella should be locked down and unable to be moved by therapist; cue patient that activation should be comfortable and does not need to be maximal
Straight-leg raise	1. Quadriceps and hip flexor strength 2. Dynamic knee control 3. Muscle reeducation 4. Core muscle strengthening	Supine with knee extended, bend opposite knee and put the foot flat on the floor to stabilize the spine	"Breathe, tighten quadriceps, lift leg to 60 degree angle, lower slowly, relax quadriceps, exhale"; if performed in standing, cue patient to "tighten knee then lift leg as in a soldier march"	Make sure patient has full control of knee via quadriceps set and maintains extension while lifting the leg (i.e., avoid a quadriceps lag); if patient is unable to perform in supine, decrease lever arm length relative to gravity; i.e., perform in standing
Short arc quad	1. Quadriceps strengthening 2. Muscle reeducation 3. Eccentrics for tendinopathies	1. Supine or long sitting with knee flexed over a bolster or short sitting with block for knee flexion 2. Standing	"Tighten quadriceps, lift foot until knee is extended, lower slowly" or "pretend you are trying to gently kick a ball"	1. If for eccentrics only, have patient lift leg to full extension with contralateral leg, then quadriceps set and lower involved leg slowly; work only in pain-free range, which may be any portion of the knee extension range of motion 2. The shorter lever arm in standing often makes this an easier exercise
Multi-angle isometrics	1. Quadriceps strengthening 2. Muscle reeducation	Short sitting with knee flexed	"Push and hold for 6 seconds, then relax." Repeat approximately every 15 degrees or in positions as dictated by injury or surgery	Can use manual resistance from another person, isometric against opposite leg, isometric against resistive bands, or with an ankle weight, using the contralateral limb to move the involved knee to the appropriate angle and hold
Knee extension: isotonic concentric and/or eccentric contractions	1. Quadriceps strengthening 2. Muscle reeducation	Short sitting	"Straighten out your knee, hold and lower slowly"	Verbal cues will change depending upon type of muscle contraction
Hamstring isometrics	1. Hamstring strengthening 2. Muscle reeducation	Short sitting, long sitting, or supine	"Tighten and hold your hamstrings as if you were trying to pull your heel back toward your buttocks"	Can be done at any angle or at multiple angles, as with multiple angle isometrics for the quadriceps
Hamstring curls	1. Hamstring strengthening 2. Muscle reeducation	Nearly any position depending upon how resistance is applied: standing, sitting, prone, supine, etc.	"Bend your knee pulling your heel toward your buttocks"	Ankle weights: best lever against gravity is in standing; in prone exercise will become gravity assisted after 90 degrees of flexion, making it an eccentric quadriceps exercise Resistive bands: any position Isokinetics: any position

Many persons also need power for performing work or recreational activities that require generating a great deal of strength in a short period of time (as in jumping activities or lifting very heavy objects). Chapter 5 describes a variety of strength, endurance, and power training activities. Plyometric exercises are commonly used to build power in the muscles surrounding the knee joint. It is critical that the individual is ready for such vigorous, impactful activities, or an overuse injury may occur. Also be sure that activities of this level are necessary and indicated for the patient. Not all patients are candidates for plyometric exercises. Common weight-bearing exercises for the lower extremity can be found in **Table 20-4**. These exercises encourage cocontraction of synergistic muscles.

Neurologic Causes

Neurologic disorders can produce impairments in muscle performance in muscles surrounding and supporting the knee joint. The most common cause is a lumbar spine injury or disease. In addition to directly affecting the quadriceps or hamstring musculature, lumbar spine pathology affecting proximal or distal musculature affects gait and other movement patterns. Altered movement patterns affect knee joint mechanics and ultimately the joint itself. Any complaints of knee joint impairments should prompt examinations of the spine and proximal and distal joints.

Other neurologic disorders, such as multiple sclerosis or Parkinson disease, profoundly affect the ability to produce torque about the knee. Each of these situations must be evaluated within the context of the disease process. Because many muscles and movement patterns are affected, a more global examination is necessary to determine the treatment strategy.

Some authorities have suggested there is a neurologic component to PFP. Studies of different quadriceps activation patterns in response to a patellar tendon tap have suggested timing differences in those with and without PFP.[15–17]

The key consideration when designing interventions for those with neurologically mediated impaired muscle performance is ensuring use of the desired muscle. Neurologic weakness produces alterations in firing patterns to accomplish movement in the most efficient manner possible. Synergists may accommodate for weakness, or biomechanical modifications may enhance the activity of other muscles as compensation for the weakness. For example, a forward lean during stair ascent allows the hip extensors to compensate for weak quadriceps (**Fig. 20-14**). Close monitoring of exercise quality is necessary to ensure training of the desired muscle (see **Building Block 20-1**).

BUILDING BLOCK 20-1

Consider the patient in Display 20-1, Case Study No. 1.

1. Given the history and examination findings, what are the likely compensations this patient is making in order to maintain her functional abilities?
2. How might your treatment program reflect these compensations? What exercises or components might be emphasized?
3. Write possible short- and long-term goals for this patient.

TABLE 20-4

Common Weight-Bearing Exercises for the Lower Extremity

EXERCISE	POSITION	PATIENT CUES	KEY POINTS
Wall sits/slides	Feet away from wall so that tibia remains vertical at lowest point of sit	"Squeeze your buttocks together and tighten your quadriceps. Slowly slide down the wall"	Core tight and stabilized; hips, knees, feet in alignment, avoiding valgus at knees. A resistive band can be placed around the distal femur with cues to the patient to keep the legs in alignment. This will increase gluteus medius activation.
Weight-bearing terminal knee extension (TKE)	Standing facing therapist or stationary object with tubing attached; tubing around posterior aspect of knee	"Keeping your foot fixed on the floor, extend your knee against the resistance of the tubing"	Tighten quadriceps with gluteals as a secondary agonist; avoid trunk flexion
Squat	Feet shoulder width apart, hips, knees, and feet in line; may modify depending upon patient situation	"Sit back like sitting on a chair; keep trunk upright, slight curve in low back; hips and knees in line"	Avoid forward lean; can be performed, full (to 90 degree flexion), partial, or mini; can be advanced by adding resistive tubing under the feet, weights in hands, or weight bar across shoulders
Split squat (stationary lunge)	Feet in stride with pelvis level	"Squat down keeping trunk vertical and avoid leaning forward"	Keep tibia in front vertical; tighten pelvis and keep neutral spine
Lunge	Normal stance with one foot stepping out	"Step forward and squat down"	Can be performed stepping forward, backward, or to side
Step-ups	Facing step	"Tighten quadriceps and hip muscles, then step up and return to the start position"	Can be performed stepping forward, backward, or to side; keep good alignment of hip, knee, and foot

FIGURE 20-14 **(A)** Ascending stairs using proper mechanics. **(B)** Ascending stairs with the hip extensor muscle substituting for a weak quadriceps muscle.

Muscular Strain and Contusions

The ability to produce torque at the knee can be affected by muscular strain injuries. The quadriceps and hamstring muscle groups are the most commonly injured, often the result of sudden decelerative forces. The quadriceps decelerates the flexing knee during the loading response of the gait cycle, and the hamstrings decelerate the forward swinging shank during the terminal swing phase. In sprinters, the hamstring works eccentrically to rapidly decelerate the tibia during the swing phase, and is at risk of injury during that phase. These eccentric muscle contractions may produce macrotraumatic or microtraumatic injury.

In addition, the quadriceps may be injured as the result of a contusion. A blow from an object such as a ball or hockey puck can produce a deep muscle contusion. With both a muscle strain and a contusion, the initial bleeding that occurs within the muscle must be controlled through relative rest, gentle stretching, and icing. The acute phase is followed by progressive mobility and strengthening. When returning the patient to function, the affected muscle should be retrained to fit the expected activity. For example, the runner with a hamstring strain injury as a result of the swing phase of gait should be trained in an open chain, decelerative function (**Fig. 20-15**). For those returning to sports, plyometric exercises

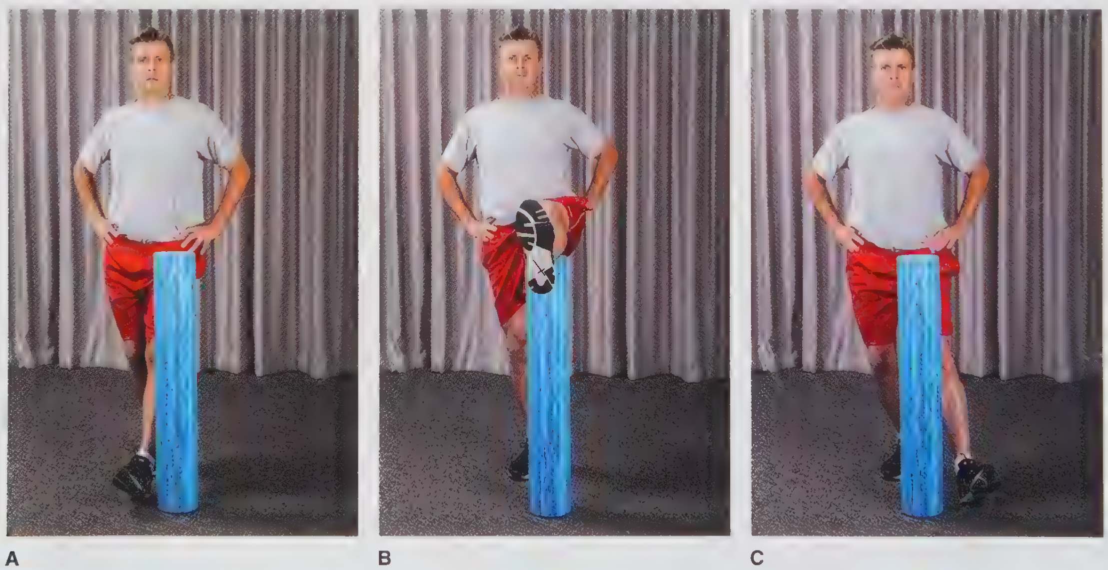


FIGURE 20-15 Open chain hamstring muscle training performing rapid concentric and eccentric hamstring contractions. **(A)** The patient starts with their involved leg on one side of the barrier (in this case, a foam roller), and rapidly lifts the leg up to the top of the barrier. **(B)** The hamstrings must act eccentrically to decelerate the leg as it reaches the top of the barrier. **(C)** The patient rapidly lowers the leg on the other side of the barrier, remaining as close as possible to the barrier. This is a concentric contraction of the hamstrings. The foot is lightly tapped on the ground, and the movement is rapidly performed back to the starting position. The movement is repeated rapidly without a pause.

are an excellent choice for retraining the lower extremity muscles. In addition, proper instruction and utilization of core muscles is a key component of lower extremity muscle rehabilitation (**Evidence and Research 20-1**).

EVIDENCE and RESEARCH 20-1

Hamstring strains are a common sports-related injury; the risk of reinjury is as high as 35%. Research has shown that athletes who completed a core stabilization and progressive agility program had a significantly lower reinjury rate than those who completed a traditional program.[18] Of the athletes who completed the agility rehabilitation program, 13% suffered a recurrent hamstring injury during the year following completion of the rehabilitation program, whereas 70% of athletes completing a traditional rehabilitation program suffered a recurrent injury. More recently, the effectiveness of two rehabilitation protocols for acute hamstring injury in Swedish elite sprinters and jumpers was compared. One protocol consisted of traditional stretching and strengthening; the other program consisted of multiplanar concentric and eccentric muscle lengthening exercises. Similar to the previous study, the authors found the athletes in the multiplanar group returned to sport sooner and suffered less reinjuries than the traditional rehabilitation group.[19]

Disuse and Deconditioning

Disuse of the knee musculature occurs primarily in the quadriceps and may occur as a result of an injury at the knee or from any other joint in the kinetic chain, including the low back. An injury at an associated joint can prevent participation in usual activities, leading to disuse of musculature throughout the kinetic chain. Disuse of the quadriceps affects the loading and midstance phases of the gait cycle, during which the quadriceps decelerate the flexing knee, followed by a change of direction and acceleration into knee extension. This quadriceps action decreases load on the joint surfaces and is critical in maintaining the health of the knee joint (**Display 20-2**).

The quadriceps muscles work to decelerate the body when descending stairs and, along with the hip musculature, to ascend stairs and arise from a sitting position. Disuse can lead to profound changes in how activities of daily living (ADLs) are performed. Failure to perform these activities efficiently and continuously places additional loads on adjacent joints. Treatment should focus on the primary cause of the disuse as well as strengthening activities for the quadriceps muscle (see **Building Block 20-2**).

BUILDING BLOCK 20-2

Consider the patient in Display 20-2, Case Study No. 2 to answer the following questions:

1. Do you think the patient's activity limitations and participation restrictions are related to underlying impairments? If so, how might you evaluate this theory?
2. If you are unable to determine the underlying cause of his functional loss, or if you believe it to be a combination of multiple factors, please suggest three exercises that might address the multifactorial nature of the problem.
3. Write some possible short- and long-term goals for this patient.

DISPLAY 20-2

Impaired Muscle Performance Due to Disuse and Deconditioning

Patient Case Study No. 2: The patient is a 78-year-old male who complains of increased leg tiredness with walking and inability to walk as far as he could previously; having difficulty getting in and out of chairs and ascending stairs; knees "feel weak." The patient has moderate to severe osteoarthritis in both knees.

PMH: Chronic asthma; stable ventricular tachycardia with right bundle branch block since 1988; renal cancer status post radical nephrectomy in 2001; left flank gunshot wound 62 years ago with continuous problems with abdominal hernias; bilateral hand tremor, left greater than right, getting worse per patient report.

Obs: The patient has bilateral Trendelenburg pattern, truncal obesity and B LE atrophy; walks with short steps, DOE after walking into treatment room from waiting area

6 Minute Walk Test: at rest: HR 49, O2 sat 96%; distance walked 885 feet without assistive device with 1 rest period; post-walk vitals: HR 116, recovers in 3 minutes; O2 sat 96%

BERG Balance Scale: 47/56 total score. Indicates a low risk of falls with standing tasks without upper extremity support. With no history of falls in the last 6 months, indicates 22% probability of future falls. Dynamic Gait Index: 21/24 total score, without an assistive device, indicates a low risk of falls with walking

MMT: normal throughout except: hip abd 4/5 B; hip ext 4-/5 B; knee extension 4/5 B

ROM: normal throughout with the exception of decreased hip external rotation

Functional Strength: requires extensive UE use for transfers in and out of chair

Activity Limitations

1. Patient unable to walk more than 400 feet without stopping to rest.
2. Unable to walk more than one flight of stairs.
3. Inability to walk on uneven ground.
4. Able to squat only ¼ of normal depth.

Participation Restrictions

1. Patient unable to maintain household and yard due to LE weakness and fatigue.
2. Unable to participate in his usual walking group, a primary social outlet for him.

THERAPEUTIC EXERCISE INTERVENTION FOR COMMON DIAGNOSES

Ligament Injuries

Anterior Cruciate Ligament

The ACL is one of the most commonly injured ligaments in the knee. The short- and long-term morbidity associated with an ACL injury with or without reconstructive surgery has made this injury the nemesis of many athletes. Fortunately, ACL injuries have become better understood and better managed, resulting in significant decreases in morbidity. The ACL tear usually occurs as the result of rapid deceleration, hyperextension, or rotational injury and does not involve contact with another individual. Injury to the ACL is frequently associated with injuries to the MCL, the medial meniscus, and the lateral meniscus. In the adolescent, the ACL may avulse from the tibial spine rather than tear in the midsubstance, and it should be surgically repaired with bone-to-bone fixation.

Although functioning independently, the ACL and PCL guide the instant center of rotation of the knee, thereby controlling joint arthrokinematics. Any alteration in normal kinematics can produce focal areas of increased articular cartilage and soft tissue loading. Sequelae such as degenerative joint disease and tendinitis must be considered when determining prognosis and treatment approach (**Evidence and Research 20-2**). Injury to the ACL can result in significant activity limitations and potential participation restrictions because of its role as the primary restraint against anterior tibial translation. Patients with ACL-deficient knees were found to have altered joint arthrokinematics in the transverse plane during walking.[20] The authors suggest that repeated rotational instability may play a role in the development of meniscus tears or osteoarthritis (OA). Rupture of the ACL results in substantially increased anterior translation of the tibia on the femur, with the maximum occurring between 15 and 45 degrees of flexion. The posterior horn of the medial meniscus provides secondary restraint against anterior tibial translation and is at risk of injury after an ACL rupture. The ACL provides stability against tibial medial and lateral rotation against varus and valgus stresses.

Because of its role in controlling the instant center of rotation, some individuals experience episodes of instability after ACL injury and subsequently fail conservative management. They may have surgery using the central one-third of the patellar tendon, the hamstring or quadriceps tendon, or an allograft.[22] Regardless of graft selection, those involved in high-demand sports may have more difficulty returning to activities without symptoms. Severe articular cartilage injury to the medial and patellofemoral compartments, as well as the presence of a lateral meniscal tear are predictive of poorer outcomes.[23] In addition, functional testing at 6 months, specifically, the single-legged hop tests, can predict the likelihood of successful outcome at 1 year after ACL reconstruction. Patients with minimal side-to-side differences on the crossover hop test at 6 months will have good knee function at 1 year if they continue with their current training regimen. Preoperative single-legged hop tests are not able to predict postoperative outcomes.[24] However, in the individual with a tear of the ACL who is managed conservatively, continued vigorous activity with an unstable knee can lead to meniscal tears, especially at the posterior horn of the medial meniscus.

Significant impairments, activity limitations, and participation restrictions occur after ACL tears, and are outlined in **Table 20-5**.

Persons may become disabled because these limitations prevent return to work, leisure activities, or basic or instrumental ADLs. This may be the beginning of a downward spiral of decreased physical activity, increased weight gain and obesity, and systemic disease, such as diabetes.

Rehabilitation issues of concern when treating the individual after ACL injury include the impairments, activity limitations, and participation restrictions identified during the evaluation. In addition, any concomitant injuries and the impairments caused by them must be identified. Associated injury to the MCL, meniscus, or articular cartilage impacts the rehabilitation program. The arthrokinematic changes and potential for secondary injury guide rehabilitation. Resistive open chain quadriceps exercises between 15 and 45 degrees are often avoided because of the increased anterior tibial translation found with this type of exercise.[25] This translation is minimized in a closed chain exercise, a good choice after ACL injury or reconstruction. Because of the difficulty in returning to deceleration and cutting maneuvers, the rehabilitation program should include these types of movements in addition to multiplanar resistive, balance, and coordination activities. Exercises may include resisted lateral movements, resisted rotational movements, and activities on unstable surfaces. Individuals returning to high-demand athletics frequently participate in a plyometric program as well (see **Building Block 20-3**).

EVIDENCE and RESEARCH 20-2

The development of knee osteoarthritis (OA) after anterior cruciate ligament (ACL) injury has been reported in the literature. A recent meta-analysis reported on the progression of OA after ACL injury, with a mean follow-up of 10 years. The authors found that 20.3% of ACL-injured knees had moderate or severe radiologic changes compared with 4.9% uninjured ACL-intact contralateral knees. Interestingly, after sustaining an ACL injury, irrespective of whether the patients were treated operatively or nonoperatively, the relative risk (RR) of developing minimal OA was 3.89, while the RR of developing moderate to severe OA was 3.84. ACL tears treated nonoperatively had a higher RR of 4.98 of developing any OA compared with those treated with reconstructive surgery, who had a RR of 3.62. The authors concluded that ACL injury predisposes knees to OA. As a clinician counseling patients who have injured their ACL, this information should be considered when educating patients. Regardless of whether the patient is managed conservatively or surgically, the patient must understand their role in the long-term management of their knee. The patient should be encouraged to maintain a healthy weight, and continue strength training, flexibility exercises, and cardiovascular exercise throughout their lifetime to promote the long-term health of their knee.[21]

TABLE 20-5

Common Impairments, Activity Limitations, and Participation Restrictions Following Knee Ligament Injuries

LIGAMENT INJURY	EXAMINATION FINDINGS	ACTIVITY LIMITATIONS	PARTICIPATION RESTRICTIONS	REHABILITATION ISSUES
ACL tear: acute	Effusion + Lachman test + Arthrometer testing Pain, instability, LOM, limited WB	Need for assistive device ADL, IADLs limited Difficulty with stairs	Inability to participate in work, sports, leisure activities requiring any physical exertion, full WB or lifting or carrying objects	Concomitant injuries (MCL, meniscus, etc.) Avoid open chain quadriceps exercises from 15 to 45 degrees due to increased anterior tibial translation. Restore full motion, prepare for surgery if planned
ACL tear: chronic (symptomatic)	Chronic low-grade effusion + Lachman's, pivot shift tests Instability + Arthrometer testing	Inability to participate in usual activities due to instability	Inability to participate in usual activities due to instability	Protection of secondary stabilizers such as medial meniscus Joint protection perspective
PCL tear	+ Posterior drawer, posterior sag tests Effusion, LOM, limited WB	Need for assistive device ADL, IADLs limited Difficulty with stairs Difficulty walking down ramps/inclines	Inability to participate in work, sports, leisure activities requiring any physical exertion, full WB, or lifting or carrying objects	Protection of structures in medial and anterior compartments History of osteoarthritis, varus alignment, patellofemoral pain, and arthrofibrosis
MCL tear	Loss of full extension, flexion + Valgus stress test at 30 degrees Tender over MCL History of valgus stress Local swelling but no joint effusion	Difficulty with frontal and transverse plane movements Difficulty walking on uneven surfaces	Inability to participate in work, sports, leisure activities requiring walking on uneven surfaces, frontal plane movements, etc.	Structural properties of ligament may lag behind clinical testing ability
LCL tear	History of varus, hyperextension stress Loss of full extension + Varus stress test at 30 degrees Tender over LCL Local swelling but no joint effusion	Minimal limitations unless combined with posterior-lateral corner injury Difficulty with frontal plane movements and may have difficulty with walking if increased varus is noted with ambulation	Limitations in high-demand physical activities, especially those involving quick direction changes	Prolonged course of ligament remodeling, as the weight-bearing phases of ambulation constantly tense the LCL

ACL, anterior cruciate ligament; WB, weight bearing; ADL, activities of daily living; IADL, instrumental activities of daily living; MCL, medial collateral ligament; PCL, posterior cruciate ligament; LOM, loss of motion.

BUILDING BLOCK 20-3

Consider a 22-year-old male recreational basketball player who tore his ACL 2.5 weeks ago and will be undergoing surgical ACL reconstruction in a few weeks if he continues to experience instability. He also has a first-degree MCL injury.

1. Describe three exercises you might use to strengthen his quadriceps in preparation for surgery. Include rationale for your choices.
2. What criteria might be used for initiating frontal or transverse plane activities? Provide examples of low-level frontal and/or transverse plane activities.

Because of the high incidence of ACL injuries in athletes, particularly female athletes, clinicians have been searching for factors predisposing females to these injuries, and for interventions to prevent their occurrence.[26–31] A number of factors have been considered, including joint laxity, postural factors (i.e., genu recurvatum, excessive foot pronation), notch width, neuromuscular coordination, hormone levels, training and conditioning, and position. Sorting out the contributions of these factors has been a challenge, particularly because there is overlap among many of the factors. Factors such as increased knee laxity, increased dynamic knee valgus, and high abduction loads during landing from a jump seem to be predictive of future ACL injuries.[32]

However, a large body of evidence is accumulating supporting the success of neuromuscular training (NMT) programs on the biomechanics of jumping, neuromuscular performance and on the subsequent incidence of ACL injuries.[27,33–38] These studies have found that NMT can improve neuromuscular performance by improving the biomechanics of landing from a jump and by decreasing knee adduction moments and peak landing forces.[39] More importantly, NMT programs have significantly reduced the incidence of ACL injuries[26,28,29,31–34,36,37,39,40] (**Evidence and Research 20-3**).The NMT programs should include education on the proper mechanics of landing, jumping, acceleration, deceleration, and changing direction (see **Patient-Related Instruction 20-1**). It is difficult to determine which component resulted in the decreased incidence of injury: the education, strength increases, neuromuscular coordination improvement, or changes in biomechanics/posture. However, the combination of these factors in the NMT program has been effective in decreasing ACL injuries in female athletes (see **Display 20-3**).[26,28,29,31–34,36,37,39,40]

EVIDENCE and RESEARCH 20-3

In a meta-analysis by Sugimoto et al,[41] the authors found a greater knee injury reduction in female athletes who participated in neuromuscular training (NMT) as compared to females who did not participate in NMT. In fact, the NMT reduced the risk of sustaining an ACL tear by 46%. In a subsequent meta-analysis, the authors determined the potential dosage effects of NMT for ACL injury reduction in female athletes. The authors found that NMT of long duration (>20 minutes) was more effective than short-duration (<20 minutes) NMT. NMT performed two times per week or greater indicated greater ACL injury reduction compared to NMT performed one time per week. The authors concluded that the higher NMT volume, the greater prophylactic effectiveness of the NMT program and increased benefit in ACL injury reduction among female athletes.[42]

For individuals involved in sports requiring deceleration, cutting, jumping, and pivoting, ACL reconstruction may be necessary to allow return to the previous competitive level. A new ligament is comprised of either the middle third of the patellar tendon or quadriceps tendon or a looped hamstring tendon. An allograft may also be used. The ligament is placed within the knee arthroscopically and is fixated in bony tunnels. A sample protocol for rehabilitation following ACL reconstruction can be found in **Table 20-6**. A similar program can be followed for nonoperative treatment of ACL injuries, keeping in mind any complications of continued instability.

Patient-Related Instruction 20-1

Proper Landing, Cutting, and Direction Change Techniques for Prevention of ACL Injuries

- Land softly on both feet with weight distributed equally over both lower extremities
- Land on the forefoot and roll to the rearfoot
- Keep knees over toes, avoiding letting the knees roll in
- Activate and tighten hip and thigh muscles while landing to decelerate the landing
- Take several small steps to slow down and change direction, rather than a plant and twist

DISPLAY 20-3

Neuromuscular Training for Injury Prevention

- Warm-up: any large muscle group activity
  - Jogging
  - Bicycling
  - Calisthenics
- Flexibility: stretching hip and leg muscle groups via static and dynamic stretching
  - Quadriceps and hamstring muscles
  - Hip flexors, extensors, rotators, abductors, adductors
  - Calf musculature
  - Low back
- Dynamic balance: teaching proper landing techniques
  - Land on ball of foot
  - Hop with knees bent
  - Land with knees in flexion
  - Knees under hips avoiding hip internal rotation and knee adduction
- Dynamic balance: impact activities
  - Front-back and side-to-side hopping
  - Hop and stick the landing
  - Cone hopping: with and without turns
  - Agility drills including direction changes
  - Vertical box hops: single and multiple, with and without turns

Posterior Cruciate Ligament

PCL injuries represent an estimated 1% to 30% of all knee ligament injuries.[43] Most injuries occur as the result of a trauma such as a motor vehicle accident, with fewer PCL injuries occurring in sports.[43] The mechanism producing a PCL injury is most often a blow to the anterior aspect of the tibia, forcing it posteriorly. Less commonly, the PCL is injured as a result of hyperflexion, hyperextension, or a varus or valgus injury. In the case of hyperextension, the ACL is usually injured first. In the varus or valgus injury, the respective collateral ligament is injured, and in some cases, the ACL is injured before the PCL injury.

The PCL is the primary restraint to posterior translation of the tibia on the femur, providing approximately 95% of the resistance against posterotibial translation.[44] A tear of the PCL results in significant increases in posterior tibial translation, with the greatest occurring between 70 and 90 degrees.[43,44] The PCL also resists varus or valgus translation and is a secondary restraint to lateral tibial rotation.[43,44] Along with the ACL, the PCL helps control the instant center of rotation at the knee and joint arthrokinematics. The alteration in joint arthrokinematics after PCL rupture can result in significant problems. Articular cartilage contact pressures in the medial and anterior compartments are increased after PCL rupture, with peak medial pressures at 60 degrees and peak anterior compartment pressures at 90 degrees of flexion.[43] The individual with a PCL rupture generally complains of pain related to these changes, as well as PFP, rather than frank instability.

TABLE 20-6

Rehabilitation Following an ACL Reconstruction

	PHASE 1	PHASE 2	PHASE 3	PHASE 4
Goals	1. Full active knee extension comparable to contralateral knee and flexion to 125 degrees 2. No swelling 3. Knee control weight-bearing and non–weight-bearing 4. Normalize gait	1. Restore posture and control with basic movements 2. Increased lower extremity and core strength 3. Increased static and dynamic balance 4. ROM equal to contralateral leg	1. Performance of multi-plane strengthening and functional exercises 2. Effective eccentric control for impact loading 3. Functional dynamic mobility	1. Single-leg control during impact 2. Effective posture and eccentric control with direction change 3. Efficient performance of skill activities
ROM and mobility	Knee extension with bolster under ankle Prone hang Supine wall slides Heel slides Seated knee flexion Patellar mobilization	Continue phase 1 until goal is achieved Stationary bike with seat lowered for gentle stretch Prone knee flexion Stretching for other lower extremity muscle groups	Continue previous exercises as needed Add dynamic warm-up and dynamic mobility activities (i.e., skipping all directions, carioca, shuffles, etc.)	Continue dynamic warm-up
Muscle performance and proprioception	Quadricep and hamstring sets Standing leg lifts Weight shifts Double leg minisquats Toe raises Core strength (abdominals, crunches, etc.)	Squats Step backs down off a step Stationary lunge Single-leg balance with arm and weight shift perturbation Core strength (advanced crunches and bridges)	Squat with knee lift Squat and reach Retro step-up Lunge walk (forward, back, side, diagonal) Takeoff and landing drills Advanced balance exercises Core strength (continue to advance)	Landing control: Jump rotations Fast feet and lunge Multi-plane leap and land Stop and go Hopping Cutting and pivoting drills Lunge with resistance Advanced core activities
Gait and cardiovascular	Diagonal weight shifts Backward stepping Step over 4 in obstacle	High knee walking all directions Hurdler walk with hip circles Diagonal stride and hold forward and back	Progress to appropriate cardiovascular activity	Progress to sport or activity-specific cardiovascular training

ACL, anterior cruciate ligament; ROM, range of motion.

The natural history of the PCL-deficient knee is difficult to assess because of the heterogeneity of most populations studied. Many patients remain asymptomatic and are able to return to their preinjury activity levels, but others develop osteoarthritic changes in the medial and anterior compartments.[43] The clinician must consider the possibility of these changes and modify the rehabilitation program appropriately. Some persons with multiple ligament or soft tissue injuries undergo reconstruction of the PCL using static restraints such as the central one-third of the patellar tendon, Achilles tendon, or allograft.[45]

The extent of impairments, activity limitations, and participation restrictions after PCL rupture depends on associated injuries (see Table 20-5). When patients are seen for chronic activity limitations because of PCL deficiency, the subjective complaints usually are related to medial and anterior compartment pain, PFP and difficulty ambulating down a decline or stairs. The literature suggests that the compensatory muscle activity seen with ambulation in the PCL-deficient knee includes increased quadriceps and gastrocnemius activation, with decreased hamstring activity, which results in decreased posterior movement of the tibia on the femur.[43]

The issues affecting the rehabilitation approach are related to the potential medial and anterior compartment changes. Any additional ligament injuries that could further alter arthrokinematics or medial meniscal damage that could modify articular cartilage pressures have the potential to exacerbate compartmental changes. Comorbidities such as underlying osteoarthritic changes, a varus alignment, or history of PFP negatively alter the prognosis. These issues guide the framework from which the rehabilitation program is designed. As in treating the ACL-deficient knee, open chain resistive exercise (knee flexion in this case) can increase posterior tibial translation. As such, closed chain activities are an important therapeutic exercise mode. A sample program following PCL reconstruction can be found on the website.

Medial Collateral Ligament

The MCL consists of the tibial collateral ligament and the middle one-third of the medial capsule (deep portion), which is subdivided into a thin anterior third, a strong middle third, and a moderately strong posterior third.[46] The incidence of MCL injuries is significantly higher than that of LCL injuries, and the MCL has been reported to be the most frequently injured ligament of the knee.[46] Damage to the MCL occurs less frequently at the femoral insertion compared with the tibial insertion because of differences in the insertion site structures. The MCL is usually torn as a result of a valgus stress caused by force to the lateral side of the knee or by forced abduction of the tibia, as occurs when catching the inside edge of a ski. Associated injuries may include the ACL and medial meniscus. In the adolescent, injury to the femoral or tibial growth plate often precedes injury to the MCL and should be considered in the differential diagnosis.

The MCL is the primary restraint against valgus loads, and it resists tibial medial rotation. In the ACL-deficient knee, however, the superficial MCL also plays a role in controlling anterior tibial translation. Injury to the superficial MCL significantly increases anterior tibial translation at 90 degrees of flexion.[47] But, unlike the cruciate ligaments, the MCL has the capacity for repair without surgical intervention. Most MCL injuries heal well without any long-term damage to the knee, despite some residual valgus laxity. For this reason, most MCL injuries are usually treated conservatively.[46,47] In the individual with a combined MCL and ACL injury, a short period of recovery usually is allowed, followed by reconstruction of the ACL. Injuries to the MCL in the presence of ACL ruptures do not heal as well as isolated MCL sprains and may require additional time to heal.[46] Certain situations exist which warrant surgical intervention of the MCL. If the superficial MCL is torn from the tibial insertion and it is displaced outside the pes anserinus tendons, the ligament is unable to reattach to its insertion on the tibia, and surgical stabilization is indicated. Surgical reattachment of bony avulsions has an excellent prognosis.[47]

The impairments, activity limitations, and participation restrictions seen after acute MCL sprains are similar to those of cruciate ligament sprains (see Table 20-5). The prognosis after isolated MCL sprain is generally good because of the ligament's ability to heal well. Some individuals may experience difficulties with lateral and rotational movements or with activities on uneven surfaces. Persons returning to physical work or higher level recreational activities are most at risk of limitations in these areas. Although the clinical examination may be benign after 6 to 8 weeks of rehabilitation, the lengthy ligament remodeling process may limit the MCL's tolerance for high-demand loading.

The most significant rehabilitation issues in the isolated MCL injury are the fact that the remodeling process lags behind the clinical examination findings. In addition, the implementation of frontal and transverse plane rehabilitation techniques is critical. Traditional clinical examination procedures are not sensitive enough to determine readiness to return to high-demand activities. Frequently, the individual has full ROM, symmetric strength, minimal or no valgus laxity, no effusion, and no tenderness to palpation a few weeks after injury with proper rehabilitation. However, the MCL is not stressed much in ordinary daily activities or even in sagittal plane activities such as straight-ahead running. The ligament must be loaded and trained just like muscle tissue to ensure adequate remodeling for high-demand activities. Loading in the frontal and transverse planes must occur to strengthen the ligament and its bony attachments and to ensure a safe return to physical activities (**Figs. 20-16** and **20-17**). A sample program for rehabilitation following a grade II MCL injury can be found on the website (see **Building Block 20-4**).

FIGURE 20-16 Side stepping in the pool is an early lateral movement activity.

FIGURE 20-17 More challenging frontal plane activity includes weight shifting on rocker boards while using a medicine ball to increase the movement of the center of mass.

BUILDING BLOCK 20-4

Consider a 35-year-old patient with a second-degree MCL injury who desires to return to recreational ice hockey.

1. Describe three frontal plane and three transverse plane exercises that you would use once the patient tolerated exercise in this plane (early phase).
2. Progress these same exercises to an advanced level to prepare this patient to return to activity.

Lateral Collateral Ligament

Injuries to the LCL are much less common than injuries to the MCL, and like MCL injuries, they heal well and without significant long-term disability. The LCL is the primary restraint to varus stress, and because of its location posterior to the axis of rotation, it also resists hyperextension, especially in the presence of a varus stress.[48] LCL injuries usually result from hyperextension varus forces, with or without contact with another individual. Complete tears occur in the ligament midsubstance or at the fibular insertion. Associated injuries may occur to the posterolateral structures, including the joint capsule, arcuate ligament, biceps femoris or popliteus tendons, or cruciate ligaments.[48] In the adolescent, injury to the growth plate usually precedes ligament injury and should be considered in the differential diagnosis.

The natural history of the LCL injury rarely includes long-term disability because of its healing potential. Surgical repair of the isolated LCL is rarely performed. The most common indication for surgical treatment of the LCL is when the injury is seen concurrently with injury to the posterolateral corner of the knee. Patients with grade 3 laxity, defined as greater than 10 mm of varus laxity or greater than a 10 degree increase in external rotation at 30 degrees of knee flexion, should be treated operatively.[49] In addition, like the MCL, a bony avulsion of the LCL attachment should be managed surgically.

The activity limitations and participation restrictions seen after a LCL injury are fewer than those seen with an MCL injury. Most individuals are minimally limited after this injury, except in the case of a third-degree tear or concomitant ligament or capsular injury (see Table 20-5). In addition, patients who ambulate with a varus thrust, which would create a tensile load to the ligament, may have their rehabilitation decelerated initially.[50]

Rehabilitation issues are similar to those for MCL injuries. The prolonged course of ligament remodeling must be considered, along with the importance of retraining the individual and loading the ligament in the frontal, sagittal, and transverse planes.

Treatment of Ligament Injuries

Interventions should be aimed at achieving specific goals related to impairments, activity limitations, and participation restrictions. Impairments should be addressed if they are associated with an activity limitation or participation restriction or if continued impairment could lead to participation restriction in the future. Pain and effusion can be managed in the short term with physical agents, mechanical and electrotherapeutic modalities, and gentle therapeutic exercise. Cold packs, ice massage, compression therapies, and electrical stimulation are commonly used to minimize pain and effusion. Therapeutic exercise such as active and passive ROM activities within a comfortable range can provide lubrication to joint surfaces and can assist in resorption of excessive joint fluid. The patient should receive instruction in the application of these procedures at home and receive additional guidance regarding activity modification to minimize pain and effusion.

Traditional physiologic stretching and osteokinematic active and passive ROM activities facilitate restoration of preinjury joint motion. Occasionally, joint mobilization techniques may be necessary, although ligamentous injury, when managed conservatively, generally results in too much mobility rather than too little. However, lengthy immobilization or muscle inhibition of the quadriceps may result in a loss of knee extension ROM. Neuromuscular reeducation exercises such as quadriceps setting, hamstring setting, and other muscle activation techniques can restore the ability to fire muscles, which is a prerequisite for normalization of movement patterns. The home program should include exercises to facilitate ROM increases and neuromuscular reeducation exercises to advance gains made in the clinic (**Fig. 20-18**) (see **Self-Management 20-4**).

FIGURE 20-18 Active assistive ROM for knee flexion using a towel. As knee flexion increases, the hamstrings will become shortened generating less force. At this point, the patient can use the towel to pull further into knee flexion.

SELF-MANAGEMENT 20-4
Performing Flexion and Extension Mobility Exercises During the Day

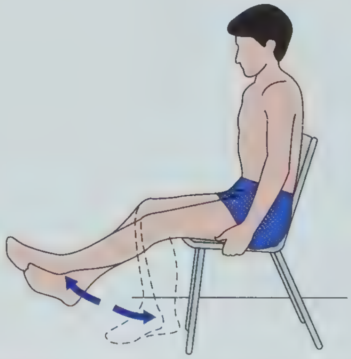
Purpose: To increase mobility in the knee

Position: Sitting or in another position of comfort

Movement Technique: Actively extend the leg as far as possible and then bend it back as far as possible. You may use your other leg to help lift it the last little bit or to push it back a little farther. If lifting your leg is a challenge, you can place your foot on a towel on a floor with a smooth surface and slide your foot along the floor to increase knee flexion and extension.

Dosage:

Repetitions: ______________________ times



The pool is an excellent environment for performing mobility, normalizing gait, and initiating balance and gentle strengthening exercises. The water's buoyancy minimizes weight-bearing while the hydrostatic pressure controls effusion. Walking, physiologic stretching, leg kicks, toe raises, single-leg balance, and squats can be easily accomplished in the pool (**Fig. 20-19**). If the patient recently had surgery, cover the surgical incision with a bioclusive dressing and obtain medical clearance from the operating physician.

As the patient progresses out of the acute phase, more vigorous exercises may be initiated. Continuation of ambulation training and progression to ambulation without an assistive device are primary considerations for the return to normal activities. Land-based, closed chain exercises such as wall slides, minisquats, step-ups, stair stepping, and leg presses can facilitate functional activities such as stair-climbing, rising from a chair, and getting in and out of a car (**Fig. 20-20**). Balance and coordination exercises such as step-ups, wobble board, single-leg pulleys, and toe raises without support can retrain balance reactions. Any motion loss, impaired muscle performance, pain, or effusion that is related to activity limitations should be addressed concurrently. Traditional progressive resistive exercises can be incorporated, keeping in mind the arthrokinematic issues. Weight machines, free weights, isokinetic devices, pulleys, and body weight are means to accomplish increases in the ability to produce torque (see **Building Block 20-5**). The clinician must be aware of the loads placed on the knee ligaments with various exercises and use caution to avoid overstressing a healing ligament. For example, resistive hip adduction using a resistive band around the ankle places a significant load on the MCL, which may be fine in the late stages but too much in the early stages (**Fig. 20-21**). At home, the use of body weight as resistance in the form of wall slides, squats, lunges, and step-ups is convenient and cost effective (see **Patient-Related Instruction 20-2**).

FIGURE 20-19 Single-leg minisquats in the pool are performed to increase mobility and strength.

FIGURE 20-20 Single-leg wall slides.

BUILDING BLOCK 20-5

The patient is a 36-year-old female UPS driver with a second-degree L knee MCL injury that occurred 3 weeks ago when she caught her foot on the step of her truck while getting out to do a delivery. She has recovered full ROM and has functional quadriceps strength for light activities. She is returning to work next week doing deliveries of packages <20 lb. Truck requires ability to use a clutch.

1. Design three exercises to help her with the functional demands of her job.
2. In trying to get the exercise dose correct, consider that the exercises may have been too easy or too hard. For each exercise, besides increasing or decreasing the repetitions, describe a way to make the exercise easier and a way to make it harder.

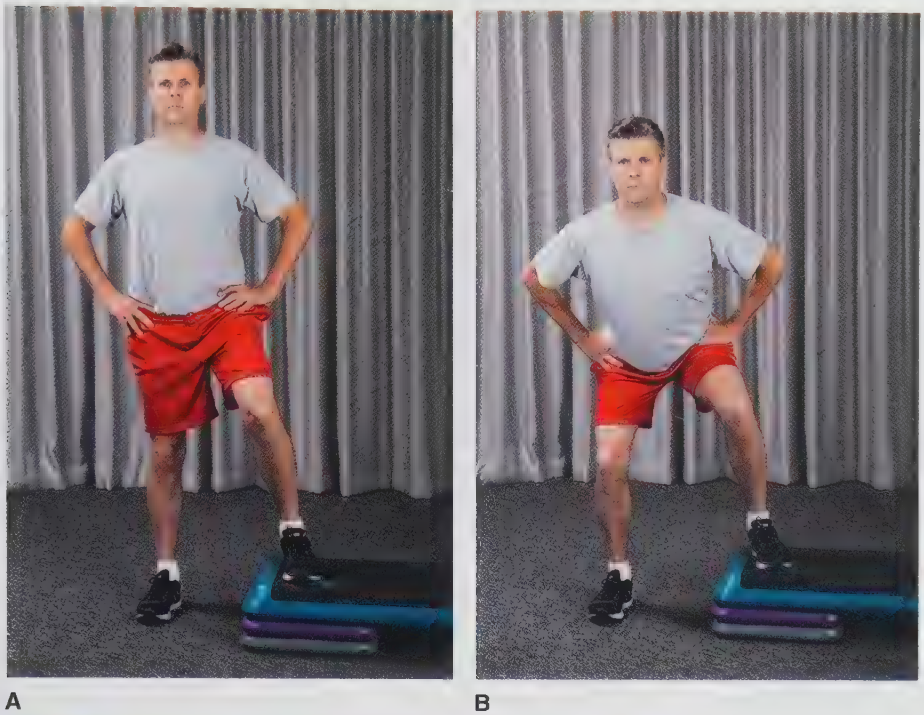


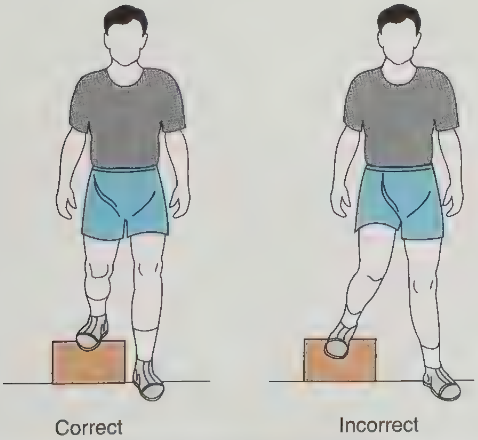
FIGURE 20-21 A transition between double-leg and single-leg strengthening is a modified squat with one leg on a step. The patient will have some weight in the leg on the step, but most of the weight is in the leg on the ground. The higher the step, the more weight that is shifted to the leg on the ground. **(A)** Start position. **(B)** End position.

Patient-Related Instruction 20-2

Performing Weight-Bearing Exercises

When performing exercises in weight-bearing, the following important points should be reviewed:

1. Place only the amount of weight on your leg as prescribed by your clinician. This may be only part of your body weight.
2. Be sure that your knee is at the correct angle, as directed by your clinician.
3. Avoid locking or hyperextending your knee (bending it backward).
4. Keep your knee in line with your toes and your hips. Avoid letting your knees "roll in" (i.e., being "knock-kneed").
5. Squeeze your buttock muscles together, and use the muscles in the front of your thigh, as directed by your clinician.
6. Hold each exercise for the amount of time specified by your clinician. Be sure to breathe in and out slowly while performing each exercise.



The final phase of rehabilitation helps return the patient to their premorbid level of function in ADLs, work, or recreation. Because the activity level and functional goals are different for each patient, the rehabilitation program must be tailored to individual needs. For the individual returning to sedentary work and recreational walking, discharge to an independent program may be considered after motion, strength, endurance, balance, and impairments and activity limitations have been normalized. The patient should demonstrate a thorough understanding of the home management of impairments, including inflammation, pain, ROM, and strength. For individuals returning to a higher level of physical functioning, such as physical labor or sports activities, reconditioning to that level is necessary. This may require advanced work-related activities such as lifting, pushing, pulling, and carrying objects over uneven surfaces. A functional capacity evaluation may be performed to determine restrictions or precautions affecting a return to work.

Running, cutting, jumping, and sports skill activities can help ensure a safe return to sporting activities (**Fig. 20-22**). A running program or sport-specific drills may be used to test readiness to return to play. Completion of an appropriate functional progression can ensure a safe return to sports. Although this program does not need to be under the direct supervision of the physical therapist, it should be constructed with and guided by the clinician in conjunction with the patient. Any deficits in movement patterns should have been corrected by the clinician in the earlier therapy stages and should not be an issue at the functional progression stage.

Fractures

Knee fractures can involve the patella, distal femur, or proximal tibia. These fractures generally occur as a result of trauma such as a fall or motor vehicle accident but can also result from osteoporosis.

FIGURE 20-22 **(A)** Lateral crossover running in the late stage of rehabilitation. **(B)** Slide board lateral movements.

The rehabilitation issues associated with knee fractures include the cumulative effects of the original trauma, surgical procedures, and immobilization. A trauma significant enough to fracture a bone also causes substantial soft tissue damage, which is frequently overlooked. Damage to articular cartilage and fractures extending through the articular cartilage to the joint surface (intraarticular fractures) have the potential to affect the long-term health of the joint, and these issues should be considered in the rehabilitation program.

Patellar Fractures

Patellar fractures account for approximately 1% of all skeletal injuries and occur most frequently in persons between the ages of 40 and 50 years.[51] A direct blow to the anterior knee, as seen with a fall or a motor vehicle accident, typically results in a comminuted fracture.[52] Fortunately, the majority of these fractures are nondisplaced, but bear in mind that significant damage to the articular cartilage can occur. More commonly, patellar fractures occur indirectly via a forceful contraction of the extensor mechanism, which ultimately exceeds the strength of the bone.[52] Indirect fractures typically result in a transverse fracture or an avulsion of the inferior pole of the patella. The degree of knee flexion, the patient's age, the overall health of the bone, and the velocity of injury can affect the type and location of the patellar fracture.[52]

The goal of patellar fracture management is to restore the extensor mechanism and optimize articular cartilage congruency at the patellofemoral joint. Conservative treatment, consisting of immobilization and rehabilitation, may be indicated. However, surgical intervention, such as open reduction with internal fixation (ORIF) utilizing Kirschner wires (K-wires) or a partial patellectomy may be warranted to maximize articular cartilage congruency and to restore the extensor mechanism. Because of the morbidity associated with immobilization, ORIF is often the treatment of choice for medically sound candidates. Because of the superficial nature of the patella, the hardware is frequently removed after healing is ensured. Occasionally, a small fragment or fragments are removed rather than fixated (i.e., partial patellectomy). A total patellectomy is only indicated in extremely rare cases, as complete removal of the patella results in a 50% reduction in quadriceps strength.[52] The prognosis after patellar fracture is good if PFP, muscular atrophy, and loss of motion (LOM) are addressed. These impairments occur regardless of treatment method. With conservative management, the clinician must also be aware of the effects of immobilization on the soft tissues.

Distal Femur Fractures

Distal femur fractures are rare and severe. In the younger population, they are the result of a high energy trauma, whereas in the elderly, they can result from a low-energy movement, such as a twisting injury.[53] Associated fractures are common and include the patella, tibial plateau, foot, ankle, and hip. Distal femur fractures can be classified as pure supracondylar, supracondylar and intercondylar, or monocondylar, each with subclassifications. Fractures through the growth plate occur in children and adolescents and are challenging to treat, with complications that require a secondary surgery 40% to 60% of the time.[54] Poor outcomes have been associated with Salter–Harris classification III and IV in 29% to 32% of cases.[54]

Distal femur fractures can be managed conservatively or surgically. Nondisplaced, minimally displaced, stable, or impacted fractures or fractures in individuals who are not surgical candidates may be treated with immobilization. Because of the morbidity associated with lengthy immobilization, and because over 50% of fractures are intraarticular, surgical ORIF is often the treatment of choice.[53] Reduction of distal femur fractures requires restoration of the anatomic alignment and mechanical axes in the sagittal, frontal, and transverse planes. The specific surgical procedure and fixation choice depend on factors such as the type and location of fracture, quality of bone, associated injuries, and the patient's age and lifestyle. Complications after ORIF include deep vein thrombosis, infection, and delayed union or nonunion.[53]

Tibial Plateau Fractures

Tibial plateau fractures occur almost exclusively as the result of trauma such as motor vehicle accidents, pedestrians hit by cars, accidental falls, or twists or direct blows to the knee. Fractures are typically produced by a combination of valgus stress and axial compression while the knee is flexed and result in lateral plateau, medial plateau, or bicondylar fractures.[55] Although numerous classification systems for tibial plateau fractures exist (Schatzker, AO, Duparc), the general classification is based upon morphology[56]:

1. Split fracture, in which the margin of the tibial plateau is separated from the rest of the plateau
2. Compression fracture, in which the subchondral bone is crushed but the margins are spared
3. Combination split-compression fracture

Compression fractures are the most difficult to diagnose, because the depressed fragments are often missed on standard radiographs. As such, a CT scan is commonly performed on patients with a tibial plateau fracture.[56] Compression fractures are also the most difficult to treat, because adequate reduction requires the elevation and stabilization of depressed fragments. Compression fractures are seen most commonly after falls from heights and in elderly individuals with osteoporosis.

Treatment of tibial plateau fractures depends on the location and type of fracture. Compression fractures with depressed fragments require surgical elevation and stabilization of the fragments. These fragments are supported with bone grafts. Split fractures are stabilized with screws, wires, or plates. Conservative management with or without traction and immobilization is an option that must be considered in light of the deleterious effects of immobilization. Postoperative or post immobilization rehabilitation depends on the numerous factors outlined previously.

Treatment of Fractures

Treatment programs for individuals with fractures at the knee may begin once the fracture site is stable, either through surgical methods or via immobilization. Persons with fractures surgically fixated generally begin mobility and strengthening exercises soon after the operation (see **Self-Managements 20-5** and **20-6**). Active and passive ROM for flexion and extension and functional mobility exercises for the entire kinetic chain are initiated early. Quadriceps setting and hamstring setting exercises are started early to retrain these muscle groups. When permitted, closed chain weight-bearing exercises should be initiated, even if only partially weight-bearing (see **Patient-Related Instruction 20-3**). This will be determined by the physician based upon the fracture site and healing, as well as by the patient's ability to control the knee. Before beginning any weight-bearing exercise, the patient should demonstrate a good quadriceps set and the ability to dynamically control the knee. These activities can enhance articular cartilage nutrition throughout the kinetic chain and provide a stimulus for muscle activation. An exercise bicycle with little or no resistance can enhance nutrition and muscle activity in the area while improving mobility.

Pool exercise is excellent for the individual with a knee fracture. Weight-bearing may be limited while muscle activation and mobility exercises are performed with assistance from buoyancy. Passive motion assisted by buoyancy or active motion can improve ROM about the knee (**Fig. 20-23**). Gait can be normalized with or without railing assistance.

SELF-MANAGEMENT 20-5
Prone Hang for Knee Extension

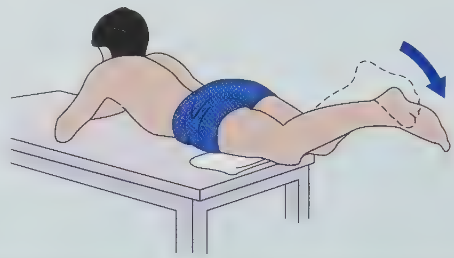
Purpose: To increase mobility in knee extension and stretch tight tissues behind the knee

Position: On your stomach, with your knee just over the edge of the table; a towel under your thigh may be more comfortable.

Movement Technique: Let your knee straighten by hanging over the table's edge. Your clinician may want you to put weight on your ankle or to use your other leg to increase the stretch. Hold for 1 to 2 minutes.

Dosage:

Repetitions: ____________________ times



SELF-MANAGEMENT 20-6
Straight-Leg Raises

Purpose: To increase the strength of the quadriceps and hip flexor muscles and to improve control of the knee

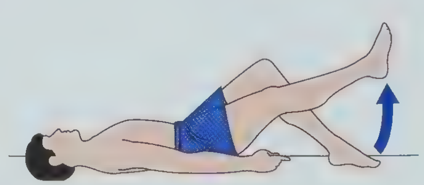
Position: Lying on your back, with your opposite knee bent and foot flat on the floor; stomach muscles are tightened.

Movement Technique: This is a four-step process.

1. Perform a quadriceps set, tightening the quadriceps muscles.
2. Slowly raise the leg until it is even with the opposite thigh.
3. Slowly lower the leg back to the floor.
4. Relax the quadriceps set. Be sure to relax the quadriceps muscle between each repetition.

Dosage:

Repetitions: ____________________ times



Patient-Related Instruction 20-3

Walking with Crutches

When walking with crutches and some of your weight on the involved lower extremity, several guidelines should be followed:

1. Make sure your weight is on your hands, not under your arms. Your arms should be slightly bent when your crutches fit properly.
2. When walking, place your crutches out first, followed by your involved leg and then your uninvolved leg.
3. Place your involved heel down first, let your knee bend slightly, and allow your foot to roll toward your toes as you begin to bring your uninvolved leg forward.
4. As you bring your uninvolved foot through, bend your involved knee, and pick it up behind you. Straighten the involved knee as you bring it past your crutches to place it on the floor in front of you. Your knee should be straight just before your heel contacts the ground.
5. When using a single crutch, be sure to use it on the side *opposite* your injured knee.

Check with your clinician to ensure that your gait with crutches is correct.

FIGURE 20-23 Buoyancy-assisted knee flexion using a buoyant strap. The return motion (to extension) is buoyancy resisted, eliciting a concentric quadriceps muscle contraction.

Meniscal Injuries

Although the menisci were once thought to be useless remains of leg muscles, their importance is now well understood.[57] The meniscus absorb shock during weight-bearing activities, assist in joint lubrication, and restrain anteroposterior tibial translation in ACL-deficient knees.[57] Because of its many roles, the importance of the meniscus to the long-term health of the knee has resulted in efforts to preserve the meniscus following injury. The menisci are composed primarily of type I collagen and are more fibrous than articular cartilage. The herringbone arrangement on the surface allows for shear forces that occur with normal joint arthrokinematics; the deeper major fiber orientation is circumferential. The menisci receive their blood supply from the medial and lateral superior and inferior geniculate arteries and have variable vascularity. The vascular supply penetrates 10% to 30% of the width of the medial meniscus and 10% to 25% of the width of the lateral meniscus. The peripheral one-third is often called the red zone, the middle one-third is the red-white zone, and the central one-third is the white (avascular) zone. The meniscus receives its nutrition by diffusion, and it has a low metabolic rate and a low reparative response. Repair of the meniscus considers this low reparative response and often uses the peripheral blood supply to assist the healing process.[57]

The menisci have many functions, underscoring the importance of maintaining their structure. In addition to enhancing joint congruity and stability, the menisci also function to transmit load across the knee joint, with approximately 40% to 50% of the compressive load transmitted through the meniscus in full extension and 85% at 90 degrees of flexion.[58] Partial meniscectomy with a 10% decrease in contact area increases peak local stresses by 65%, whereas total meniscectomy decreases the contact area by 75% and increases peak local stresses by 235%.[59] Total meniscectomy is no longer routinely performed because of the Fairbanks changes seen postoperatively. These changes include marginal femoral osteophyte ridging, flattening of the medial femoral condyle, and narrowing of the joint space.[60] In addition, the menisci work as shock absorbers, although the subchondral bone is the main static shock absorber at the knee. Some of the most important functions of the menisci are joint lubrication and articular cartilage nutrition. The biphasic properties of the meniscus assist in providing a lubricant film across the joint surface with cyclical loading and unloading of the knee.[61]

The meniscus is most often injured traumatically, although degenerative tears are also common. Traumatic tears typically require more energy and usually occur in the younger, active population or in individuals who sustain trauma via a fall or motor vehicle accident. In contrast, degenerative tears occur with advancing age, are often complex tears, and can be sustained through low-energy movements. For example, a degenerative tear can be precipitated by a stress as simple as turning to walk a different direction.

Treatment

Degenerative tears associated with articular cartilage lesions often require surgery to remove loose fragments and to stimulate a healing response in the articular cartilage. Acute traumatic tears may heal without intervention if the tear is in the periphery, where a blood supply exists, and if the tear is longitudinal. Some tears may not heal but remain asymptomatic.[62] Tears producing mechanical symptoms such as catching, locking, and effusion are treated by partial meniscectomy or by meniscal repair. The treatment of choice depends on the type and location of the tear, on the associated injuries, and the overall health of the knee joint. For example, a meniscal repair in the posterior horn of the medial meniscus in an ACL-deficient knee does not heal well. However, if the ACL is reconstructed simultaneously, the meniscal repair has an opportunity to heal if provided a blood supply. In contrast, complex degenerative tears are nearly impossible to repair and probably will fail in the presence of articular cartilage degeneration.

The management of patients after a partial meniscectomy must consider the changes in load distribution and increases in peak local stresses associated with this procedure. The knee has been distributing and dispersing loads during activities based on the patient's anatomy for many years. Suddenly, the load distribution is changed, and other structures must shoulder the burden of the load previously supported by the intact meniscus. The joint's ability to adapt to this change in loading pattern depends on numerous factors, including lower extremity alignment, quadriceps function, comorbidities, and the response to the stresses placed on it (i.e., Wolff's law). The body must have time to adapt to the changing loading pattern, and although some individuals adapt quickly, others may develop symptoms of overload such as inflammation, effusion, or pain. Any activity that produces significant shear forces with compressive loading (e.g., squatting, steps) may overwhelm the load-bearing capabilities in some knees. Individuals with suboptimal alignment, degenerative joint disease, poor quadriceps function or neuromuscular control, or limited ROM will most likely experience difficulty.

Issues associated with meniscal repair are related to the normal meniscal motion during knee flexion and extension, the shear forces across the repair, and the location and type of tear repaired. The meniscus moves posteriorly up to 12 mm during knee extension to flexion, with most motion occurring between 0 and 15 degrees and beyond 45 degrees.[63] Although motion up to 80 to 90 degrees is permitted in the early phase actively and passively, weight-bearing activities through a large range should be avoided. Early partial weight-bearing or weight-bearing as tolerated is often permitted depending on the tear size, type, and location. The knee goes through 60 degrees of motion during normal gait. Repairs in the white zone, repairs with additional vascular access, or repairs of complex or radial tears are protected longer, and progression is dictated by the procedure. A sample program for intervention following meniscal repair can be found in **Table 20-7**.

TABLE 20-7

Rehabilitation Guidelines Following Meniscal Repair

	PHASE 1	PHASE 2	PHASE 3
Goals	1. Post-op knee protection 2. Restore extension ROM 3. Eliminate effusion 4. Restore leg control	1. Single-leg stance control 2. Normalize gait 3. Good control and no pain with functional movements, including step-up/down, squat, partial lunge at <60 degrees of flexion	1. Good control and no pain with sport and work-specific movements, including impact
ROM exercises	Knee extension on bolster Prone hangs Supine wall slides to 90 degrees Heel slides to 90 degrees	Stretching for patient-specific imbalances	Stretching for patient-specific imbalances
Strength exercise	Quad sets Straight-leg raise Standing 4-way leg lifts with brace Calf raises with brace	Nonimpact balance and proprioceptive drills Gait drills (stepping over hurdles, etc.) Hip and core strengthening Quadriceps strengthening: closed chain 0–60 degrees flexion	Strength and control drills related to sport or work movements Sport/work-specific balance and proprioceptive drills Hip and core strengthening Movement control exercises beginning with low velocity, single plane progressive to higher velocity, multiplanar movements Impact control exercises beginning 2 feet to 2 feet and progressing to single foot
Cardiovascular exercise	Upper body circuit training or UBE	Nonimpact endurance training: Stationary bike	Sport and work-specific energy demands

(continued)

TABLE 20-7

Rehabilitation Guidelines Following Meniscal Repair (*continued*)

	PHASE 1	PHASE 2	PHASE 3
Precautions	1. Gradually wean from 2 to 1 to 0 crutches as long as the knee is in the locked brace and there is no increase in pain or swelling 2. Keep brace locked for all weight-bearing activities for 2–4 w 3. No flexion past 90 degrees	No forced flexion past 60 degrees Avoid post-activity swelling No impact activities	Post-activity soreness should resolve in 24 h Avoid post-activity swelling Avoid posterior knee pain with flexion
Progression criteria	1. Pain-free gait with locked brace without crutches 2. No effusion 3. Active knee flexion to 90 degrees	1. Normal gait on all surfaces 2. Able to carry out functional movements without pain or unloading affected leg 3. Demonstrates good control 4. Single-leg balance >15 s	Return to work/sport when patient achieves dynamic neuromuscular control with multi-plane activities without pain or swelling

ROM, range of motion; UBE, upper body ergometer.

DEGENERATIVE ARTHRITIS PROBLEMS

Articular Cartilage Lesions

Articular cartilage is a unique tissue that has remarkable properties, including an ability to be deformed and regain its original shape, exceptional durability, and an unparalleled low-friction surface.[64] These are just a few of the properties that make articular cartilage so difficult to reproduce. Despite the prevalence of artificial joint replacements, the average life of an artificial joint is much shorter than that of native articular cartilage. This comparison highlights the unique characteristics of this material, which functions optimally in the presence of adequate ROM, joint stability, and an equitable load distribution.[65]

Articular cartilage is composed primarily of water, type II collagen, and proteoglycans.[66] Water is approximately 65% to 80% of the weight of articular cartilage and is responsible for its biphasic properties.[66] The majority of water in articular cartilage is located in the interstitial intrafibrillar space and is held in place by negatively charged proteoglycans. This fluid phase provides articular cartilage with its ability to deform and dissipate load.[66] The water content decreases with age, resulting in increased stiffness and deformation of cartilage and also decreasing its biphasic material properties. This decrease contributes to the changes seen in the normal aging process. Every joint has its own pattern or "footprint" on the surface, reflecting the specific shear forces the joint has incurred over time. Articular cartilage in adults receives its nutrition by diffusion; the cartilage in children receives some nutrition from the underlying subchondral bone.[66]

Articular cartilage responds to loads in a time-dependent manner like any other viscoelastic material; it creeps under a constant applied load and relaxes under a constant deformation. When an external load is applied to the cartilage surface, an instantaneous deformation occurs, and approximately 70% of the water within the cartilage may be moved, until the compressive stress within the articular cartilage matches the applied stress, and equilibrium is reached. Stress and relaxation also occur, depending on the length of time the cartilage is loaded. Cartilage also increases the congruity of the surfaces, distributing loads over a greater surface area. The ability to withstand compressive loads (based on these properties) varies from joint to joint and within the same articular surface.[7]

From a mechanical perspective, the requirements for a healthy joint include three factors: (1) freedom of motion, (2) stability, and (3) an equitable load distribution.[65] These necessities form the basis for some of the treatments for articular cartilage lesions. Adequate lower extremity strength to absorb loads during the loading response of the gait cycle, and normal movement patterns help minimize excessive loads on the articular cartilage. Partial thickness articular cartilage lesions in adults do not heal, but they may not get any worse in a joint with good mobility, stability, and an equitable load distribution. However, in an ACL-deficient knee or a knee with a significant varus alignment, the lesion may progress from partial to full thickness. When a lesion continues to degrade to subchondral bone, a bleed will occur, and the healing process commences. This is the rationale for the microfracture technique, one of the marrow stimulation techniques. The microfracture technique uses an awl to place multiple small holes in the lesion to create a bleed to stimulate a healing response. However, the replacement tissue is fibrocartilage, which is a lesser-quality tissue than the original articular cartilage. This fibrin clot may be adequate for the individual, especially if adequate motion, joint stability, and equitable load distribution are present.

The rehabilitation program must consider the fundamental requirements for a healthy joint when determining the appropriate mode and progression of therapeutic exercise. Activities that minimize shearing forces while increasing stability and mobility provide the foundation for the therapeutic exercise program (see **Patient-Related Instruction 20-4** and **Building Block 20-6**). Additionally, the therapist must consider the importance of adjacent joints on knee function. Interventions directed toward the hip such as strengthening and mobilization have been shown to improve symptoms at the knee.[67–69]

Patient-Related Instruction 20-4

Tips to Maintain the Long-Term Health of Your Knee

The following tips can help you maintain the long-term health of your knee:

1. Maintain the mobility of your knee. With your clinician's help, choose a few simple exercises to be done daily to maintain your ability to fully bend and straighten your knee.
2. Keep the muscles around your knee strong, especially the muscles in the front of your thigh and your hip muscles. With your clinician's help, choose a few simple exercises to be done daily to maintain the strength of your leg.
3. Maintain a healthy body weight.
4. Wear good supportive shoes that provide some shock absorption.
5. If necessary, use a supportive device (e.g., cane, crutch) when walking long distances.

BUILDING BLOCK 20-6

Consider the 78-year-old patient with knee osteoarthritis in Display 20-2, Case Study No. 2. You have determined that the patient's sense of weakness in the knees is due to a combination of weak hip extensor muscles and weak quadriceps muscles. For each muscle group, describe three exercises that would isolate and focus strengthening on that group.

Surgical Procedures

A variety of surgical procedures are used to improve function in patients with articular cartilage lesions. They can be classified as marrow stimulation techniques, resurfacing procedures, realignment procedures, and arthroplasty. Marrow stimulation techniques, such as abrasion arthroplasty, drilling and microfracture, create a bleed at the joint surface in an attempt to initiate a healing response. These procedures result in the articular cartilage defect being filled in with fibrocartilage, which mechanically does not withstand the test of time. It may provide some temporary relief until the fibrocartilage fails. Resurfacing procedures include techniques such as osteoarticular transplants and autologous chondrocytes implantation. Discussion of these procedures can be found in Chapter 11.

Unicompartmental Osteoarthritis: High Tibial Osteotomy and Unicompartmental Joint Arthroplasty

Osteoarthritis can affect any or all of the three compartments (medial, lateral, patellofemoral) of the knee joint. About one-third of patients have OA predominantly in only one compartment, called unicompartmental OA.[70] Although the most common unicompartmental OA is patellofemoral, approximately one-third of patients suffer from medial-sided OA, whereas isolated lateral compartment OA of the knee is seen in only 3% of the patients.[70] The goal of treatment of unicompartmental OA is to reduce pain, restore function, and improve quality of life. Surgical options to treat unicompartmental OA include high tibial osteotomy (HTO) and unicompartmental knee arthroplasty (UKA), whereas a total knee arthroplasty (TKA) is commonly reserved for patients with OA in multiple compartments.

The HTO may be performed when medial compartment OA is due to varus alignment; a supracondylar (femoral) osteotomy can be used to treat unicompartmental OA due to a valgus alignment.[71,72] Malalignment causes excessive loading of one compartment of the joint, resulting in subchondral sclerosis, loss of cartilage space, and osteophyte formation, all of which are indicative of OA. The ideal candidate for an HTO is less than 60 years old and active, with symptomatic mild-to-moderate varus knee (5 to 15 degrees) with mild medial compartment involvement, good knee ROM, and a stable knee.[70] The surgical technique requires a wedge cut in the proximal tibia with a concurrent fibular osteotomy performed as well.[73] Complications include infection, nonunion, patella baja, infrapatellar scarring, peroneal nerve palsy, and lateral ligament laxity. The 10-year survivorship rate of HTOs has recently increased from 50% to 80%.[74]

Rehabilitation after tibial osteotomy is guided by the requirements for a healthy joint and the sudden change in loading patterns across the compartments. The change in weight-bearing distribution may overload a previously underloaded compartment. The bony and soft tissues need adequate time to remodel and adapt to the change. How well the tissues adapt varies significantly from individual to individual, accounting for the variation in intervention choices, treatment frequency, and treatment duration. Restoration of normal ROM is essential to ensure distribution of loads over as large a range as possible. Normalization of movement patterns to minimize impact loads and excessive compartmental loading can prolong the life of the osteotomy. Quadriceps strengthening for shock absorption during the loading response of the gait cycle can minimize loads on the articular cartilage and subchondral bone.

A second option for patients with unicompartmental OA is a unicompartmental joint replacement (UKA).[75] Although the UKA was introduced in the 1970s, it did not gain wide acceptance due to poor early results, high failure rates, and high technical demands. Recently however, with improved prostheses, surgical techniques, and postoperative outcomes, the UKA has become a viable option for patients with unicompartmental OA.[74] UKA is the partial surface replacement of the knee joint; advantages include the ability to replace a single component of the joint while preserving bone stock, resulting in a faster recovery time and minimal invasiveness compared to TKA.[74] The ideal candidate for a UKA is a patient between 45 and 65 years of age with a low-to-moderate-demand knee and minimal pain at rest. In addition, the patient must not be obese, must have ROM from

0 to 90 degrees with minimal axial malalignment.[74] The surgical procedure involves resurfacing of the distal femur and proximal tibia in the affected compartment, and can be performed with robotic assistance.[76] Outcomes following UKA have improved dramatically. The 15-year survivorship rate has been reported to be as high as 95.7% with a 25-year survival rate of 72%.[74] Patient satisfaction mirrors these excellent survivorship results, particularly in activities requiring complete knee ROM, such as going down stairs and kneeling.[74]

Rehabilitation following a UKA involves ROM exercises, strengthening exercises for the lower extremity and balance exercises, similar to the plan of care for the patient after a HTO. The difference, however, is the knee of the patient who has undergone a UKA has not had any malalignment issues addressed; as such, the load incurred by each compartment remains unchanged. However, the arthritic compartment has been resurfaced with prosthetic components, abolishing the arthritis-related pain. As such, exercise progression is based on symptom tolerance. Outcomes after UKA are good. Approximately 97% of patients return to low to moderate sporting activities after a UKA; 88% of the patients after UKA felt that surgery had increased or maintained their sporting ability.[77]

Total Knee Arthroplasty

Individuals with significant bicompartmental (medial and lateral) or tricompartmental (medial, lateral, and patellofemoral) OA and associated impairments, activity limitations, and participation restriction are candidates for TKA. These individuals may have undergone previous osteotomies or unicompartmental arthroplasties that subsequently deteriorated and may present with impairments such as pain, joint instability, or LOM. Pain is one of the chief indications for TKA; stability, bone integrity, and age are additional considerations.[78] Patients generally seek medical attention when the pain becomes disabling, affecting their ability to participate in community, work, leisure, or basic ADLs. The materials and techniques used in TKA procedures have advanced significantly, thereby increasing the patient pool, minimizing complications, and decreasing participation restriction.

The prostheses used are classified in many ways, including the degree of constraint (i.e., unconstrained, partially constrained, or fully constrained), and the type of fixation (i.e., cemented, cementless, or hybrid). The prosthesis choice depends on the status of the bone and any soft tissue deformities (e.g., ligament laxity, absence of PCL). Most prostheses are tricompartmental and partially constrained with hybrid fixation. Hybrid fixation usually includes a cemented tibial component and cementless femoral component.[79] Information regarding the type of prostheses and fixation utilized should be obtained prior to initiating treatment.

Each design has its strengths and weaknesses and should be matched to the specific needs of the patient. Cemented fixation allows for earlier weight-bearing than biologic ingrowth, but loosening at the bone–cement interface may be problematic. The uncemented femoral component decreases operative time, reduces polyethylene wear from cement debris, and avoids an adverse reaction to the materials, but is more costly and requires a more precise fit. The tibial component is the most problematic in both cemented and uncemented designs, with difficulty achieving fixation resulting in micromotion and failure. Specific design features are incorporated to assist in balancing soft tissues in three planes to avoid instability problems.

Complications of TKA include component loosening, infection, peroneal nerve palsy, patellar instability, fracture, instability and osteolysis. Bone ingrowth is negatively affected by nonsteroidal anti-inflammatory medication.[80] Other complications include polyethylene wear reactions, resulting in pain, effusion and LOM developing about 5 years after surgery. Most complications are on the medial side, and the component may sink into the tibia on the medial side.

Several factors affect the rehabilitation approach after TKA. The type of prosthesis provides an indication of the underlying stability, bone quality, and ultimately the prognosis. Fixation choice also affects rehabilitation, with non-cemented components protected longer to allow biologic ingrowth. Patellar instability is a problem in 5% to 30% of TKAs, and the clinician should be alert to signs of patellar subluxation or dislocation.[81] Most prosthetic designs assume that no ACL exists and that the PCL is variably intact. The medial and lateral ligaments and joint capsule provide most of the stability. In addition, the status of the patient's overall lower extremity can affect rehabilitation. Individuals with OA at the knee may have concurrent changes in other lower extremity joints. Limitations in ROM at the hip and ankle can affect the function and prognosis at the knee. Barring any complications at other lower extremity joints, it is reasonable to acquire 120 degrees of knee flexion postoperatively. Patients with <120 degrees of flexion after TKA use compensatory movements of the hip, trunk, and ankle during daily activities. See **Table 20-8** for a sample rehabilitation program following TKA.

TABLE 20-8

Rehabilitation Following TKA

	PHASE 1: INPATIENT	PHASE 2: EARLY OUTPATIENT	PHASE 3: MID- TO LATE OUTPATIENT
Goals	Pain control Independent in bed mobility Independent in transfers Safe stair ambulation Safe use of assistive device ROM 5–90 degrees	Pain and swelling control Independent in mobility, transfers, stairs, and ambulation ROM 0–100 degrees Strength 3/5 to 4/5	Return to previous activities Gait 300 ft without assistive device ROM 0–120 degrees Effective home exercise maintenance program

TABLE 20-8

Rehabilitation Following TKA (*continued*)

	PHASE 1: INPATIENT	PHASE 2: EARLY OUTPATIENT	PHASE 3: MID- TO LATE OUTPATIENT
Mobility	Tibiofemoral joint: AROM, AAROM, PROM into flexion and extension Joint mobilization: patellar mobilization, tibiofemoral distraction and mobilization Continuous passive motion Heel slides	Patellar mobilization AROM of all LE joints Stretching of major muscle groups Tibiofemoral mobilization	Mobilization as needed Contract-relax, other stretching activities as needed
Muscle performance	Quadriceps, hamstring, gluteal setting Active knee extension Straight-leg raises TKE Hip abduction	Resisted knee extension Leg raises in all directions Minisquats Toe raises Hamstring curls Leg press Isokinetics Lunges	Progressive resistive exercises Lower extremity and core strengthening exercises Activity-specific strengthening
Functional activities	Transfers Bed mobility Assistive device use; ambulation with walker or crutches Stair negotiation	Gait training with or without assistive device Up and down from chair Stair negotiation Balance activities	Work or activity-related activities, including addressing balance impairments ADL, IADL activities
Cardiorespiratory	N/A	Stationary bicycle as tolerated Water walking	Per patient preference
Other	Ankle pumps for circulation Ice, compression for pain and swelling	Ice, compression as necessary to control swelling Community mobility	
Progression criteria	Independent in bed mobility Independent in transfers Ability to ambulate 150 ft with standby assistance Ability to negotiate stairs safely	ROM 0–115 degrees Strength 4/5 or 75% of contralateral side Full weight-bearing although may still use assistive device Ambulation 300 ft Stairs using alternate pattern	

TKA, total knee arthroplasty; ROM, range of motion; AROM, active range of motion; AAROM, active assisted range of motion; PROM, passive range of motion; LE, lower extremity; TKE, terminal knee extension; ADL, activities of daily living; IADL, instrumental activities of daily living; N/A, not applicable.

Interventions for Degenerative Arthritis Problems

Interventions used by physical therapists should address the impairments, activity limitations, and participation restrictions identified during the initial and subsequent evaluations. Impairments should be treated if they are associated with an activity limitation or participation restriction or if continued impairment could lead to participation restriction in the future. For example, limited ROM after abrasion arthroplasty may not be immediately disabling, but it could lead to future activity limitations or participation restriction by overloading focal areas of articular cartilage or by damaging other joints because of compensatory movements. Individuals with articular cartilage damage cannot expect to be cured of their problem, but they must learn to manage their symptoms and maintain the long-term health of their joint. Individuals with joint surface damage must demonstrate an understanding of the independent management of impairments, including inflammation, pain, and mobility and strength loss.

After surgery, physical therapy interventions are generally aimed at the acute impairments of pain, effusion, and LOM and neuromuscular control. Physical agents, mechanical and electrotherapeutic modalities, and gentle mobility exercises can minimize pain and facilitate resorption of an effusion. Therapeutic exercise in the form of active and passive motion, physiologic stretching, and joint mobilization can facilitate normal osteokinematics and arthrokinematics. After the surgical incisions are healed or with the use of a bioclusive dressing, many of these impairments can be treated in the pool. The hydrostatic pressure of water minimizes effusion, and water's buoyancy can be utilized to limit weight-bearing to a comfortable level. If progressive loading of the joint surface is the goal, gradually decreasing the water's depth can slowly increase the joint load.[82–84] Isometric exercises for the quadriceps, hamstrings, and gluteal muscles help reeducate these muscles while facilitating circulation.

In the subacute phase, rehabilitation continues to focus on residual impairments, activity limitations, and participation restrictions identified during reexamination. Ambulation training and progressive weight-bearing advance according to the specific injury and therapeutic procedure. The rehabilitation should continue to focus on restoring full mobility, normalizing gait, and reestablishing full function to the individual. Mobility activities should emphasize activities that enhance articular cartilage nutrition, such as gentle active and passive ROM or cyclic compressive loading and unloading. Combining these two modes should be approached with caution to avoid overloading developing or remodeling fibrocartilage or articular cartilage. Closed kinetic chain exercises with significant weight-bearing through a ROM should be incorporated judiciously with close monitoring of increased pain or effusion. Strengthening exercises must respect the changes in loading patterns after some surgical procedures. Eccentric strengthening of the quadriceps and gluteals facilitates shock absorption during the loading response phase of gait, stair and incline descent, and lowering into a chair. Strengthening can be initiated in an open kinetic chain and progressed to a closed kinetic chain as the joint tolerates. Similar exercises must be performed on a daily basis as part of the home exercise program to continue the advances made in the clinic.

The final rehabilitation phase emphasizes return to the previous activity level or a higher level, depending on the goals of the patient and the integrity of the joint. For the individual undergoing a tibial osteotomy, the expectation is to return to a higher level of function because of a decrease in pain and restoration of joint congruency. Each person should be provided with a functional retraining program tailored to the activities to which he or she will be returning. Moreover, the importance of continuing an exercise program incorporating activities to maintain the long-term health of the joint must be emphasized. Demonstration of the ability to home manage an exacerbation of symptoms is fundamental to safe and cost-effective long-term management of articular cartilage lesions. Patient education to manage lifestyle factors such as walking distances, floor surfaces, time spent in static standing, maintenance of appropriate body weight, shoe wear, and use of assistive devices is also a critical intervention.

TENDINOPATHIES

Tendinopathies about the knee occur most frequently in the patellar tendon but can also be found in the hamstring tendons, the quadriceps tendon and pes anserine tendon. In addition, ITB friction syndrome can be considered a type of tendinopathy. Although tendinopathies can result from an acute injury, they usually are caused by microtrauma or overuse. Repetitive loading without adequate recovery time prevents normal adaptations within the tendon to occur. Although single loads do not exceed the strength of the tendon, cumulative loads exceed the reparative capabilities. Intrinsic factors contributing to tendinopathies include malalignment, limb length discrepancies, and muscular imbalance or insufficiency. Aging tissue has a lower reparative capability, diminishing its ability to recover from overuse. Extrinsic factors include training errors, surfaces, environmental conditions, and footwear.[85]

Patellar Tendinopathy

Patellar tendinopathy typically occurs at the insertion of the tendon into the distal pole of the patella. It is distinct from Sinding-Larsen–Johanssen disease, which is apophysitis of the distal patellar pole, and from Osgood–Schlatter disease, which is apophysitis at the tibial tubercle. Both of these syndromes occur in adolescents before closure of the growth plates. Patellar tendinopathy has also been called *jumper's knee* because of its high prevalence in jumping and impact sports. The eccentric nature of jumping places tremendous loads on the patellar tendon, often resulting in overuse. The patellar tendon attaches one of the strongest muscle groups in the body, the quadriceps femoris, to its insertion using the patella to increase the lever arm of the muscle. The loads generated by the quadriceps mechanism are transmitted through the tendon to its bony attachments. Areas of increased stress such as transitional zones are susceptible to overuse. In the adult with closed epiphyses, the transition zone on the undersurface of the patella's distal pole is the most vulnerable area.

Tendinopathies of the patellar tendon can take various forms. Tendinopathies tend to demonstrate a normal macroscopic appearance, but microscopic abnormalities at the bone–tendon junction most always exist.[86] Necrosis and fragmented tissues with mucoid degeneration usually involve the deep central fibers at the tendinous insertion and can be palpated at the undersurface of the patella's distal pole.[87]

Individuals with patellar tendinopathies present with various degrees of impairments, activity limitations, and participation restrictions. The person often reports a history of pain and stiffness in the anterior knee that improves as the knee is warmed. The knee then gets sore as the activity continues, and gets stiff and sore after completion of the activity. Point tenderness is experienced on the undersurface of the distal pole of the patella and is best palpated by tipping the inferior border anteriorly to allow access to the undersurface. This is best achieved by pushing the superior patellar pole posteriorly with the knee over a bolster, in approximately 30 degrees of flexion. Activity limitations may include abnormal walking or running gait, pain with jumping, landing from a jump, pain with kneeling, or pain when ascending and descending stairs. Participation restrictions can include an inability to participate in community, work, or leisure activities, depending on the individual's lifestyle and activity limitations.

Treatment

Rehabilitation for the individual with patellar tendinopathies focuses on the patellar tendon's role in decelerating knee flexion in gait, jumping, descending stairs, and many other functional activities. The role of tendon length and ability to perform deceleration during activities forms the foundation for the rehabilitation program. Stretching exercises to ensure adequate tendon length are combined with eccentric quadriceps strengthening of progressively increasing velocity up to the speeds used in daily activities. Before an individual can perform an eccentric muscle contraction, she must be able to preset isometric tension in the muscle. The rehabilitation program may begin with isometric contractions before progressing to isotonic and eventually eccentric contractions (**Evidence and Research 20-4**). Eccentric contractions can be performed in

EVIDENCE and RESEARCH 20-4

Patellar tendinopathy can be very debilitating. Cook et al[93] found that more than one-third of athletes presenting for treatment for patellar tendinopathy were unable to return to sports within 6 months; 53% of athletes with patellar tendinopathy were forced to retire from sports.[94] Most recently. a clinical commentary by Malliaras et al suggested a four-step approach to the management of patellar tendinopathy.

1. **Isometric Loading:** Five repetitions of 45-second isometric mid-range quadriceps exercise at 70% of maximal voluntary contraction have been shown to reduce patellar tendon pain for 45 minutes post exercise.
2. **Isotonic Loading:** Pain must remain 3 or less out of 10 on a pain numeric rating scale. Isotonic load is important to restore muscle bulk and strength through functional ranges of motion.
3. **Energy Storage Loading:** Initiating this stage is based on the following strength and pain criteria: (1) good strength (e.g., ability to perform four sets of eight repetitions of single-leg press with around 150% bodyweight for most jumping athletes); (2) good load tolerance with initial energy storage exercises defined as minimal pain (3 or less out of 10 on a pain numeric rating scale) while performing the exercises, and return to baseline pain (if there was an initial increase) during load tests such as the single-leg decline squat within 24 hours. This phase focuses on eccentric loading of the tendon, Variables that are trained include the rate, volume and intensity of eccentric loading. (This is what is thought of as the traditional eccentric exercise approach to patients with tendinopathy.)
4. **Return to Sport:** Progression back to sports specific training can be commenced when the individual has progressed through energy storage progressions that replicate the demands of their sport in regard to the volume and intensity of relevant energy storage functions. At that time, stage 3 exercises are replaced by a graded return to training and eventually competition.[95]

an open or a closed chain, recognizing that substitution may occur during a closed chain exercise. However, body weight used during a closed chain exercise may provide enough assistance to the injured tendon to allow for adequate strength training. A vigorous eccentric program is recommended prior to any surgical intervention.[88] Eccentric squats performed on a decline board (a board declined approximately 25 degrees) have been shown to be effective in treating patients with patellar tendinopathy.[89] In most research, patients performed exercises with external resistance on a decline board for 3 sets of 15 repetitions twice daily for up to 12 weeks. It has been suggested that the eccentric exercise results in decreased neovascularization at the tendon and resultant decreases in pain and improvements in function.[90,91] To create an optimal healing environment, adjuncts to the therapeutic exercise program are used and typically include forms of cryotherapy. The outcome for conservative management of patellar tendinopathy shows that only 55% of athletes achieve an excellent or good outcome 12 months post injury.[92]

Iliotibial Band Syndrome

Iliotibial band syndrome (ITBS) is the most common cause of lateral knee pain in individuals who regularly jog, bicycle, or walk for exercise.[96–98] Postural problems such as anterior pelvic tilt, knee hyperextension or hyperpronation, combined with poor mechanics, such as decreased gluteus medius or quadriceps activity, can be predisposing factors. Biomechanical analysis of patients with ITBS showed greater hip adduction and knee internal rotation moments compared to patients without symptoms.[96–98] Increased hip adduction and femoral internal rotation causes increased ITB strain at the lateral femoral condyle. It has been suggested that the *rate* of strain is more important than the *magnitude* of the strain, particularly in runners.[99] While ITBS has traditionally been considered to be the result of friction over a bursa as the band passes anterior and posteriorly over the lateral femoral condyle, biomechanical and anatomic studies suggest that few people actually have a bursa in this area.[100,101] Moreover, it has been suggested that the band does not actually move across the epicondyle, but that the appearance of movement is the result of tensioning of the anterior and posterior bands of the ITB.[100]

The individual presenting with ITBS often complains of a sharp, stabbing pain at the lateral femoral epicondyle that begins with the onset of activity and worsens as the activity progresses. Palpable tenderness over the lateral femoral epicondyle can confirm the diagnosis. Predisposing factors such as poor postural habit of standing in genu recurvatum and whole-limb pronation or muscle imbalance should be identified during the examination. Hamstring, gluteal, quadriceps, iliopsoas, and ITB flexibility and strength should be assessed. Any impairments or activity limitations identified during the examination should form the basis for the rehabilitation program. In many cases, a combination of predisposing factors, activity choices, a rapid increase in activity and impairments converge to produce ITBS.

Treatment

Rehabilitation focuses on the identification and treatment of predisposing factors, impairments, and activity limitations. Patient education regarding these factors and conscientious participation in self-managing this problem contribute to a successful outcome. Postural education and identification of the underlying impairments (e.g., hip rotator weakness, core weakness, lack of flexibility in the lower extremity) provide the foundation for appropriate stretching or strengthening exercises. Stretching for the hip and knee musculature with emphasis on good posture is the mainstay of treatment. These stretches may be performed on land or in the pool (see Figs. 20-10 through 20-12). Ice may be used to treat pain and inflammation associated with this problem. Self-mobilization or massage is commonly used to decrease the pain associated with ITB symptoms. Foam rollers or other firm materials can be rolled along the ITB to self-massage this tissue.

Patellofemoral Pain Syndrome

The typical patient with patellofemoral pain syndrome (PFPS) is a young female who complains of pain in the anterior aspect of the knee.[102,103] The pain is aggravated by closed chain knee extension activities such as ascending or descending stairs, squatting, rising from a chair, or jumping. A wide variety of interventions for PFPS have gained widespread acceptance in the clinical community, including general and specific hip and knee strengthening using both open and closed kinetic chain exercises, providing surface EMG biofeedback, stretching, acupuncture, low-level laser therapy, patellar mobilization, corrective foot orthoses, patellar taping, and external patellar bracing.[104,105] Unfortunately, experimental evidence to support the use of many of these approaches, either combined or in isolation, is lacking, and conventional clinical practice often flies in the face of what little evidence does exist. An understanding of what is known about the efficacy of various interventions, and, where the research lags behind clinical practice, a thorough understanding of the etiology of the condition should guide the intelligent choice of management strategies for the patient with PFPS.

Cause: Etiology

The causes of PFPS can be due to a macrotrauma, such as a patellar subluxation or dislocation, or from microtrauma, caused by overuse with patellar malalignment. Frank dislocation resulting from a blow to the knee is simple to determine through history. Recurrent subluxation is suggested when the patient reports that her knee gives way with a sharp pain, usually with slight knee flexion combined with tibial external rotation in weight-bearing. Rates of patellofemoral dislocations are highest during adolescence.[106] Patients with acute traumatic patellar instability will experience chronic instability or PFP. Age at initial dislocation, anatomic abnormalities, including trochlear dysplasia, and activity level may predispose a patient to a poor outcome.[107] Patella alta also increases the risk of patellar instability. Other causes of the knee "giving way" should be ruled out. Other sources of instability include ligamentous tears, meniscal pathology, and quadriceps inhibition.[12]

Microtrauma due to overuse can be a cause of PFP; not all patients with PFP demonstrate lateral subluxation or tracking.[108] This suggests other reasons must exist, and one should look for an increase in usage patterns associated with the onset of the anterior knee pain. Again, the patient's history will provide the clues, with repetitive work or recreational activities that stress the knee being key factors. The patient may report an increase in running distance, a change in running surface, an increase in workload demands, or a change in shoe wear.

It is generally accepted that PFPS results from a cascade of events. Poor alignment of the patella in the trochlear groove, typically with the patella seated laterally, results in poor distribution of the patellofemoral joint reaction forces (PFJRF) on the posterior aspect of the patella.[109] The PFJRF is the amount of pressure on the joint surfaces of the patellofemoral joint, and is a function of the flexion angle of the knee and the amount of tension developed by the quadriceps muscle. As the knee flexes and the quadriceps become more active, the PFJRFs increase. Under normal circumstances, the pressure is distributed to both the medial and lateral facets, and with near end-range flexion, to the odd facet. When the patella tracks poorly, the PFJRFs will be concentrated into a smaller contact area, resulting in increased shear on the articular surfaces, leading to tissue breakdown, pain, and impaired function.[109,110] There is some evidence that runners who develop PFP have increased impact forces during heel strike and push off as compared to runners without PFP.[111] In addition, foot posture was not found to be different between individuals with PFPS and controls.[112] The possible causes of patellar malalignment seen with microtrauma are generally separated into two basic categories. The first includes problems with the static structures such as the shape of the osseous surfaces or length of the fascia. The second category of patellar malalignment etiology includes issues related to the dynamic structures about the knee. As the discussion that follows suggests, there is a lack of consensus in the research literature with regard to the etiology of PFPS, although the search continues. In the meantime, clinical experience and outcome studies demonstrate the effectiveness of conservative treatment for this disorder, although the relative effectiveness of any individual intervention has yet to be shown.

The Role of Static Structures

The Q-angle is formed by a line drawn from the anterior superior iliac spine (ASIS) to the middle of the patella, and from the middle of the patella to the tibial tuberosity. In theory, a greater Q-angle would be associated with increased lateral forces on the patella and therefore associated with lateral patellar tracking. The Q-angle can be measured in supine, standing (either single or double leg), and either statically or dynamically. Because of this large variability, the association between Q-angle and PFP remains in question.[2,113,114] This underscores the need for the whole lower kinetic chain to be evaluated in the patient with PFPS.

The depth of the trochlear groove may play a role in PFP.[115] In a study by Powers et al, subjects with a shallower trochlear groove had a laterally tilted patella in terminal extension (30 to 0 degrees) and a laterally displaced patella in the last 9 degrees of extension.[116] Although a defect in the trochlear groove is not amenable to physical therapy intervention, understanding all the contributing factors to the patient's PFPS will guide the clinician to establish realistic goals for the patient.

It has been theorized that controlling overpronation at the foot would help alleviate PFPS by positively affecting the Q-angle. Foot pronation causes tibial internal rotation, which, when carried into late midstance and terminal stance when the knee is extended, will cause hip internal rotation as well. This shifts the patella medially relative to the ASIS and theoretically increases the lateral forces on the patella. However, the utilization of foot orthoses, either custom or off-the-shelf, in the management of PFPS remains controversial.[117–124] Clearly more work needs to be done to determine the effectiveness of foot orthoses in the management of PFPS.

The Role of Dynamic Structures

Historically, there had been discussion about the role of the VMO, and the VL muscles' function in the development of PFPS. The thought was that an imbalance in the amount of pull or the timing of the contraction of these muscles could either cause or allow the patella to track laterally in the trochlear groove, resulting in a concentrated force on the retropatellar surface. And although this theory has been tested repeatedly via numerous studies, it appears there is no difference between symptomatic and asymptomatic subjects in either amount of VMO:VL EMG activity or the timing of the onset of the two heads of the quadriceps.[113,125] Another early theory suggested that joint effusion could cause pain and inhibit quadriceps function in the knee.[12] In addition, other theories supported a difference in reflex response times or neural adaptations as contributing factors to PFPS. However, most of these studies were refuted or found to have flaws within their methods.[11,111,114,126,127] However, research has consistently shown that improving quadriceps strength and endurance is an integral part of any rehabilitation program for PFPS.[126,128]

More recently, the increased forces on the lateral undersurface of the patella have been attributed to increased femoral internal rotation, which brings the lateral femoral condyle into contact with the lateral retropatellar surface.[129] The increased femoral internal rotation may be osseous, due to femoral anteversion, or may be dynamic, due to gluteus medius weakness.[69,125,126,130] Increasing evidence has demonstrated the benefits of incorporating hip strengthening to the multifaceted plan of care of the patient with PFPS.[69,125,126,130] Hip strengthening, either in isolation or combined with quadriceps strengthening, for the management of PFPS, has been proven to be successful.[120] In addition, hip strengthening exercises in addition to quadriceps exercises appear to be more beneficial than quadriceps strengthening alone for the management of PFPS[126] (**Evidence and Research 20-5**).

EVIDENCE and RESEARCH 20-5

Strengthening of the hip abductors, specifically the gluteus medius, has been shown to be effective in reducing pain and increasing function in patients with PFPS, particularly in women. When prescribing gluteus medius strengthening exercises, it is imperative that the clinician know which exercises provide the greatest amount of electromyographical (EMG) activity. Studies have found the following %MVC of the gluteus medius with each listed exercise[131,132]:

Exercise	% Maximal Voluntary Contraction (MVC)
Side plank, DL down	103
Sind plank, DL up	89
Single limb squat	82
Sidelying hip abduction	81
Clamshell	76
Single limb squat	64
Lateral band walk	61
Single limb deadlift	58

In addition to dynamic muscular imbalances at the hip, foot or ankle dysfunction can cause a change in the angle of pull of these muscles and lead to altered patellar tracking as well. As such, management of impairments at the foot and ankle must be addressed as well.

Differential Diagnoses

It is important to differentiate PFP from other disorders of the knee. Generally, PFPS will manifest in the anterior aspect of the knee as a diffuse ache, with the pain aggravated with activity such as ascending or descending stairs. Other pathologies, however, will also cause anterior knee pain; therefore, general questions about the location of the pain may not be helpful in establishing the correct diagnosis. In addition, disorders can coexist, further complicating the picture. Other causes of anterior knee pain include irritation of the infrapatellar fat pad, patellar tendinopathy, Osgood–Schlatter disease, Sinding-Larsen–Johansson disease, or pes anserine bursitis.

Patients with PFP may complain of the knee locking or giving way. A patient may report that their knee “locks,” which actually may be a catch or click in the patellofemoral joint, versus true knee locking, as seen with meniscal pathology or a cruciate injury. “Giving way,” as described by the patient, may be quadriceps inhibition, commonly seen in patients with PFPS with low-grade swelling.[12] Regardless, these types of complaints warrant further investigation during the physical examination.

Examination

History taking should narrow the differential diagnosis for the clinician. Specifically, questions should determine if the mechanism of injury is due to a macrotrauma, repeated microtrauma, or if congenital structural problems play a role. Questions regarding aggravating and alleviating factors may help differentiate between anterior knee pain, patellar subluxation, and patellar dislocation.[107–109] Particular attention should be paid to determining what activities reproduce the patient’s pain, as these motions can be used to monitor the patient’s progress and the efficacy of an applied intervention.

Examination should include an assessment of the patient’s static alignment. Impairments in static structures, such as femoral anteversion and foot pronation, can be identified. Dynamic assessment might reveal impaired motor control or performance. For example, the patient may have asymmetry or excessive lateral weight shift when assuming a single limb stance posture. This may signal weakness of the hip abductors or lack of hip control. This will result in a relative hip adduction on the stance limb (Trendelenburg stance), which will bias the knee toward an increase in Q-angle, resulting in an increase in the lateral forces acting on the patella and lateral patellar tracking. In addition, over time, the hip adductors may become shortened.

Postural deviations, such as standing with most of the weight on one limb, and habitual usage can result in changes in the normal length--tension relationships of the muscles. It is important to perform a careful assessment of muscle function in the entire lower extremity. A useful assessment of function that incorporates the entire lower extremity is the step-down task. When properly performing this task, the knee should remain aligned over the second toe. The hip should remain in the same alignment as during double limb stance, with allowance made for slight weight shift over the weight-bearing leg as the non–weight-bearing leg is lifted. Excessive lateral shift or a drop of the non–weight-bearing pelvis suggests hip weakness, particularly in the abductors and extensors. In addition, if the knee moves medially over the foot during the step-down, weakness of the hip abductors, extensors, and hip external rotators should be suspected. If increased foot pronation occurs, poor muscular control of the posterior tibialis and gastrocnemius/soleus complex may be the cause. This movement pattern will result in relative hip adduction and increase the lateral pull on the patella. When this pattern of movement is observed, assessment of muscle strength (manual muscle testing at minimum) in these muscles is mandatory. The results of the strength tests will guide the choice of exercises.

Intervention

An appropriate management plan for PFPS should be based on the evaluation of all the collected data, which is distilled into a diagnosis. Issues related to impairments of body structures are not appropriate for physical therapy intervention. However, habitual movement patterns can be corrected with movement reeducation. ROM impairments and motor deficits can be addressed through strengthening, stretching, and manual interventions. Once pain has been reduced, rehabilitation of the extensor mechanism and control of proper lower extremity alignment are the foundation of managing PFPS.

Historically, much has been made about the imbalance between the VL and the VMO as a causative factor in PFPS. It was once thought that the VMO was primarily responsible for stabilizing the patella medially, and that poor VMO function would result in lateral tracking of the patella and cause PFPS.[110] However, despite multiple investigations, there does not seem to be a consensus about whether there is reduced VMO activity in patients with PFPS.[2,111–114,125,126,130,133–135] What has been supported in the literature is the use of general quadriceps strengthening to improve the overall function of the quadriceps, as discussed below.[115]

Evidence for PFPS Interventions It is important to address the symptoms experienced during knee extension, particularly closed chain. Pain will cause muscle inhibition and therefore will interfere with daily activity, such as walking, and will limit any attempt at muscle strengthening. Interventions that minimize pain should be implemented. These include icing, electrical stimulation, and soft tissue massage as indicated. Additionally, an intervention that appears to be of benefit to reduce anterior knee pain during closed chain activities is taping. Several studies have shown that patellar taping or the use of Kinesio Tape can decrease knee pain.[116,124,129,136] While the exact mechanism of the pain relief is unknown, it appears that taping alters neither the amplitude nor the timing of the vasti muscles.[120,123] However, the tape may distribute the PFJRF more evenly across the posterior surface of the patella, increasing contact area. And although the precise mechanism of decreased pain is not well understood, functional measures improve after the application of tape[113,120] (**Evidence and Research 20-6**).

EVIDENCE and RESEARCH 20-6

The effectiveness of taping, bracing, and Kinesio Tape for the treatment of PFPS has been examined. Patient with PFPS were taped three different ways: will a medial pull, with a lateral pull, and neutral (no pull). Each patient performed four single step-downs with each taping method, as well as with no tape, and reported their pain. The authors found that all taping methods significantly decreased pain when compared to the untaped condition. The authors concluded that patellar taping produced an immediate decrease in pain in patients with PFPS, irrespective of how taping was applied. As such, the tape may decrease pain by simply increasing contact area of the patella within the trochlear groove. It is unlikely that taping works by altering patellar position.[124]

In lieu of taping, patellofemoral braces may also be effective in reducing pain and increasing patellofemoral contact area.[117–119,122] While there is no evidence that supports the use of knee orthoses in all patients, it may be that a trial use of an orthosis will benefit certain patients.

Once pain has subsided, improving the static and dynamic alignment of the entire lower extremity can be addressed. The presence of structural deformities may be addressed using compensatory measures, such as over-the-counter foot orthoses. Although foot orthoses have been shown to be better than flat inserts in the short term, they do not improve outcomes when added to typical physical therapy interventions.[121]

Other than structural deformities, the main impairments associated with poor alignment are limitations in ROM, muscle flexibility, and motor function. Patients with PFPS demonstrate significantly less flexibility of the gastrocnemius, soleus, quadriceps, and hamstrings compared to healthy control subjects.[137] ROM limitations can be generally categorized as either being due to joint mobility restrictions or to soft tissue shortness. Appropriate joint mobilization techniques should be used to improve hip, tibiofemoral, patellofemoral, tibiofibular (both inferior and superior), talocrural, intercarpal, and metatarsophalangeal joint motion, as indicated by examination findings (see Chapter 7). Soft tissue restrictions can be addressed using soft tissue mobilization techniques that address specific areas of hypomobility, through longitudinal stretching either done manually by the therapist or done by the patient independently, or both. Contract-relax techniques work well in improving the overall length of the muscle. With regard to PFPS, key areas that need to be addressed include improving hip adduction (indicated by a positive Ober test), hip extension (Thomas test), external hip rotation, knee flexion with the hip extended (Thomas test), and ankle dorsiflexion (see **Table 20-9**). There is evidence that a 3-week program of quadriceps stretching improves flexibility, pain, and knee function.[138] Poor ankle dorsiflexion can lead to compensatory pronation at the subtalar joint, which causes internal rotation of the tibia. As noted earlier, this may adversely affect patellar alignment. Posterior glides of the talus on the tibia will increase ankle dorsiflexion at the talocrural joint, while stretching of the gastrocnemius will also increase dorsiflexion. ITB tightness affects patellofemoral and tibiofemoral kinematics; stretching the ITB has been advocated as part of an overall intervention program, with positive outcomes reported.[127,139] Based on the structure, tissue makeup and tensile properties of the ITB, it is unlikely that a stretching or soft tissue mobilization program will significantly lengthen it. It is more probable that length is gained in the proximal attachments of the ITB, likely the tensor fasciae latae. In addition, soft tissue mobilization might gate pain, which may improve knee function.

A simple active combined hamstring and gastrocnemius stretching exercise that can be performed in sitting is appropriate and convenient for most patients. In a sitting position, the patient should support the low back with a firm hand support to maintain the lumbar lordosis. The patient then slowly extends the lower leg while maintaining this lumbar lordosis. At the end of the comfortable ROM, the patient should dorsiflex the foot intermittently at 3-second intervals. Prolonged holding of this position might irritate the sciatic nerve, as nerves, when stretched, can become hypoxic. This exercise can be performed frequently throughout the day (see **Self-Management 20-7**).

TABLE 20-9

Stretching Exercises to Address Hip Soft Tissue Mobility Impairments

IMPAIRMENT–LACK OF:	PATIENT POSITION	KEY POINTS
Hip extension	Half-kneel Supine, leg off table Sidelying Prone	■ Bias the pelvis into a posterior pelvic tilt to maximize the length of the hip flexors
Hip flexion (with a focus on 2–joint hip extensors)	Supine straight-leg raise Knee extension with hip maintained in flexion	■ Bias the pelvis into an anterior pelvic tilt to maximize the length of the hamstrings
Hip adduction	Half-kneel	■ Maximize stretch to tensor fasciae latae, minimize lateral trunk stretch
Hip external rotation	Half-kneel on a chair	■ Stabilize pelvis
Knee flexion with hip extended	Half-kneel Sidelying with the knee flexed Prone with the knee flexed	■ Bias the pelvis into a posterior pelvic tilt to maximize the length of the rectus femoris
Ankle dorsiflexion	Standing	■ Bias the foot into supination to isolate ankle dorsiflexion ■ Address both gastrocnemius and soleus

SELF-MANAGEMENT 20-7
Hamstring and Gastrocnemius Stretching While Maintaining a Lumbar Neutral Position

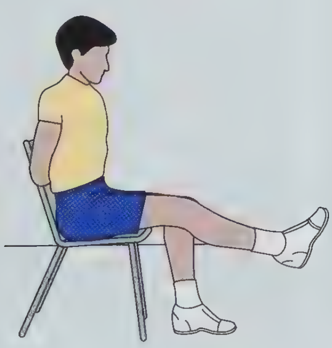
Purpose: To increase the flexibility of the hamstring and calf muscles

Position: In a sitting position, place one hand behind your back to maintain the proper position of your lower back.

Movement Technique: Maintaining this position, slowly straighten the knee until you feel a gentle stretch behind your thigh. While holding this position, pull your toes up, flexing your ankle until you feel a gentle stretch behind your calf. Hold for 3 seconds.

Dosage:

Repetitions: ______________________ times



Once pain has been addressed, the cornerstone of management of PFPS is improving strength and neuromuscular control of the lower extremity.[11,140–142]

All resistance exercises should be performed in a pain-free ROM. It may be that only isometric exercise is tolerated in a highly irritated condition. If this is the case, multi-angle isometrics should be employed. There is no reason to emphasize terminal knee extension over exercise in greater amounts of flexion. Avoidance of patellofemoral joint compression forces can be counterproductive, considering that cartilage nutrition is dependent in large part on weight-bearing. The guiding principle should be dispersing the PFJRF by increasing the patellofemoral contact area by improving patellar tracking. As the patient progresses to closed chain exercises, examples of controlling the ROM include altering the depth of squat, height of the step (step-ups) or height of the chair (stand to sit exercise).

A review of the available literature showed strong evidence that both open and closed kinetic chain exercises lead to equal long-term good functional outcomes, even at a 5-year follow-up.[128] However, considering interventions should be directed at improving activity limitations and participation restrictions, given the principle of specificity of exercise, closed chain exercises may be a better choice for most patients.

Performing all exercises with proper lower extremity and trunk alignment is essential to addressing dynamic malalignment issues. For example, step-up and step-down exercises are important, as stairs are a problem for most individuals with PFP. In performing this exercise, the patient should maintain the knee aligned over the second toe. Exercise difficulty should be adjusted to allow motion through the total target ROM while maintaining good alignment. This may affect the choice of open versus closed chain exercise. For example, many individuals with PFPS have poor eccentric control during stair descent. When asked to control the step-down motion, many are unable to do so because of pain or inadequate muscle control. In this case, the step-down exercise from a standard step height is too demanding of the patient and is contraindicated because the patient cannot maintain optimal alignment. Starting with a small step, perhaps 4 inches, may be appropriate. In addition, open chain strengthening may prove beneficial at this point, as specific muscles can be targeted for strengthening and the appropriate amount of resistance applied. In addition, taking into consideration the functional task required, emphasizing eccentric exercises in open chain would begin the training necessary for control of lowering the body weight during the step-down task. For example, sidelying hip abduction with weight applied to the knee or ankle will selectively strengthen the gluteus medius. Eccentric contractions can be accomplished by assisting in the concentric lifting of the leg. One way to accomplish this is to simply have the patient flex the knee while raising the leg (shortening the lever arm and therefore decreasing the resistance to the abductors), and extending the knee prior to lowering the leg, thereby increasing the resistance during the eccentric phase of the movement. Alternatively, it may be that closed chain exercises can be performed using equipment that can minimize body weight, such as a leg press or inclined squat machine. These machines and others like them allow the amount of resistance to be adjusted to proper levels, as opposed to full weight-bearing exercises that demand control of body weight. Once strength has improved and pain has subsided, a progression toward closed chain exercises is indicated.

The speed of the movement is an important exercise variable to consider. As the patient's control of the movement improves at slower speeds, the speed of movement should be increased to approximate normal function. Good alignment and form are still paramount goals regardless of the speed of movement. The individual should move slowly enough to be able to stop at any point during the motion to correct malalignment. Close observation can detect poor alignment of the hip, knee, and ankle or substitution at the hip (**Fig. 20-24**). The use of mirrors and video recordings of movements can be beneficial. A mirror provides immediate feedback to the patient and encourages the patient to self-correct.[143] In addition, the use of a mirror has been shown to positively affect transfer of skill to other tasks, even at 1 and 3 months post training[143] (**Evidence and Research 20-7**). Utilization of video recordings, such as those created with an iPad, can provide the patient with feedback. Oftentimes, fast movements can be played back for the patient at a slower speed to increase motor learning and help the patient identify faulty movement patterns.[105]

EVIDENCE and RESEARCH 20-7

Observational learning, as with video feedback, is an effective way to enhance motor skill learning. Imitation of body movements that are observed activates mirror neurons. The mirror neurons map the observed movements onto a motor program. Interestingly, mirror neurons fire when an action is performed as well as when a similar action is observed (as in watching video of oneself performing the skill).[105] In a study by Onate et al,[144] both verbal and self-video feedback were tested during a jump-landing task.

The group that received both verbal and self-video feedback significantly reduced peak vertical ground reaction forces compared to the group that was instructed to self-analyze jumps using internal feedback and a control group, who received no feedback.[144]

When a faulty movement pattern is identified, bracing or taping may offer increased neuromuscular control during activities.[145] Lastly, when observing closed chain exercises, remember the foot position can influence the lower extremity alignment. Ideally, the foot should be in a position close to neutral for all standing activities. To obtain a relatively neutral position of the foot, the tibialis posterior should lift the subtalar joint while the peroneus longus stabilizes the first ray. Pressing down (plantar flexing) through the first metatarsal head is often

A

B

FIGURE 20-24 **(A)** Patient performing a squat exercise. **(B)** Progressing to a lifting exercise.

a beneficial cue to facilitate correct alignment and appropriate muscle recruitment. Recruitment of the foot intrinsic muscles to maintain a stable arch should be encouraged.

Postoperative Rehabilitation

The three most commonly performed surgical procedures for the patellofemoral joint include:

- Arthroscopic debridement of patellar or femoral chondral degeneration
- Lateral retinacular release for severely restricted lateral structures
- Realignment procedures for those with more complicated biomechanics

Surgery for PFPS is utilized very judiciously, as surgical outcomes are no better than conservative management, even at a 5-year follow-up.[143] Rehabilitation after any of these procedures should follow the program as previously outlined. With arthroscopic debridement, the program should progress without problems unless significant pain or swelling exists. If more progressive chondral damage has occurred, more caution should be placed on gradual and careful reintroduction of activity and exercise to allow the accommodation of the chondral surfaces. With lateral retinacular releases, care should be taken to ensure the lateral retinaculum does not adhere to surrounding soft tissues. Aggressive releases must be progressed much more slowly than conservative releases, because postoperative pain and large amounts of edema are common. Realignment procedures require careful patient selection and are typically only considered after conservative management has failed. The Maquet procedure, which is an older procedure, involved advancing the tibial tuberosity anteriorly 2 to 2.5 cm via a bony wedge. The rationale of this procedure was to reduce patellofemoral pressure.[146] However, the complication rate was fairly high, and rehabilitation was lengthy. As such, the procedure has fallen out of favor and is rarely performed. More recently, the medial patellofemoral ligament (MPFL) has been identified as the primary medial restraint to a laterally subluxing patella. In patients with a history of recurrent patellar instability, the MPFL can be stretched or completely torn, rendering it nonfunctional. Surgery to reconstruct the MPFL has become increasingly popular.[147] The goal of this procedure is to recreate the MPFL, thereby resisting lateral dislocation and restoring stability. Many surgical techniques as well as grafts are used to accomplish this. Graft options include semitendinosus, patellar or quadriceps tendon, and allografts. Systematic reviews show favorable outcomes while failure rates continue to decrease.[147] Management of the patient after a MPFL reconstruction includes a focus on ROM, patellar and tibiofemoral mobility, neuromuscular reeducation, and lower extremity strengthening. Close attention should be paid to the quality of quadriceps contraction and patellar tracking.

Prognosis

The prognosis for PFPS is generally good.[105] Strengthening exercises, in addition to stretching of the hamstrings, quadriceps, hip flexors, and gastrocnemius, combined with activity modification have proved to be effective in managing PFPS.[115] Regarding strengthening exercises, closed chain exercises are more closely associated with ADLs than open kinetic chain exercises. Although both open and closed chain exercises were effective in decreasing patient's pain, there is a tendency for better results with the use of closed chain exercises.[128] Most recently, studies have supported the addition of hip strengthening exercises, combined with quadriceps strengthening exercises, to decrease PFPS.[134,145,148–150] Lastly, although the addition of off-the-shelf foot orthoses and patellar taping may be of benefit, at the cornerstone of every well-designed intervention program is therapeutic exercise, including stretching and strengthening.

KEY POINTS

- The relationships among the lumbopelvic, hip, knee, ankle, and foot necessitate a thorough examination and an integrated approach to treatment. This includes hip and core muscle strengthening for distal problems.
- Impairments of body structures, including femoral anteversion, coxa valgum and varum, genu valgum and varum, a shallow trochlear groove, and foot pronation can predispose the patellofemoral joint to poor tracking, resulting in excessive loads.
- Impairments of body functions such as mobility or muscle performance loss at the hip, ankle, or foot can be manifested as symptoms in the anterior knee.
- Because of these compensations and the relationships among joints, therapeutic exercises may be performed incorrectly, allowing substitution to occur.
- Examination of the patellofemoral joint must include muscle length and joint mobility at the hip, knee, and ankle, as well as static and dynamic assessment of the patella.
- Examination of key functional movements such as ascending or descending stairs or a step-down task will reveal lower kinetic chain mechanics.
- Improvements in impaired joint and soft tissue mobility, muscle performance and motor control, and general quadriceps strengthening result in positive outcomes with PFPS.
- Currently, no evidence exists to support specific recruitment of the VMO separate from the rest of the quadriceps.
- The major impairments of body structures at the knee are genu valgum and genu varum. These postures predispose the lateral and medial compartments, respectively, to excessive loads.
- Impairments of body functions such as mobility loss at the knee can be compensated by motion at other joints. For example, increased ankle, hip, or lumbar motion can compensate for decreased knee flexion.
- Palpation, education, and biofeedback are techniques to ensure proper muscle firing patterns without substitution during rehabilitative exercises.
- Loss of the meniscus can lead to degenerative joint disease. Treatment after meniscectomy should focus on preservation of articular cartilage and joint protection techniques.
- The major function of the quadriceps muscle in the long-term health of the knee is its ability to absorb shock eccentrically in the loading phase of the gait cycle. A focus on eccentric, closed chain quadriceps exercise in the first 0 to 15 degrees of flexion is essential to maintain the health of articular cartilage.
- Patellar tendinopathy results from the tendon's inability to withstand eccentric forces during impact activities. The rehabilitation program must eventually progress to eccentric impact activities if the patient is to return to this type of activity.

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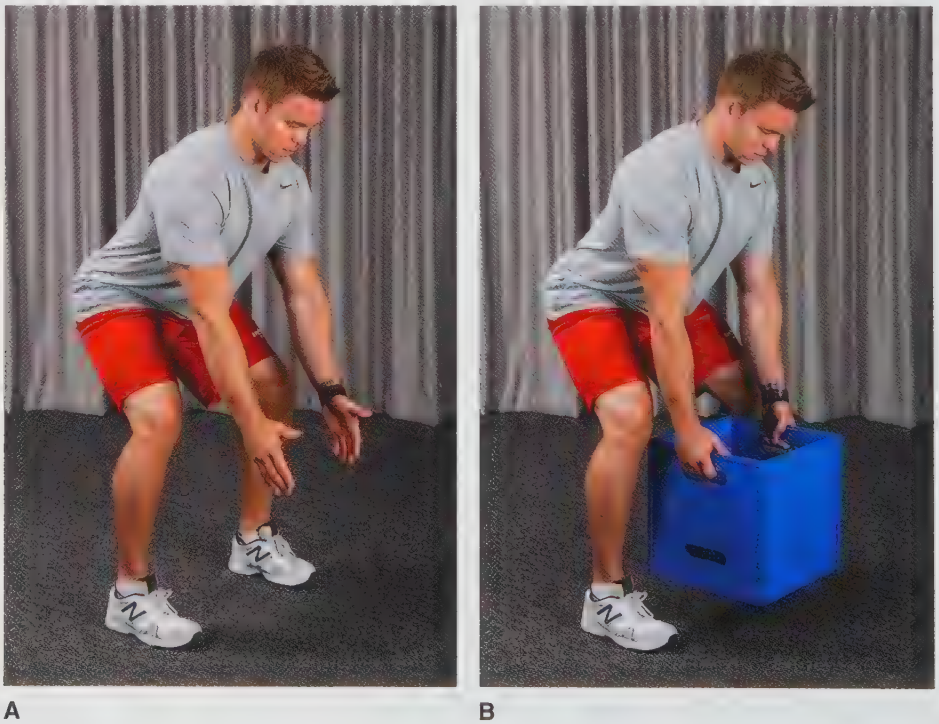

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- Patellar tendinopathy results from the tendon's inability to withstand eccentric forces during impact activities. The rehabilitation program must eventually progress to eccentric impact activities if the patient is to return to this type of activity.

LAB ACTIVITIES

1. Demonstrate the likely gait pattern if your quadriceps strength was 3/5.
2. Demonstrate three strengthening exercises to treat quadriceps strength impairment, given a strength grade of 3/5.
3. Demonstrate two exercises to treat the activity limitations seen in the gait pattern.
4. Is an assistive device necessary? If so, what would you choose for this patient if she had no other impairments? Fit and instruct the patient in use of the device.
5. Demonstrate the likely gait pattern if the patient's quadriceps strength was 2/5.
6. Demonstrate three strengthening exercises to treat the quadriceps strength impairment, given a strength grade of 2/5.
7. Refer to Case Study No. 2 in Unit 7. Instruct your patient in the first phase of the exercise program. Have your patient demonstrate all exercises.
8. Create five exercises for a patient with subacute patellar tendinitis.
9. Determine your patient's 10 repetition maximum for a straight-leg raise with the weight.
   a. At the ankle
   b. Above the knee
10. Teach your patient how to check quadriceps firing during the following activities:
    a. Isometric quadriceps contraction while
       i. Sitting with the knee at 90 degrees
       ii. Sitting with the knee at 70 degrees
       iii. Sitting with the knee at 45 degrees
       iv. Sitting with the knee at 30 degrees
       v. Sitting with the knee at 0 degrees
    b. Wall slide
    c. Sit to stand
    d. Lunge
    e. Gait

CRITICAL THINKING QUESTIONS

1. Read Case Study No. 6 in Unit 7.
   a. List the patient's impairments and activity limitations.
   b. Describe the relationship between this patient's impairments and activity limitations.
   c. Describe the relationship between this patient's impairments, activity limitations, and any participation restriction.
   d. Identify and prioritize short- and long-term goals.
   e. Choose a specific goal, and describe five different exercises used to achieve that goal. Include posture, mode, and movement.
   f. This patient is returning to work as a delivery truck driver. Describe three functional exercises that can prepare him for this activity.
   g. Presume that this same patient is returning to work as a basketball referee. Describe three functional exercises that can prepare him for this activity.
2. Read Case Study No. 3 in Unit 7.
   a. Describe three exercises to address her difficulty with stairs. Include posture, mode, movement, and precautions.
   b. Given her history, describe three exercises to increase the endurance of her quadriceps muscles. Include posture, mode, movement, and precautions.
   c. Describe three exercises to increase the endurance of her calf muscles. Include posture, mode, movement, and precautions.
   d. The patient no longer feels any muscle fatigue when performing the exercises outlined in questions b and c. Describe how you would progress each of these exercises. Include dosage parameters.

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CHAPTER

21 The Ankle and Foot

JILL MCVEY • CARRIE M. HALL

The ankle and foot interact with the knee, hip, and trunk to produce smooth, coordinated movement throughout the entire limb. Understanding these relationships is key to developing a successful therapeutic exercise program for the ankle and foot. Anatomic impairments (e.g., femoral anteversion, genu valgum, forefoot equinus), physiologic impairments (e.g., joint hypermobility, diminished muscle performance, loss of balance), or trauma at one joint can lead to dysfunction at other joints in the kinetic chain. Appropriately addressing this interplay throughout the kinetic chain typically results in improved lower extremity function. Specific examination techniques and exercise interventions are essential for long-term resolution of impairments, activity limitations, and participation restrictions.

COMMON FOOT TYPES

The following suboptimal foot types are described as structural and are therefore considered anatomic impairments.

Subtalar Varus

Subtalar varus is defined as an inverted twist within the body of the calcaneus.[1] While the foot is held in the subtalar neutral position, the bisection of the posterior calcaneus is inverted relative to the bisection of the distal tibia and fibula (**Fig. 21-1**). Subtalar varus may result in excessive pronation during loading response and midstance phases of gait. The subtalar joint may resupinate in midstance; however, if the excessive pronation is significant, the subtalar joint may not reach the ideally neutral to slightly supinated position before heel rise. This may result in decreased midtarsal joint stability and increased forefoot shearing during terminal stance, potentially straining supportive soft tissues.

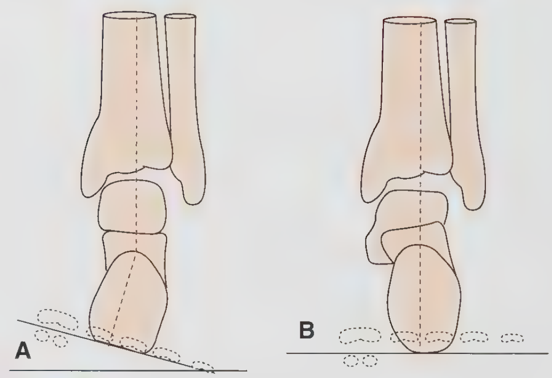


FIGURE 21-1 Posterior view of right foot subtalar varus. **(A)** Uncompensated subtalar varus. **(B)** Compensation for this impairment is usually excessive pronation. (From Gould JA. Orthopaedic and Sports Physical Therapy. 2nd Ed. St. Louis, MO: C.V. Mosby, 1990.)

Forefoot Varus

Forefoot varus is an inversion deviation of the forefoot relative to the bisection of the posterior calcaneus (**Fig. 21-2**).[2] A forefoot varus posture may result in excessive pronation during midstance. As with subtalar varus, prolonged pronation enables excessive forefoot mobility during push off, increasing lower extremity medial rotation when lateral rotation should occur. This rotational fault can contribute to symptoms anywhere up the kinetic chain.

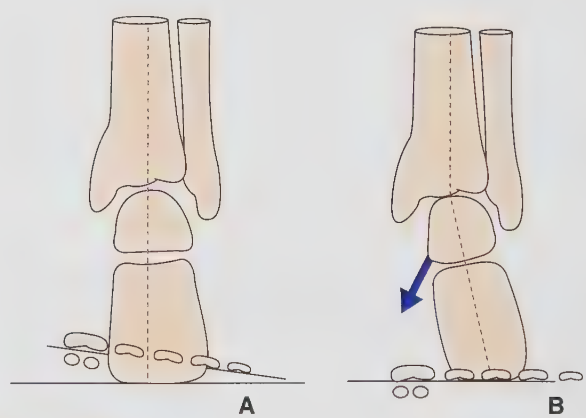


FIGURE 21-2 Posterior view of right foot forefoot varus. **(A)** Uncompensated forefoot varus. **(B)** Compensation for this impairment is usually excessive pronation. (From Gould JA. Orthopaedic and Sports Physical Therapy. 2nd Ed. St. Louis, MO: C.V. Mosby, 1990.)

Forefoot Valgus

Forefoot valgus is an eversion deviation of the forefoot relative to the bisection of the posterior calcaneus (**Fig. 21-3**).[2] This may result in early and excessive supination in midstance phase. This produces foot rigidity and may compromise terrain adaptation

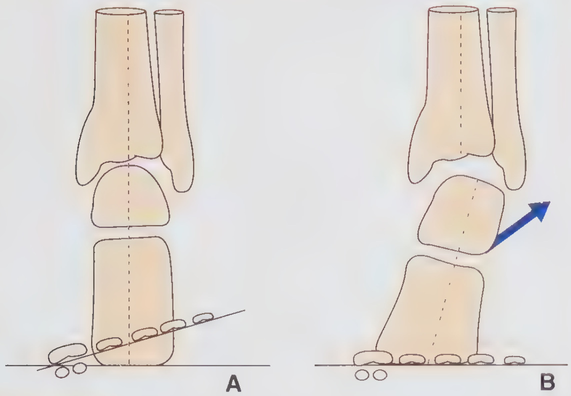


FIGURE 21-3 Posterior view of right foot forefoot valgus. **(A)** Uncompensated forefoot valgus. **(B)** Compensation for this impairment is usually excessive supination. (From Gould JA. Orthopaedic and Sports Physical Therapy. 2nd Ed. St. Louis, MO: C.V. Mosby, 1990.)

and shock absorption. This may also cause a lateral weight shift, creating greater forces at the fifth metatarsal and potential lateral instability. At terminal stance, the subtalar joint is likely to pronate to shift body weight from the lateral stance foot to the contralateral limb. The altered loading and subsequent instability increases the vertical ground reaction forces and may increase the risk of developing plantar pathology.[3]

Ankle Equinus

Ankle equinus is a structural abnormality of the talocrural joint whereby the 10 degrees of talocrural dorsiflexion necessary for gait is absent.[3] If ankle equinus is compensated, the forward progression of the tibia during stance phase forces significantly increases subtalar and midtarsal pronation; this may lead to a variety of lower limb pathologies including Achilles tendinosis, plantar fasciitis, and digital neuritis.[3,4] If uncompensated, the patient may manifest a "bouncy" or apropulsive gait secondary to early heel rise, which excessively increases pressure on the forefoot.[4] During the examination, the clinician must determine if the patient presents with a true osseous deformity versus limited talocrural dorsiflexion due to short or stiff extrinsic musculature or a stiff talocrural joint (see **Building Block 21-1**).

BUILDING BLOCK 21-1

Name one possible deviation in body structures and functions you would expect to see in an individual with:

1. Forefoot varus
2. Ankle equinus

EXAMINATION AND EVALUATION

Examination and evaluation of the foot and ankle must consider the findings related to the foot and ankle and their relationships to more proximal segments. While the tests described in this section are primarily for the ankle and foot and should be considered in any foot and ankle examination, examination of the knee and hip is also essential.

Patient/Client History

The patient's history guides the overall examination and provides the clinician with important information about activity limitations and participation restrictions. In addition to standard history and subjective examination questions, the clinician should inquire about usual footwear and daily activities, as these extrinsic factors can affect (or cause) symptoms.[5] The clinician uses this information to choose tests according to the patient's symptoms and designs a treatment program to address the impairments, activity limitations, and participation restrictions described by the patient.

Balance

Balance is important to assess when a patient presents with foot and ankle dysfunction. See Chapter 8 for details.

Joint Integrity and Mobility

Several special tests are recommended to assess the integrity of foot and ankle structures. Magee[6] provides a complete listing and description of special tests, including varus and valgus stress testing of the ankle and the anterior drawer test.

Muscle Performance

All ankle and foot muscle function should be tested. Any proximal muscles that may affect the foot and ankle should be tested as well, as their weakness can compound distal mechanical faults. Muscular performance of the trunk, hip, knee, foot, and ankle should be tested in a logical order and based on patient history information and the clinician's impression.

Pain

Assessing the patient's pain is performed as part of their subjective examination and further clarified during the objective examination. Palpable tenderness, warmth, and swelling are objective indications of inflammation. The subjective and objective information are then correlated to guide the remaining examination and treatment planning.

Posture

Observation of posture and position of the lower extremity, including the lumbopelvic and hip regions, is an important aspect of the examination.[6–8] A detailed discussion of foot and ankle alignment is available in the online supplement to this text.

Range of Motion and Muscle Length

Range of motion (ROM) and muscle length examination for this region should include both the foot and the ankle as well as the knee, hip, and spine. The following tests of ROM and muscle length should be performed:

- Hip and knee ROM and muscle length
- Femoral anteversion/retroversion
- Calcaneal inversion and eversion ROM
- Midtarsal joint supination and pronation ROM
- First ray position and mobility

- Hallux dorsiflexion ROM
- First to fifth ray mobility
- Ankle dorsiflexion and plantar flexion ROM with the knee flexed and extended

Assessing ankle dorsiflexion with the knee flexed and extended will help determine whether any observed flexibility impairments are due to stiffness/shortening of the gastrocnemius, soleus, or both. As it attaches on the femur, a short or stiff gastrocnemius will limit ankle dorsiflexion with the knee extended whereas a short or stiff soleus will impair ankle dorsiflexion regardless of knee angle.

Impairments of Body Structures

Observed alignment faults may result from either an impairment of body structure or function. Whereas an impairment of body function can be altered with appropriate interventions, such as joint mobilization or muscle strengthening, an anatomic impairment cannot because it is a fixed structural abnormality. However, it can be accommodated with orthotic therapy and movement reeducation to prevent the development of associated impairment of body function. Please refer to the "foot types" section at the beginning of this chapter for information on recognizing structural impairments.

Other Examination Procedures

A variety of additional examination procedures may be used depending on the specific patient situation. For example, patients with diabetes should have sensory testing and assessment of pulses. Anthropometric measurements such as circumferential measures are important in patients with swelling of the foot or ankle. Other measures include:

- Footwear and orthotic assessment to evaluate fit and wear.
- Assessment of foot callous patterns for evidence of shearing and load transfer.
- Observational gait analysis to determine foot and ankle kinematics.

THERAPEUTIC EXERCISE INTERVENTION FOR COMMON IMPAIRMENTS OF BODY FUNCTIONS

Abnormal alignment and movement patterns (see Chapter 9) can excessively stress and strain soft tissue and bony structures, leading to cumulative microtrauma and musculoskeletal pain. If left untreated, this can result in musculoskeletal system pathology that limits participation in meaningful activities. Impairments of body structures (anatomic impairments) throughout the lower extremity can lead to suboptimal alignment and movement patterns of the foot and ankle. Conversely, anatomic impairments of the foot and ankle can impair alignment and movement patterns at the knee, hip, pelvis, and spine.

Therapeutic exercise is an invaluable clinical tool for treatment of body function impairments of the ankle and foot. This section provides examples of therapeutic exercise for the treatment of impairments in balance, muscle performance, pain, posture and movement, ROM, muscle length, joint mobility, and integrity.

The clinician may need to appropriately modify based on individual signs and symptoms. Exercise recommendations for specific diagnoses of the ankle and foot are addressed in a later section.

Balance Impairment

Only a well-conditioned and neurologically trained ankle can function in a variety of directions as the center of gravity fluctuates, sometimes through extremes of motion, as the patient simultaneously performs actions with other extremities. The clinician should take care to vary the speed and intensity of training as appropriate to enable maximal functional carryover and to prevent reinjury. The array of training surfaces and conditions is vast, allowing ample opportunity to offer fresh challenges throughout a patient's rehabilitation.[9]

An average person recovering from an ankle or foot injury/condition should be able to balance on one leg for 30 seconds with eyes closed and mild external perturbation (i.e., with a balance board, foam, a balance machine, or another person providing an external force). This prepares the patient to regain balance through improved neurologic input to the ankle and foot musculature.

The Specific Adaptations to Imposed Demands (SAID) principle states that given stressors on the human body, whether biomechanical or neurological, the involved tissues will specifically adapt to the stressor.[10] While standing on a pillow is helpful to develop increased balance time and neurologic control, the intervention needs to be eventually tailored to enable return to specific functional activity performance. An elderly patient who sustains an injury from slipping on gravel may not prevent future falls unless the surface they practice balance on is similar to gravel. Another patient may need to return to high-level gymnastics; in this case, sport-specific drills implemented on a low balance beam are appropriate. Plyometric exercises in the form of progressive height jump-down activities prepare the ankle/foot to balance during high-impact activities.

Restoration of balance and coordination requires position sense, or proprioception. With an ankle sprain or muscle strain, peripheral proprioceptive nerve fibers are often injured. Just as muscles can become deconditioned after a period of disuse, so too can proprioception. The proprioceptors should be retrained in a controlled, progressive manner starting as soon as possible. Use of a balance board can provide predictable and progressive stress. The following exercise progression can be used at home without special equipment:

- Balancing on one leg with eyes open; progress to eyes closed standing in a door fame with hands close to the door jam for safety.
- Controlled weight shifts to the limits of stability while standing on one leg with eyes open; progress to eyes closed.
- Swinging the uninvolved lower extremity first in flexion and extension and then in abduction and adduction (see **Self-Management 21-1**). The faster and greater excursion of the swing, the more the static stance is challenged.
- Hopping from one foot to the other with practice of stabilization in one-legged stance.

Elastic bands can be used for the advanced patient. The band is tied in a circle and looped around a table leg or similar secure structure. Standing facing the table leg, the patient places their

SELF-MANAGEMENT 21-1
Balance Activities

Purpose: Increased balance on a single leg.

Position: Standing on one leg, near a counter or in a doorway to provide a surface to stabilize if necessary. Keep a slight bend in the knee.

Movement Technique: Level 1: Practice standing on a single leg with your eyes open for 30-second periods, practicing with and without a mirror.

Level 2: Eyes open, no mirror, standing on unstable surface.

Level 3: Eyes closed.

Level 4: Eyes closed, standing on unstable surface.

Dosage:

Repetitions: ______________________

Frequency: ______________________

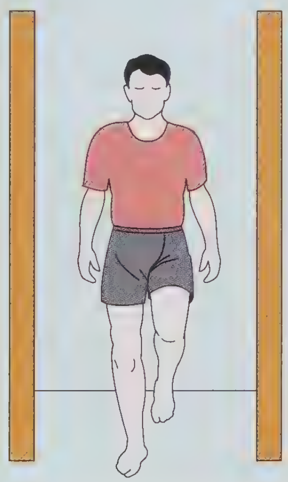


FIGURE 21-4 Resisted hip adduction retrains balance and proprioception on the weight-bearing limb. A chair or other stable surface must be available to ensure patient safety.

uninvolved ankle inside the circled elastic band. While balancing on the involved foot, the patient extends their hip against the elastic band. The patient performs extension–flexion oscillations before returning to double-limb support. The patient then turns 90 degrees and performs adduction–abduction oscillations into the band (**Fig. 21-4**). The rotating continues until the patient returns to the initial starting position. The exercise can be progressed by:

- Increasing oscillation repetitions or speed
- Moving the uninvolved limb through noncardinal planes
- Upgrading the tension of the elastic band
- Adding foam or a balance board with single-limb support.

The importance of removing the visual system during balance training cannot be overemphasized. Individuals with a history of multiple ankle sprains present with impaired postural control as a result of repeated trauma to articular and ligamentous joint receptors. These individuals must rely heavily on visual cues to maintain equilibrium during dynamic activities.[11] Forcing the somatosensory system to reorganize is only possible when it is trained independent of the visual system (see **Building Block 21-2**).

BUILDING BLOCK 21-2

How might balance programs differ for the following individuals:

1. A 21-year-old college basketball player recovering from a mild ankle sprain
2. A 75-year-old woman with osteopenia recovering from a fall

Muscle Performance

Resisted exercise is used to restore muscle performance because of muscle strain, neurologic deficit, or disuse. Although open chain exercise is useful to improve physiologic strength parameters and patient awareness of muscle function (i.e., muscle reeducation), it is critical to progress the exercise to functional weight-bearing activities as soon as tolerated. In many cases, closed chain activity can be broken into simple steps to serve as a starting point for exercise prescription.

Intrinsic Muscles

The intrinsic muscles of the foot contribute to the support of the medial longitudinal arch, and work with the plantar fascia, plantar ligaments, and extrinsic musculature to control the stresses on the foot during gait.[12]

Intrinsic muscle strengthening can be performed in a sitting position. The patient makes an arch with the tarsal and metatarsals by pressing the first metatarsophalangeal joint (MTP) into the floor while rolling the arch upward. The heel and first MTP must remain in contract with the ground. Repeat this process holding for 6 seconds (see **Fig. 21-5**). Using the toes to pick up marbles and other small objects exercises the intrinsic musculature, but also recruits the long toe flexors and other extrinsic musculature, which may not be a desirable cocontraction to facilitate. Additionally, these are low-intensity exercises and may require high repetitions to achieve a training effect. Maintenance of the longitudinal and transverse arches during closed chain exercises such as small knee bends, the walk stance position, stair-stepping, and gait use the intrinsic musculature in a functional manner (see **Self-Management 21-2**). The clinician observes patient performance carefully to prevent unwanted hammer or claw toe positions during functional training drills (see **Building Block 21-3**).

FIGURE 21-5 Intrinsic muscle strengthening of the foot.

SELF-MANAGEMENT 21-2
Squatting with Longitudinal Arch Control

Purpose: Increased strength of foot intrinsics and motor control of the lower extremity.

Position: Standing, bare feet, with the arch of your foot actively lifted up, without clawing of toes (**Fig. A**).

Movement Technique: While maintaining control of the arch of your foot, squat until your thighs are parallel to the ground, then return to the starting position (**Fig. B**).

Dosage:

Repetitions: ______________________

Frequency: ______________________

A

B

BUILDING BLOCK 21-3

How might you instruct foot intrinsic strengthening so as to maximize appropriate form?

Extrinsic Muscles

The ankle musculature is vulnerable to neurologic weakness at the peripheral or nerve root level (see "Functional Nerve Disorders" later in this chapter). Careful examination and evaluation will diagnose the underlying etiology of the weakness. Optimal strengthening effects cannot be realized until neurologic sources of weakness are resolved.

Once it is determined that the musculature could benefit from progressive strengthening, open chain strengthening exercises for extrinsic musculature can be performed with elastic bands, tubing, or manual resistance. Muscles must be recruited in isolation before they can be strengthened in functional exercises to avoid substitution patterns. Care must be taken not to overload weak muscle groups, which may cause unwanted substitution patterns, abnormal joint shearing, and pain.

Strengthening the gastrocnemius and soleus can be performed in a long-sitting position with a towel roll under the talocrural joint providing heel clearance from the floor. Adding inversion will better isolate the tibialis posterior, whereas adding eversion will better isolate the peroneals. Strengthening of the tibialis anterior and toe extensors (**Fig. 21-6**) can be completed with an elastic band looped around a table leg or similar secure structure. The patient dorsiflexes against the resistance of the band, inverting slightly to isolate the tibialis anterior if desired. If this position may also be used to train pronation and supination (**Fig. 21-7**), the clinician should ensure the motion originates at the subtalar joint and not at the tibiofemoral or hip joint.

Resisted talocrural plantar flexion can be performed in a long-sitting position with the elastic band wrapped around the plantar surface of the forefoot. While holding the opposite end of the band, the patient plantar flexes against the resistance of the band (**Fig. 21-8**). A towel roll or small pillow placed under the leg proximal to the talocrural joint provides heel clearance from the floor. Resisted talocrural dorsiflexion (Fig. 21-6) and foot/ankle pronation and supination (Fig. 21-7) can be completed with an elastic band looped around a table leg or similar secure structure. The patient performs the intended movement against the resistance of the band. During these pronation and supination activities, the clinician should ensure the motion originates at the subtalar joint and not at the tibiofemoral or hip joint. A pulley and weight stack system can also be used for resistance.[9] For all extrinsic muscle strengthening activities, slow eccentric lengthening should be emphasized because of the deceleration function of these structures during gait. In the active population, it is common to see athletes perform a high volume of repetitions with various grades of exercise tubing, yet the musculature does not significantly fatigue.[9] For these individuals, manual resistance applied for 3 to 5 seconds (progressing to 6 to 10 seconds) for 10 to 12 repetitions may be a more appropriate challenge.

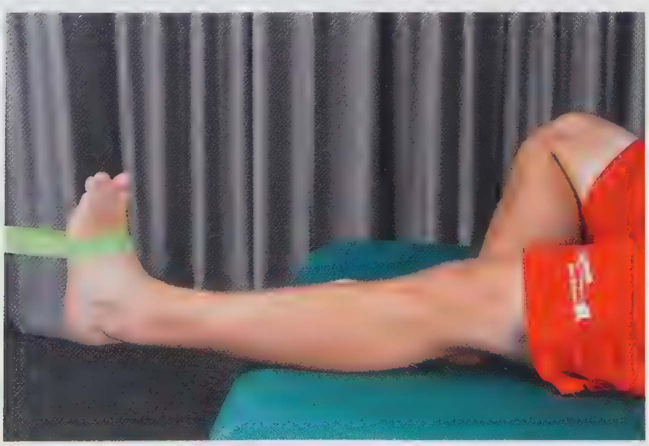


FIGURE 21-6 Talocrural dorsiflexion with a resistive band. A patient may require a high volume of repetitions to drive strength changes given the tibialis anterior's role during gait.

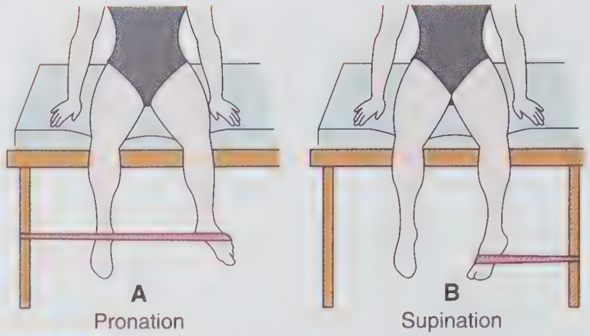


FIGURE 21-7 Resisted supination and pronation with the knee flexed. Flexing the knee minimizes hip rotation substitution. **(A)** Resisted pronation. **(B)** Resisted supination.

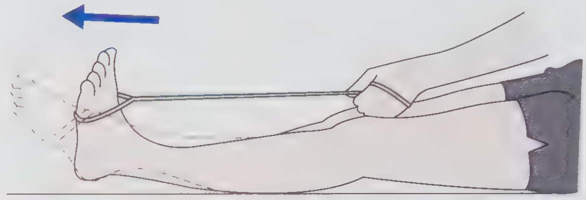


FIGURE 21-8 Resisted plantar flexion with a resistive band should emphasize plantar flexor-controlled eccentric dorsiflexion.

Closed chain, weight-bearing exercises are a natural progression toward functional activity recovery. Talocrural joint plantar flexors can be strengthened by performing double-leg toe stands off the end of a stair step with body weight equally distributed, with the emphasis on eccentrically controlling descent to end-range talocrural dorsiflexion without excessive pronation (**Fig. 21-9**). This is followed by concentric contraction to a neutral or slightly plantar-flexed position without excessive supination. The exercise is progressed by shifting weight toward the involved extremity and eventually performing a single-heel rise.

Dynamic ankle strengthening and stabilization can be performed in a sitting position with the knee at 90 degrees with the foot in contact with a small physioball (**Fig. 21-10**). This can be progressed to closed chain activities such as step-ups or lunges on a Both Sides Up (BOSU) device (**Fig. 21-11**). The latter exercises improve dynamic joint stabilization in a potentially safer context than with a wobble or balance board due to the wide and flat base of support of the BOSU device.[13]

Foot and ankle supinators can be strengthened by performing double-leg arch lifts. In a standing position, the patient is instructed to lift both arches, thereby rocking outward to the lateral portion of the feet. The clinician should ensure the patient's first MTP joint remains in contact with the floor in order to optimize the peroneus longus' action of stabilizing the first ray. Slow, controlled lowering to a neutral position is emphasized. Exercise intensity is increased by progressing body

FIGURE 21-9 A standing toe raise will strengthen a number of muscles throughout the foot and ankle as medial, lateral, and intrinsic muscles stabilize the foot and ankle while the gastrocnemius and soleus muscles plantar flex the ankle.

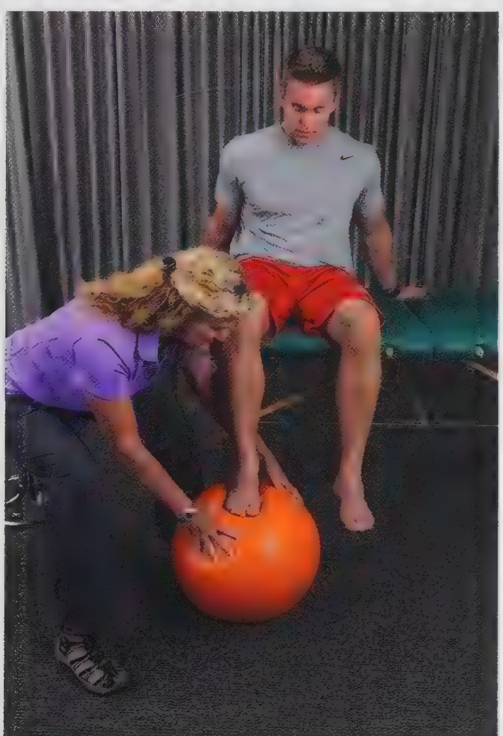


FIGURE 21-10 The therapist provides perturbations to the physioball while the patient maintains a neutral position of the knee and foot. To increase difficulty, start with predicted patterns and move to unpredicted patterns or close the eyes for an additional challenge with perturbations.

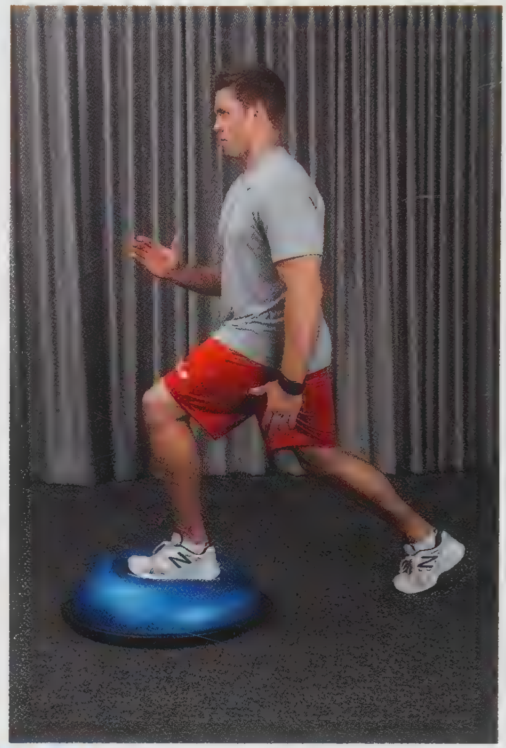


FIGURE 21-11 BOSU ball lunge. This device provides stability challenges to the ankle in a safe context when the flat side faces the floor.

weight toward the involved extremity and varying the stability of the standing surface.

Pain

Prescription of appropriate exercise intensity is key when addressing pain. The severity, irritability, and nature of the patient's pain must be assessed and considered when developing and progressing exercise. For example, exercise for the involved joint should be initiated in the pain-free range during the acute stage, just up to the painful range in the subacute stage, and slightly into the painful range in the chronic stage. Active-assisted exercise may be required if the patient demonstrates poor active control. Exercise for the involved limb's hip and knee may be indicated to prevent disuse weakness, improve proximal control, and decrease pain. In many situations, stationary biking is tolerated well and can maintain or improve cardiovascular and musculoskeletal health. Soft-tissue mobilization, taping and wrapping, thermotherapy, electrical stimulation, and a variety of other therapeutic modalities may be beneficial in conjunction with exercise for the control of pain and swelling.

Treating pain requires the clinician to determine its biomechanical cause. This chapter provides the reader with the theoretical framework and sample exercise options to diagnose and treat the underlying cause of pain.

Posture and Movement Impairment

Posture and movement impairments are often treated simultaneously with the foot and ankle. Ideal alignment and movement should be emphasized with all interventions, regardless of which impairments are addressed.

The most common faulty movement patterns affecting the ankle and foot complex are excessive pronation and supination and should not be reinforced in prescribed exercise (see **Patient-Related Instruction 21-1**). The impairments responsible for excessive pronation (e.g., short gastrocnemius, stiff talocrural joint, forefoot varus, weak posterior tibialis) or supination (e.g., hypomobile first ray, hypomobile supinated talus post immobilization, ankle equinus) must be treated specifically and addressed during functional activity performance.

Numerous repetitions of exercise derived from gait components (e.g., walk stance, single-limb stance, step-through) should be employed frequently throughout the day to shape neuromuscular function and change a habitual faulty movement pattern (**Fig. 21-12**).

Functional exercise can begin early in the rehabilitation process with consideration of the nature of the injury. The aim of a functional exercise progression is to control a variety of motions into and out of a static position at varying speeds, to further reinforce ideal posture and movement habits. The program should also be consistent with the patient's activity level and functional goals. Trunk and lower extremity alignment, strength, mobility, and movement patterns must be assessed and treated during a functional exercise program.

Ambulating on a painful foot without an assistive device results in compensations and abnormal gait biomechanics, cumulatively stressing the lower extremities and trunk. These compensations can become habits that are difficult to alter.[14] Since gait is a primary functional goal, the patient is encouraged to use a four-point gait pattern with walker or two axillary crutches in conjunction with controlled partial weight bearing and a near-normal gait pattern (i.e., heel-to-toe pattern). External support is valuable when performing static and dynamic weight-shifting drills in preparation for full weight bearing. Static weight-shifting drills consist of progressively shifting weight toward the involved foot. A bathroom scale under each foot, indicating the relative proportion of weight bearing, can be used for objectivity, control, and motivation. Dynamic weight-shifting drills may include the patient's involved foot on the floor and the uninvolved extremity stepping forward and backward. This drill can increase weight-bearing tolerance, promote heel to toe weight transfer, and facilitate controlled talocrural dorsiflexion.

Patient-Related Instruction 21-1

Ideal Alignment During Walking

You should attain ideal alignment during walking. The most difficult phase to control is during the weight-bearing phase of the step. Place the heel, ball of the foot, and toes down on the floor as three distinct areas. The heel should hit slightly on the outside border without turning the entire foot out. The weight line should progress from the outside of the foot toward the big toe. Attempt to maintain the knee over the toes, with the foot progressing straight ahead and the long arch of the foot held upward. If these alignments are maintained throughout the weight-bearing period, the foot should feel stable for push off.

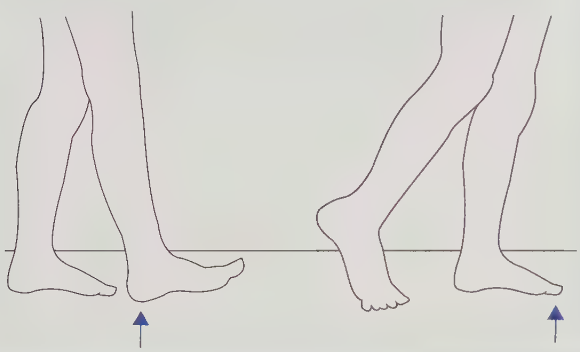


FIGURE 21-12 Walk-stance progression. Keeping the pelvis in neutral and minimizing rotation at the knee, the patient shifts their weight toward the front leg **(A)** and then flexes the back hip to 90 degrees **(B)**. The patient may balance here for as long as able before returning their flexed leg back to the start position.

Medial-lateral weight shifting can be facilitated through a circular weight-shifting drill. The patient uses an assistive device for balance and stands with weight equally distributed between their feet. The patient shifts their weight in a slow circular pattern beginning at the fifth metatarsal head. The patient then progresses posteriorly to the lateral heel, medially to the medial heel, and anteriorly to the first metatarsal head. The drill can be performed clockwise and counterclockwise and may be easier for the patient to perform with both lower extremities simultaneously. As weight-bearing tolerance improves, the drill can be progressed by increasing body weight toward a single-leg stance.

Functional exercises such as retrowalking, side-stepping, cross-over stepping, and resisted walking are also beneficial for upgrading the patient's level of function. These drills are progressed by distance, speed, and resistance through elastic tubing or a pulley and weight-stack system. Exercise must be progressed to higher levels of function (e.g., stair stepping, running, jumping, cutting, sidestep over cones, slideboard, clock step) that are appropriate for each patient's goals (see **Self-Management 21-3**). Jumping down may be a critical functional demand for athletes and persons returning to moderate- and high-intensity occupations. This task can be initiated bilaterally on a 2- to 4-in box.

Ideal alignment and movement patterns must be reinforced with each repetition of any drill. Orthotic prescription or counseling about proper footwear may be necessary to promote ideal function (see **Patient-Related Instruction 21-2**). If the patient requires a shoe to control excessive pronation, they may benefit from learning how to stress test potential footwear (**Display 21-1**).[15] However, exercise in bare feet may be appropriate during low- to mid-level activities to ensure foot muscle function enables ideal alignment and movement patterns instead of the orthotic or footwear. An exception is a severe anatomic impairment (e.g., significant forefoot varus), for which the use of a custom orthotic during all exercise is recommended.

ROM, Muscle Length, Joint Integrity, and Mobility

Pronation and supination involve all cardinal planes of movement: pronation incorporates dorsiflexion, abduction, and eversion, while supination incorporates plantarflexion, adduction, and inversion. The talocrural, subtalar, and midtarsal joints have triplane axes and therefore demonstrate triplane motion, meaning that they move in a coordinated fashion through three planes at once, to varying degrees. For example, the subtalar joint everts more than it abducts and dorsiflexes when pronating.

Passive and active-assisted ROM exercise for treatment of hypomobility should include consideration of triplane movement. When assessing accessory joint mobility or initiating joint mobilization techniques, the clinician should guide the joint through its major planes of movement (e.g., assessing subtalar joint eversion and abduction) to accurately determine the available motion.

Open chain active stretching can be progressed to closed chain passive stretching and eventually to utilization of the new mobility during functional movements. Any exercise should promote mobility of the hypomobile segment/plane while stabilizing the relatively more mobile regions in order to resolve the mobility impairment.

SELF-MANAGEMENT 21-3
Clock Step

Purpose: Improve dynamic stability, control, coordination, and proprioception of the lower extremity.

Position: Standing on involved lower extremity in the center of a circle with markers at each hour (i.e., like a clock).

Movement Technique: Single-leg squat with involved lower extremity while reaching out in a clock hour-type pattern with opposite lower extremity. Toe touch with the outstretched lower extremity. Do this in clockwise and counterclockwise directions.

Dosage:

Repetitions: ____________ times ____________ seconds

Frequency: ________________________________

First Ray Hypermobility

First ray hypermobility is defined as dorsal translation of the first metatarsal and medial cuneiform with a soft endpoint. The structures responsible for first ray stability are plantar ligaments, extrinsic muscles inserting onto the first ray, and the plantar aponeurosis. Any changes in these structures can lead to abnormal function and progressive deformity of the first ray. If deformity develops in the first ray, functional stability is often compromised.[16] For example, during the stance phase of gait, vertical ground reaction forces will excessively dorsiflex the first ray, transferring the load to the other metatarsals.[17] This may lead to acquired pes planus, metatarsalgia, and metatarsal stress fractures.

Patient-Related Instruction 21-2

Purchasing Footwear

Know your foot type. Your shoe size and width give a two-dimensional picture of your foot, but your foot is a three-dimensional object. Your foot's arch height affects the fit of your shoe. You can gauge your foot's arch height with a "wet test." Wet the soles of your feet, and then stand on a dry surface, such as a piece of cardboard, to leave an imprint of your foot. The imprint shows whether you have a flat (pronated), normal, or high-arched (supinated) foot. Match the bottoms of the shoes you are considering with your foot type.

Specific guidelines should be followed in addressing hypermobility impairments:

- In the acute phase, the hypermobile segment is protected from excessive motion by taping, bracing, casting, or use of more stable footwear.
- Adjacent hypomobile segments are mobilized with manual therapy or mobility exercise to prevent excessive motion from transferring to the hypermobile segment.
- Dynamic stabilization exercise should be initiated at the hypermobile segment while promoting controlled mobility at adjacent segments.

At the foot and ankle, dynamic stabilization exercise can include proprioceptive training (see the "Balance Impairment" section) and functional retraining (see the "Posture and Movement Impairment" section).

DISPLAY 21-1

Shoe Stress Tests

Individuals who demonstrate excessive pronation will benefit from motion-controlling footwear.

A

(A) Longitudinal stress. The toe break should occur where the patient's naturally does.

B

(B) Torsional stress. The shoe should "give" only minimally when twisted along the longitudinal axis.

C

(C) Heel counter pinch. There should be minimal to no "give."

Talocrural Joint

Talocrural joint dorsiflexion is a common limitation after injury or immobilization of the foot and ankle, resulting from a short or stiff gastrocnemius or soleus muscle, talocrural joint hypomobility, or both. Limited talocrural dorsiflexion can provoke anterior ankle discomfort during dorsiflexion. The clinician must rely on a careful examination to determine the source.

Gastrocnemius and soleus stretching are depicted in **Figure 21-13**. Carefully observe the patient during this activity to prevent excessive foot pronation to isolate dorsiflexion to the talocrural joint. If the patient is using the long-sitting position, the clinician must ensure proper patient positioning by preventing posterior pelvic tilt and lumbar flexion due to stiff or short hamstrings. A cushion under the pelvis reduces tension in the hamstrings and improves the patient's position (Fig. 21-13B). Talocrural joint dorsiflexion ROM can also be performed in a long-sitting position, but a pillow is placed under the knee to minimize the gastrocnemius and hamstring stretch. The soleus is stretched in this position if the talocrural joint has adequate dorsiflexion mobility (Fig. 21-13C).

The supine position is an alternative to the long-sitting position and can accommodate short hamstrings, maintaining more optimal lumbopelvic-hip alignment. It has the added benefit of stretching the hamstrings without overstretching the lumbar spine (**Evidence and Research 21-1**)

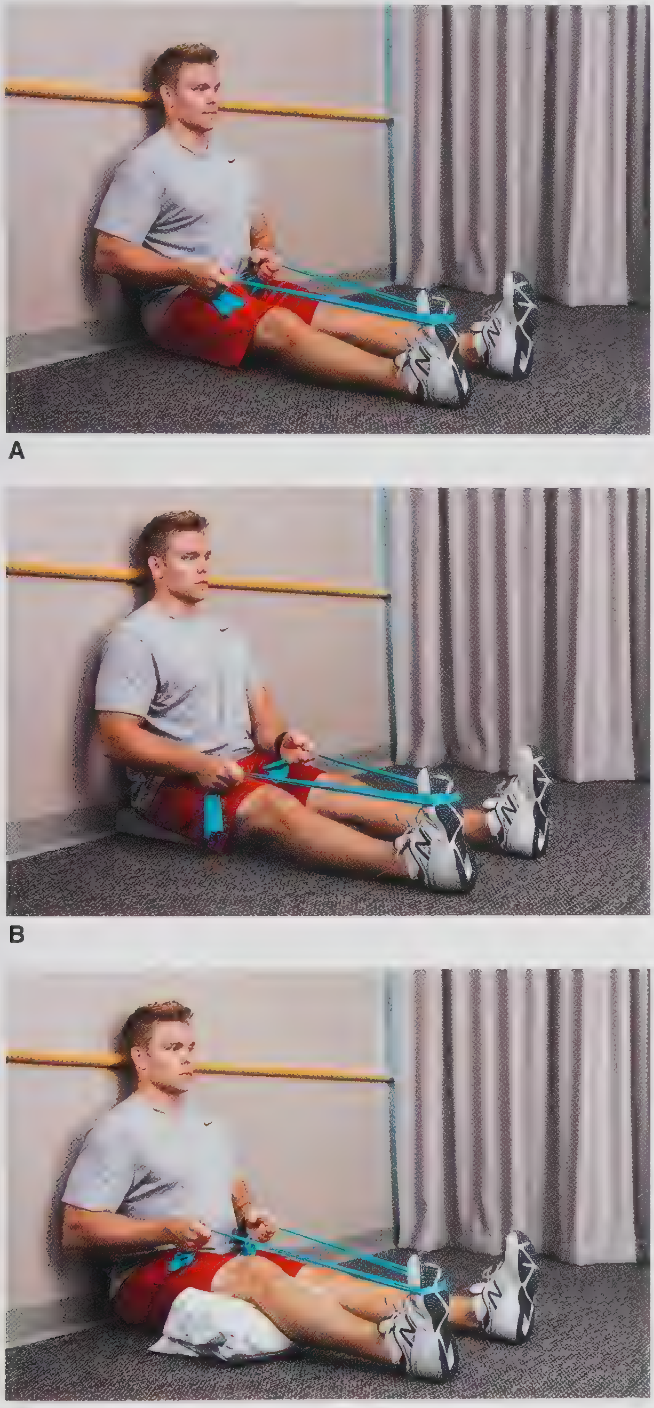


FIGURE 21-13 Increasing dorsiflexion mobility of the ankle. **(A)** Long-sitting gastrocnemius muscle stretch using a band or towel. **(B)** A cushion under the pelvis relieves some hamstring tension, allowing proper lumbopelvic posture. **(C)** Talocrural joint and soleus muscle stretching is emphasized by placing a pillow under the knees.

EVIDENCE and RESEARCH 21-1

Calf Stretching

Multiple studies find that a basic static stretching protocol is effective in not only increasing passive ankle dorsiflexion ROM[18,19] (acute effects, unilateral PF SS), but also reducing peak muscle force production and pre-activation, reducing jump height, and increasing postural sway[18-20] (PF stretch training, unilateral PF SS, acute effects). These effects resolved in approximately 10 minutes, indicating that static stretching may have an immediate effect on central nervous system inhibition[18,19] (unilateral PF SS, acute effects of unilateral PFs).

Despite the multiple effects of stretching on neuromuscular function, static stretching has no effect on injury prevention, and is not recommended in the absence of or in place of a proper warm-up[21] (update on ankle sprains).

Manual therapy techniques can be used to treat talocrural joint hypomobility. The patient can supplement in-clinic manual interventions with self-mobilization of the talus as part of their home program. The patient places the involved foot on a step and loops a stiff band or tubing around the anterior aspect of the ankle, securing the end under their other foot. The patient performs a set of lunges, with the band providing a posterior glide force on the anterior talus. The height of the step and stiffness of the band can be adjusted to improve patient comfort and increase the specificity of the mobilization. Alternately, the patient can loop the band around the back of the ankle on the tibia and place the other end of the loop around a table leg in front of them. The patient assumes a squat (either double or singe leg) position. As the patient performs a squat, the band will pull the tibia anteriorly, which must occur with normal arthrokinematics.

Lower extremity biomechanics must be considered when progressing dorsiflexion ROM exercises to a weight-bearing position. If the subtalar joint is pronated in stance, talocrural joint or gastrocnemius stretching will increase the pronation forces in the rearfoot, midfoot, and/or forefoot. Stretching should be completed with the following watch points (**Fig. 21-14**):

- The patient stands at arm's length plus approximately 6 in away from the wall.
- The subtalar joint is actively stabilized in neutral or slight supination.
- The involved foot is positioned with its lateral border perpendicular or slightly toe-in to the wall to minimize subtalar pronation forces.

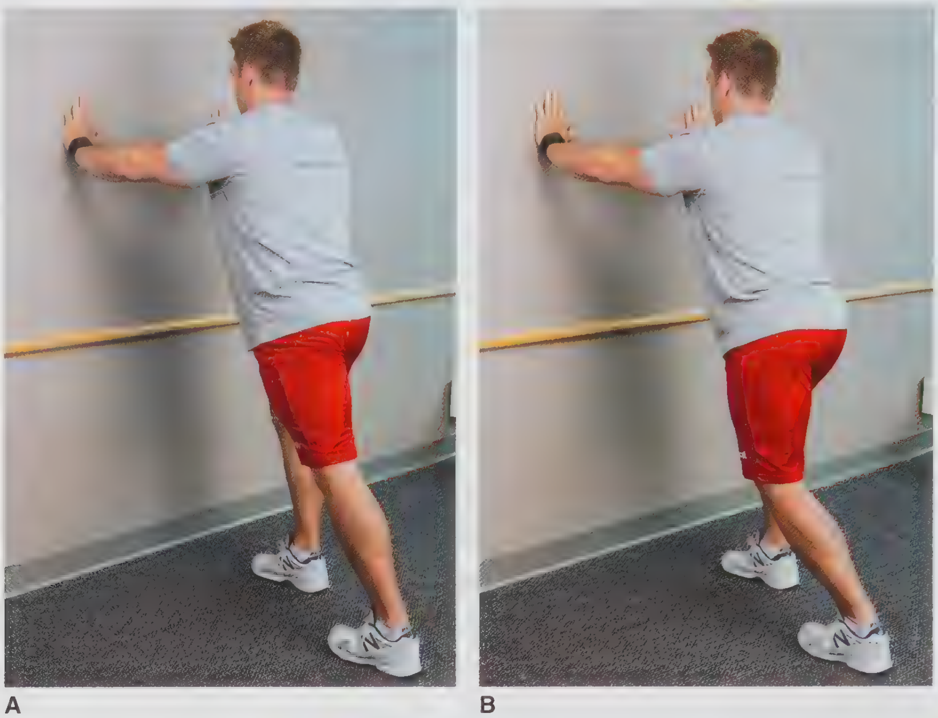


FIGURE 21-14 **(A)** The gastrocnemius muscle can be stretched by leaning against a wall. Be sure to instruct the patient to keep the foot in the sagittal plane. Any turn-out of the foot will contribute to pronatory forces. **(B)** The soleus muscle can be stretched with the knee slightly flexed. Again, instruct the patient to keep the foot in the sagittal plane.

- A small hand towel folded under the medial longitudinal arch may help support the subtalar and midtarsal joints.
- Keep knee extended to stretch the gastrocnemius; bend knee slightly to isolate the soleus.

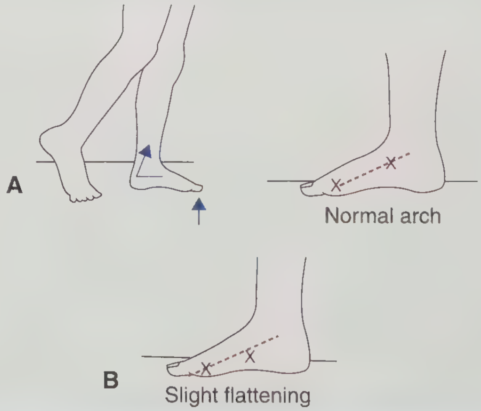
Active exercises should be incorporated into a patient's functional activities throughout the day. For example, small knee bends in standing with the arch stabilized may reinforce functional mobility of talocrural dorsiflexion instead of subtalar or midfoot pronation. Progressing small knee bends to a walk stance position reinforces gastrocnemius lengthening as the knee is in extension. The walk stance position can also be used to mobilize the hallux in order to ensure appropriate extension at terminal stance. Therapeutic exercise progression must incorporate functional retraining of newly gained mobility during swing phase and during late midstance of gait, when maximal dorsiflexion is required. As previously stated, the patient must maintain a subtalar neutral position and avoid a toe-out position with all activities (see **Patient-Related Instruction 21-3**).

Step-down training can facilitate controlled eccentric lengthening of the calf muscle group and of the knee and hip extensors. A patient stands on a 2- or 4-inch box and is instructed to maintain heel contact of the involved side while lowering the uninvolved heel to the floor (**Fig. 21-15**). This exercise may be progressed by increasing the step height, speed, and/or direction of movement of the uninvolved limb.

Patient-Related Instruction 21-3

Ankle Mobility and Walking Patterns

To restore the most ideal walking pattern, you must have adequate ankle mobility. You will be asked to perform a specific exercise or series of exercises frequently throughout the day to improve your ankle mobility. The pictures show what your walking pattern should look like. Halfway through the step, you need the most ankle mobility. Be sure that your foot remains pointed forward and does not toe-out (**Fig. A**). Be sure that you do not allow your arch to flatten (**Fig. B**).



Subtalar Joint

Subtalar joint supination mobility can be addressed with the patient sitting with the involved distal leg placed on the opposite knee. Full active supination is performed, followed by the patient using their hands to progressively pull the calcaneus and foot into greater supination (**Fig. 21-16A**). If combined with dorsiflexion, this exercise also stretches the peroneal musculature. Subtalar joint pronation mobility can be completed in a similar position by the patient actively pronating and applying graded overpressure (Fig. 21-16B). If combined with dorsiflexion, this exercise also stretches the tibialis posterior muscle. Therapeutic exercise progressions should involve functional retraining of the new pronation and supination mobility during the appropriate phase of the gait cycle.

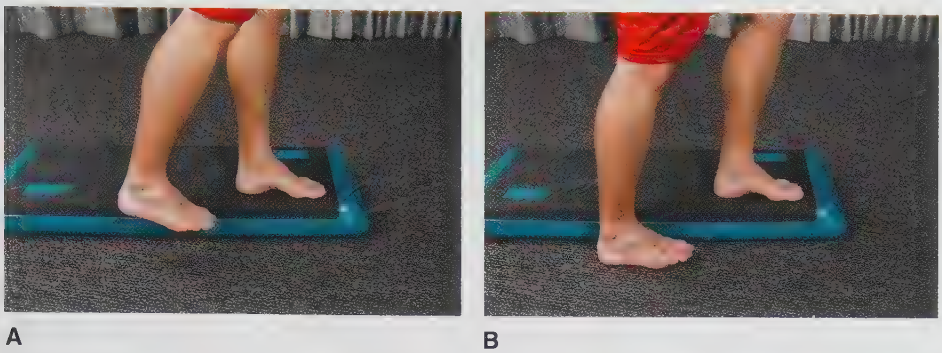


FIGURE 21-15 The medial longitudinal arch is actively lifted and stabilized **(A)** and is sustained as the opposite foot is lowered to the floor **(B)**.

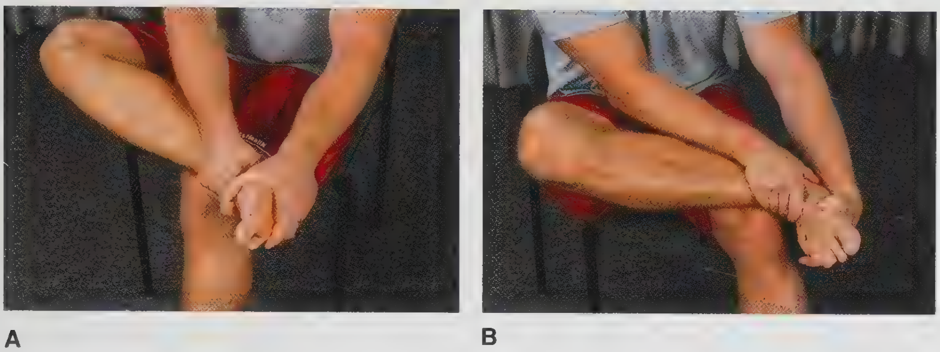


FIGURE 21-16 Passive stretching for triplane motion of the foot. **(A)** Subtalar joint supination. **(B)** Subtalar joint pronation.

Swelling

Swelling is often the result of impaired joint or soft tissue integrity. As the ankle is the most dependent weight-bearing joint in the body, swelling can become a chronic problem. Early intervention is critical to efficiently treat this impairment. Low-level dynamic exercise and compression in conjunction with frequent elevation can be effective for control of swelling. Emphasis is placed on high-repetition, low-intensity dynamic exercise for adjacent noninjured joints. For example, a patient with swelling at the rearfoot and pain with subtalar joint supination may be instructed how to perform elevated active toe flexion and extension as well as midrange talocrural joint plantar flexion and dorsiflexion (see **Self-Management 21-4**). High-repetition exercise can be prescribed as multiple repetitions at one sitting, but it is probably more effective if prescribed as moderate repetitions completed frequently throughout the day (e.g., every 2 hours).

SELF-MANAGEMENT 21-4
Toe and Ankle Active ROM

Purpose: Increased mobility in the foot and ankle after an injury

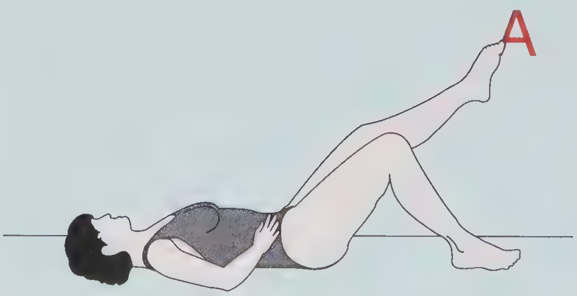
Position: Lying on your back with your foot elevated above chest level

Movement Technique: Repeatedly flex and extend your toes. Move your ankle up and down or write the alphabet with your ankle

Dosage:

Repetitions: ____________________

Frequency: ____________________



THERAPEUTIC EXERCISE INTERVENTION FOR COMMON ANKLE AND FOOT DIAGNOSES

Although therapeutic exercise prescription should be based on the impairments, activity limitations, and participation restrictions of each patient, certain impairments are commonly associated with specific diagnoses. Though this section is not exhaustive, it addresses the most common conditions encountered. The problems fall into the broad categories of connective tissue disorders (ligament sprains and ankle instability), fractures, functional nerve disorders, localized inflammation (e.g., heel pain/plantar fasciitis, posterior tibialis tendinitis/tendinopathy, medial tibial stress syndrome (MTSS), and Achilles tendinosis), and postsurgical rehabilitation (Achilles tendon repair and total ankle arthroplasty [TAA]).

Ligament Sprains

Ligament sprains are the most common sports-related injuries to the foot and ankle.[22–25] Between 70% and 80% of the sprains involve the anterior talofibular ligament (ATFL), calcaneal fibular ligament (CFL), or posterior talofibular ligament (PTFL).[8,26–28] Ligaments of the midfoot, including the dorsal calcaneal cuboid and the bifurcate ligament, may also be involved. The mechanism of injury is usually an inversion and plantar flexion twist. Isolated injuries of the ATFL constitute 65% of ankle sprains, and a combination injury involving the ATFL and CFL comprise 20% of the cases. Isolated injury of the CFL or PTFL is rare.

Ligament sprains are generally classified as one of three grades:

- Grade I: minor tearing with no functional loss of ankle stability.
- Grade II: partial tearing of the ligament with moderate instability.
- Grade III: complete rupture with significant functional instability.

Grade III sprains are further classified by degrees of injury. First-degree lateral sprains suggest complete rupture of the ATFL. A second-degree sprain is a complete rupture of the ATFL and CFL. A third-degree sprain suggests a dislocation in which the ATFL, CFL, and PTFL are ruptured.[29]

The patient can usually recall the mechanism of injury and note a specific site of pain and tenderness. Local edema is often observable. Ecchymosis may occur, indicating injury to blood vessels in the area. Stability testing of the affected ligaments may produce guarding, pain, and excessive mobility.

Syndesmosis sprains involve a disruption of the distal tibiofemoral ligaments and can occur in up to 24% of ankle injuries. This results in a diastasis, or widening, of the mortise at the talocrural joint. The mechanism of injury is external rotation on a fixed foot or extreme dorsiflexion. These mechanisms force the talus into the mortise formed by the tibia and fibula, widening this space and disrupting the distal tibiofibular ligaments; this can worsen and lead to degenerative joint changes. Clinically, reports of pain out of proportion to the injury has the highest sensitivity for diagnostic accuracy, but weight-bearing radiographs may be necessary to assess the integrity of the tibiofibular joint with a suspected syndesmosis sprain. If missed on initial evaluation, the patient may subsequently complain of posterior ankle pain, particularly when trying to push off of the involved ankle, or anterior pain when the foot and ankle are loaded.

Healing of a ligament sprain, as with soft-tissue injuries, follows a process of inflammation, repair, and remodeling. These events are sequential but each phase overlaps another, and the duration of the phases can vary individually. Optimal healing occurs with the introduction of phase-appropriate exercise and functional activity. Controlled stress promotes healing and results in a stronger repair, but excessive loading can interrupt healing and prolong the inflammatory process. The time needed for healing depends on the grade of injury, and clinical decisions should be based on signs, symptoms, and functional assessments.[29]

The initial treatment goals should focus on controlling the pain and swelling associated with inflammation. Early weight bearing,[30] ankle stability, and movement coordination impairments[4] is encouraged. Grade II sprains may require the use of axillary crutches for additional protection during ambulation (**Evidence and Researches 21-2** and **21-3**).

EVIDENCE and RESEARCH 21-2

Cryotherapy

Traditional treatment recommendations for grade I and II lateral ankle sprains during the first 1 to 4 days include rest, ice, compression, and elevation (RICE).[31,32] Cryotherapy may enable early rehabilitation due to pain control, but at present most of the rationale for using RICE or individual components is based largely on low-quality clinical trials and laboratory studies with uninjured participants or animal models.[33] Icing may actually delay tissue healing due to its effect on local vasculature.[34]

Insufficient evidence is available to determine the relative effectiveness of cryotherapy for acute ankle sprains in adults.[32,35] While superficial heating appears to positively affect muscle pain and stiffness in the acute phase of healing, no high power evidence exists for heat either.[31] Treatment decisions must be therefore made on an individual basis, carefully weighing the relative benefits and risks of each option, and based on expert opinions and national guidelines.[35]

EVIDENCE and RESEARCH 21-3

External Ankle Supports

External support in the form of wrapping, taping, or bracing promotes proprioceptive sense recovery and reduces the risk of repetitive injuries.[36] Support selection should be based on injury severity, phase of healing, and pain.[37] The most effective supports are semirigid and protect against reinjury but that allow dorsiflexion and plantarflexion.[36,38,39]

Early passive manual interventions are utilized to promote lymphatic drainage, improve anterior-to posterior talus arthrokinematics, and enable pain-free foot mobility. Mobilization at the beginning of the talocrural joint's physiologic range (i.e., grade I/II, ceasing the force before the onset of tissue resistance) is an effective treatment for improving pain-free ROM and gait variables such as step length symmetry and stride speed.[40] These gains may occur though the physiologic modulation of pain and mechanical alteration of tissues.

Midrange active dorsiflexion and plantar flexion ROM exercises are also initiated early, with care not to elongate the injured ligament. Achilles tendon stretching should commence within 48 to 72 hours of injury regardless of weight-bearing capacity, given its tendency to contract after trauma.[9] .

Progress exercise as pain and swelling are controlled and weight-bearing tolerance increases. Open chain inversion ROM is progressed as tolerated, but dorsiflexion ROM and calf flexibility can be performed more aggressively. Weight-shifting drills performed with full or partial weight bearing and with an external support help to maintain muscle tone and promote balance reactions (see **Self-Managements 21-5** and **21-6**). Proprioception boards are helpful, but exercise must be controlled to prevent interruption of tissue repair. Toe raises-off

SELF-MANAGEMENT 21-5
Dynamic Weight Shifting

Purpose: Promotes return to weight bearing and proper heel-toe weight transfer during walking

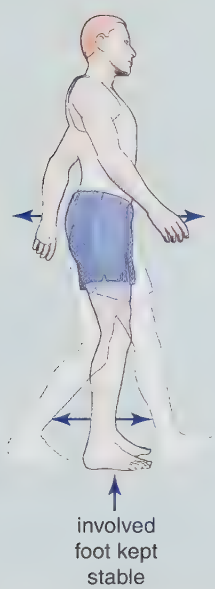
Position: Standing in a stride position

Movement Technique:
1. Step forward with ___ (uninvolved) leg, keeping ___ (involved) leg stable on the ground
2. Step back again with ___ (uninvolved) leg, keeping (involved) stable on the ground

Dosage:

Repetitions: ______________________________

Frequency: ______________________________



SELF-MANAGEMENT 21-6
Medial/Lateral Weight Shifting

Purpose: Improve control and coordination of standing balance, and prepare for dynamic activities

Position: Standing, using a supportive surface or assistive device if necessary

Level 1: Standing on two legs

Level 2: Standing on one leg

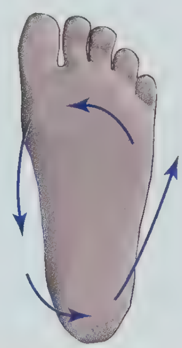
Level 3: Remove support/assistive device

Movement Technique: Shift weight in a slow, circular pattern around the perimeter of the foot. Do this in clockwise and counterclockwise directions

Dosage:

Repetitions: ____________ times ____________ seconds

Frequency: ______________________________



of a step maintains strength and flexibility of the calf. Trunk, hip, and knee exercises are helpful in preventing the effects of inactivity as well as promoting proximal control. The hip musculature is vital in maintaining ankle control, influencing foot placement and equilibrium during dynamic activities.[41] The gluteus medius in particular is active through the loading response and midstance phases of gait and can control excessive ankle inversion force moments. Early strengthening of the hip abductor musculature, especially the gluteus medius, may promote improved exercise performance and help prevent recurrent ankle sprains (see **Building Block 21-4**).

BUILDING BLOCK 21-4

A patient comes to physical therapy with a grade II ankle sprain. Initially he has non–weight-bearing orders, progressing over 4 weeks to full weight bearing. How might you progress this patient?

The collagen remodeling process is underway 3 to 6 weeks after an injury. Restoration of proprioception and muscle performance are key treatment goals to prevent recurrent hypermobility impairments. Reinjury may occur during this phase because many patients have overconfidence of their ankle's function, so return to a high level of activity should be controlled. Running at slow speeds in straight lines must precede fast speeds and cutting. Slow running in a large figure-eight pattern can be progressed to faster speeds in a smaller figure-eight pattern. Other exercises include double-leg, progressing to single-leg hopping, resisted walking or running using a pulley weight or tubing, and agility exercises. Obstacle courses and agility ladders require minimal resources and can be progressed by speed, direction of movement, and negotiation of the obstacles.[42] Functional strengthening should challenge the entire lower limb to address muscular power as well as promote appropriate body mechanics; exercises may include squats, pushing or pulling weighted objects, stair or ladder climbing.[43] External support should be used during high-level activity for 6 to 8 weeks after injury; both taping and bracing are effective in stabilizing the foot and ankle during higher level activity.[44–48]

Immediate treatment of grade III sprains is debated. Some studies suggest that, in the short term, surgical treatments do not show any advantage over functional treatment for grade III sprains.[49] More recent research recommends initially immobilizing the ankle in a below-knee cast for approximately 10 days to control swelling and protect injured tissues.

The rehabilitation approach for grade III sprains, whether treated with surgical repair or immobilization, is similar to that for grade I and II sprains. A clinician should expect greater deficits in ROM, flexibility, balance, and muscle strength throughout the lower extremity. External supports are important until full strength and proprioception have been obtained.

Recurrent sprain or functional loss is usually related to insufficient recovery of proprioception and strength, with hypomobility related to abnormal scarring or hypermobility resulting from insufficient ligamentous healing. A patient with ankle dysfunction related to hypomobility usually demonstrates limitation and pain with inversion and plantar flexion stress testing. Cross-friction massage, joint mobilization, and mobility exercises are usually beneficial. Postural control may also be compromised with an overreliance on hip balance strategies in individuals with hypermobility.[11,50]

Syndesmosis sprains are treated more conservatively than lateral ankle sprains, with an average return to play time twice that of a grade III inversion injury. Talocrural dorsiflexion involves widening of the mortise, and if this movement is unchecked due to syndesmosis injury, early or excessive weight bearing could lead to excessive strain on the injured ligaments. As such, syndesmosis sprains are treated initially with cast immobilization for 4 to 6 weeks. An unstable and widened mortise is often treated with surgical fixation.

Rehabilitation is similar to that for medial or lateral ankle sprains (**Building Block 21-5**), though some authors recommend initially limiting external rotation and end range dorsiflexion to protect healing tissues. At present, there is little research to guide rehabilitation of syndesmosis sprains.

BUILDING BLOCK 21-5

A 30-year-old female comes to physical therapy 2 months after sustaining a grade II left ankle inversion sprain. Most of her symptoms have resolved without rehabilitation but she reports increased left foot and medial knee pain that increases when she runs more than half a mile. This patient's goal is to complete a half marathon in 6 months. Past medical history is significant for multiple left ankle sprains. She has not sought physical therapy until today.

In standing, she presents with an increased left rearfoot valgus angle, apparent left pes planus, and increased medial rotation of the left femur. Left dorsiflexion is stiff and limited but nonpainful. She ambulates and runs with her left lower extremity in lateral rotation and with excessive bilateral lateral trunk flexion. Single limb stance is limited to <10 seconds on each limb with eyes open. Her squat is limited to ½ a range and she demonstrates increased L hip medial rotation and adduction with the activity. Ankle ligamentous stress testing is positive for increased nonpainful gapping of her anterior talofibular and calcaneofibular ligaments.

1. What proximal impairments in body structures and function might you expect to see?
2. Given that this patient presents with multiple problems, what interventions might be most pertinent to address first?

Chronic Ankle Instability

Even with appropriate intervention and rehabilitation, a significant number of individuals may present with mechanical ankle laxity and report instability up to a year after their sprain.[51] An even greater number will sustain multiple sprains. Clinicians should be aware of characteristics that define chronic ankle instability, which include but are not limited to increased laxity, impaired dorsiflexion ROM, deficient leg and hip strength, diminished postural control, and impaired movement strategies (**Evidence and Research 21-4**).

EVIDENCE and RESEARCH 21-4

Proprioceptive Training for Chronic Ankle Instability

The available evidence recommends at least 6 weeks of balance and coordination training to reduce the risk of reinjury in cases of chronic ankle instability.[52,53] However, the literature also indicates that the risk of recurrent ankle injury between those with and without proprioceptive training is not statistically different.[54] Additionally, balance training on unstable surfaces does not affect ligamentous proprioceptive fibers, and should not be used solely for proprioceptive training.[55]

Ongoing use of bracing during activity appears to reduce the risk of reinjury, though the mechanism is thought to be mechanical restraint rather than proprioceptive influence.[56] Further research is needed to determine the best interventions to effectively reeducate ligamentous proprioception.

Recurrent sprains resulting from hypermobility that do not respond to conservative management may require long-term use of external supports or surgical repair.

Ankle Fractures

The talocrural region sustains the highest incidence of fractures in the lower extremity. Excessive talar external rotation, abduction, or adduction within the malleoli can result in shearing or avulsion fractures of the malleoli. Ligament sprains are frequently associated with malleolar fractures. Talocrural joint fractures are commonly classified by the position of the foot (pronated or supinated) and by the direction of force exerted on the malleoli by the talus. Symptoms are similar to those of ankle sprains, although more severe in nature. **Table 21-1** contains a description of common talocrural fractures using the Lauge-Hansen classification system.[57–59]

Treatment

The key element in the acute treatment of talocrural joint fractures is the restoration of tibiotalar anatomic alignment. Fractures can be treated with closed reduction or with open reduction and internal fixation (ORIF). Fibular fractures without loss of tibiotalar alignment are usually treated with closed reduction. Fractures of both malleoli or one malleolus with a ligament rupture usually result in malalignment and therefore require ORIF. Patients are usually immobilized in a plaster cast for 6 to 10 weeks after ORIF. The clinician should note that muscle profoundly atrophies during even short periods

TABLE 21-1

Lauge-Hansen Fracture Classification

FRACTURE MECHANISM	AFFECTED STRUCTURES
Supination Adduction: extreme lateral loading of foot)	Potential distal fibula avulsion, lateral collateral sprain, shearing fracture of distal medial malleolus with sufficient force.
Supination External Rotation: external rotation of the talus on a supinated foot	ATFL sprain, fracture of distal fibula. More extreme external rotation will lead to injury of the deltoid ligament and/or avulsion fracture of medial malleolus.
Pronated Abduction: excessive talus abduction on a pronated foot	Sprain/rupture of anterior/posterior tibiofibular ligaments with possible diastasis injury. Shear fracture of lateral malleolus at the joint line.
Pronated External Rotation: external rotation of the talus on a pronated foot	Avulsion fracture of medial malleolus, tearing of anterior talofibular ligament and fibular shaft fracture. Possible tibiofibular diastasis injury.

of immobilization with no known method of prevention.[60] At present there is insufficient high-quality evidence regarding functional outcomes, adverse effects, and cost-effectiveness to draw any conclusions regarding surgical or conservative treatment. Considering the severity of the injury and duration of immobilization is key when designing appropriate interventions.

The initial phase of rehabilitation should include instruction in elevation and active exercise of the noninjured joints. Edema massage, surgical scar mobilization, and modalities for edema reduction are beneficial. Talocrural accessory joint motion must be assessed and joint mobilization techniques initiated as indicated. Active ROM begins in midrange with low intensity and high repetition activity. Controlled, partial–weight-bearing ambulation with an assistive device (i.e., walker or axillary crutches) is often the preferred mode of mobility. Conversely, unprotected ambulation may increase pain and swelling at the foot and ankle and result in undue strain at the lumbopelvic region and opposite lower extremity. Early stationary biking provides a gentle exercise for both lower extremities. Patients are instructed to pedal with the heel and progress to pedaling with the forefoot.

As the cardinal signs of inflammation resolve, treatment emphasis should focus on aggressive ROM interventions, strengthening, and functional exercise. Involved knee and lumbopelvic-hip biomechanics should be assessed and treated. The key structural deficit seen in ankle fractures is usually lack of talocrural joint dorsiflexion. Common gait compensations for limited dorsiflexion include the following:

- Abduction and external rotation of the lower extremity
- Genu recurvatum
- Excessive subtalar joint pronation

Early use of heel lifts can help eliminate these compensations (see "Heel and Full Sole Lifts" section). As function normalizes, exercise is generally better tolerated, and progress accelerates. The goal is to remove the heel lifts as soon as ROM is improved to enable normal gait patterns. If trauma was extreme and the structural impairment is deemed permanent, heel lifts can be fabricated externally on the shoe for long-term use.

Excessive subtalar joint pronation as a compensation for limited talocrural joint dorsiflexion can lead to midfoot hypermobility and dysfunction. Foot orthotics may be indicated for the current condition and future foot health. Heel lifts in conjunction with foot orthotics are an adjunct to functional strengthening and proprioceptive training. These supportive devices should be considered early in the rehabilitation process and may be needed for long-term function; periodic reassessment of the patient's dynamic foot control and function is warranted throughout the rehabilitation process to ensure that any external supports are still indicated.

As the median age of the population increases, so does the incidence of ankle fractures among elderly adults.[61] The mechanism of injury is usually low-energy, such as a fall or stumble. It is very important for these individuals to recover function as fast as possible, since bone mineral density, proprioception, and muscle strength are already reduced because of the higher age and decreased activity.

Functional Nerve Disorders

Assessment of impairments associated with nerve dysfunction affecting muscles of the lower leg, ankle, and foot should always begin with screening of proximal entrapment sites. Paresis or paralysis of muscles innervated by the posterior tibial or common peroneal nerves can be the result of lumbar spine impairment. After the spine is excluded as the source of the nerve disorder, distal entrapment sites are ruled out.

Many nerve disorders are considered to be functional, which means that the nerve is compressed during functional activity. Nerves can be compressed by bony impingements, compartment syndromes, or as a result of joint hypermobility or instability. Occasionally, a nerve can be compressed in multiple locations. It is important to understand the anatomy and innervation patterns to diagnose and treat nerve disorders appropriately (see Review of Neurology in the online supplement to this text). Nerve compression or entrapment may resolve with shoe changes, orthotics, or alteration of impairments in alignment, mobility, and movement patterns through the application of therapeutic exercise. The following sections describe selected sites for injury, compression, or entrapment of the posterior tibial and common peroneal nerves and branches.

Tibial Nerve

The tibial nerve is injured less frequently than the common peroneal nerve because of its deep and protected position within the popliteal fossa. If a lesion or entrapment occurs in the popliteal fossa, all of the calf muscles and plantar muscles of the foot are affected. A complete lesion in the popliteal fossa results in a shuffling gait and difficulty raising the heel during propulsion because of ankle plantar flexion loss. The unopposed action of the muscles innervated by the common peroneal nerve can lead to a reduced concavity of the longitudinal arch of the foot (acquired pes planus) and clawing of the toes. Sensory loss occurs on the sole of the foot and the plantar surfaces of the toes. Painful disorders, such as causalgia (a form of complex regional pain syndrome), are common with incomplete or irritative lesions.

If entrapment is suspected, the muscles surrounding the popliteal fossa must be assessed for length. If the popliteus, plantaris, and gastrocnemius are short, the tibial nerve may be compressed. Appropriate stretching and changes in alignment and movement patterns that perpetuate muscle shortening may alleviate the pressure and reduce nerve compression.

A more common disorder affecting the tibial nerve is tarsal tunnel syndrome. The tarsal tunnel is a fibro-osseous tunnel formed by the flexor retinaculum, the medial wall of the calcaneus, the posterior portion of the talus, the distal tibia, and the medial malleolus. The tibial nerve travels through this tunnel and may be compressed behind the medial malleolus, under the retinacular ligament, or via a space-occupying lesion. Compression leads to an insidious onset of sensory impairment of the medial and lateral side of the sole of the foot and toes, progressing to muscle atrophy and weakness and of toe flexion, abduction, and adduction.[62,63] Other signs and symptoms include burning, tingling, numbness, pain in the medial portion of the ankle and or the plantar aspect of the foot, local tenderness posterior to the medial malleolus, and a positive Tinel sign. End range ankle dorsiflexion and eversion may reproduce symptoms.[64] These signs and symptoms should be present but often the complete constellation is not found.[65,66]

A hypermobile subtalar joint will stretch the posterior tibial nerve due to the prominence of the posteromedial talus. Intervention for compression or entrapment in this region should include treating the impairments associated with subtalar pronation. This may involve stretching a short gastrocnemius, strengthening a weak posterior tibialis, educating the patient regarding altered postural habits, and instruction in proper foot biomechanics during gait and other functional activities. In conjunction with exercise, the use of appropriate footwear with or without bracing or orthotics to control excessive pronation may be necessary for complete resolution of symptoms related to nerve compression. Patients who do not respond to physical therapy interventions may undergo surgical decompression of the tarsal tunnel with mobility activities initiated within the first 2 weeks postoperatively.[64]

Peroneal Nerve

The common peroneal nerve is the most commonly injured nerve in the lower limb, primarily because of its superficial position as it winds around the neck of the fibula. Injury causes paresis or paralysis of all the muscles supplied by the deep and superficial peroneal nerves. The result is a loss of dorsiflexion and eversion of the foot and extension of the toes, producing foot drop and a steppage gait. Recurrent ankle sprains may also result from peroneal weakness. An accompanying loss of sensation occurs in the anterior lower leg, dorsum of the foot, and adjacent sides of all toes. A thorough knowledge of anatomy, innervation patterns, and function of the affected muscles during gait is necessary to develop an appropriate exercise program during the stages of nerve recovery. Care must be taken to prevent fatigue of a muscle recovering from a nerve injury. External support (i.e., dorsiflexion assist splint) is usually necessary during the early phases of recovery, when the muscles are weakest.

The deep peroneal nerve may become entrapped distally under the extensor retinaculum, a condition known as anterior tarsal tunnel syndrome. Trauma often plays a role. Recurrent ankle sprains place the deep peroneal nerve on maximal stretch as the foot supinates. Tight-fitting shoes or ski boots have also been implicated. Compression of the deep peroneal nerve usually results in pain radiating into the first web space. The extensor digitorum brevis may be weak or atrophied.[67] Active maximal foot eversion and dorsiflexion with maximal metatarsophalangeal joint dorsiflexion is a helpful clinical test for increasing the sensitivity of the physical examination.[65]

When treating patients with anterior tarsal tunnel syndrome, ensure that nerve compression is not caused by poorly fitting footwear. If the ankle is hypermobile or unstable, associated impairments should be treated with appropriate therapeutic exercise, footwear, bracing, taping, or orthotics to reduce excessive strain on the deep peroneal nerve. Exercise may include peroneal strengthening combined with drills to train ankle proprioceptors and help prevent recurrent ankle sprains.

Plantar Fasciitis

The plantar fascia provides stability to the foot by supporting the longitudinal arch during the propulsion phase of gait by means of the windlass mechanism.[16,68–71] "Windlass" refers to the tightening of a cable or rope. In this model, the plantar fascia simulates a cable running between the calcaneus and the metatarsal heads. Hallux dorsiflexion (extension) during terminal stance of gait winds the plantar fascia around the metatarsal heads, shortening the distance of the "cable" and elevating the medial longitudinal arch.[72]

Plantar fasciitis may be more correctly termed fasciosis because of the chronicity of the condition and histological evidence of tissue degeneration rather than inflammation. Intrinsic risk factors for painful plantar fascia include reduced plantar flexion and intrinsic foot strength, reduced ankle dorsiflexion ROM, torsional malalignment of the lower extremity, age, obesity or sudden weight gain, and foot structure.

Plantar fasciitis is typically considered a chronic overload condition with excessive pronation as the most common cause. Excessive subtalar pronation, pes planus, and/or medially shifted weight-bearing forces impose strain on the plantar fascia where it arises from the medial calcaneal tuberosity on the anteromedial aspect of the heel. A common symptom is sharp pain at the medial aspect of the heel. Patients with plantar fasciitis may report increased heel pain with the first few steps in the morning or after prolonged rest periods, which improves with further ambulation.[73] The clinician may differentiate this pain from a stress fracture or nerve entrapment, as the latter conditions will continue to provoke pain with increased walking.[74] Dorsiflexion of the toes almost always exacerbates the patient's symptoms because of the windlass mechanism loads the fascial fibers.

Other plantar structures may be painful besides the plantar fascia and should be considered for differential diagnosis, including:

- Abductor hallucis, flexor digitorum brevis, or abductor digiti minimi muscles
- The long plantar ligament
- The nearby calcaneal bursae
- Compression or diabetic neuropathy.[73,75]

Treatment

Management of plantar fasciitis must be multifactorial, as no single intervention is effective for all patients. Broadly, treatment is classified into three categories: decreasing pain, reducing tensile tissue strain, and restoring muscle strength and controlled mobility to the involved limb.[75,76]

The primary goal of treatment of plantar fasciitis in the acute stage is pain control. Passive therapeutic interventions include the use of nonsteroidal anti-inflammatory medications,[77] steroid injection, iontophoresis,[78,79] phonophoresis, ultrasound, deep tissue massage, cryotherapy, and hydrotherapy.

Activity modification may provide symptomatic relief through active rest. For the running athlete, mileage reduction, alternate activities, footwear evaluation, work reduction, and shortened workouts should be considered. Low-resistance cycling and aquatic running are effective alternatives to running on land.

Mechanical methods of reducing strain on the plantar fascia include:

- Taping
- Footwear modification
- Night splints
- Foot orthoses

Circumferential or low-dye taping of the foot is usually beneficial as an initial intervention to unload the plantar fascia and reduce pain (see **Displays 21-2** and **21-3**). Shoe modification may include a medial heel wedge to limit pronation or changing lacing to provide control of midfoot.[76] Changing to shoes with a firm heel counter to control rearfoot motion may be beneficial.

Night splints can apply low loads over a long duration in order to prevent plantar flexion and stretch tissues during sleep. Using a night splint decreases recovery time when compared to standing gastrocnemius–soleus complex stretching.[80] Individuals with chronic (>6 months duration) plantar fascia pain may derive greater benefit from custom-fabricated versus prefabricated night splints.[73]

Abnormal intrinsic rearfoot and forefoot alignment must be assessed for potential orthotic therapy. Proper orthotic prescription with appropriate forefoot and rearfoot posting can support the plantar fascia without direct pressure on the soft tissue underneath the longitudinal arch. The research literature supports the use of economic prefabricated or over-the-counter orthoses over expensive custom orthotics.[81] A temporary custom orthosis may also effectively unload the plantar fascia to promote more optimal soft tissue remodeling and resolve symptoms. Care must be taken to assess the need for orthotics as a long-term solution to the problem.

In the subacute phase, progressive cross-friction massage and stretching of the plantar fascia helps prevent abnormal scar formation and is theorized to help promote a more normal

DISPLAY 21-2
Preparing the Foot for Adhesive Strapping

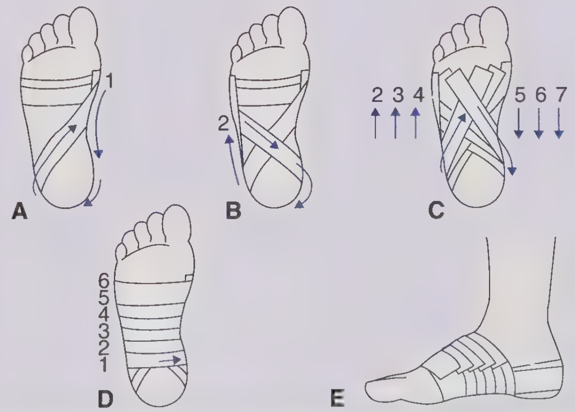
1. The foot must be clean and dry. Soap and water or alcohol wipes are used to remove perspiration and skin oils, which decrease the tape adherence to the skin.
2. Hair should be shaved to avoid irritation to hair follicles and the pain associated with pulling hair out during tape removal.
3. Skin should be sprayed with a skin preparation or "toughener" that improves tape adherence.
4. Thin foam prewrap used before taping helps protect the skin, but when maximal support is necessary, the tape should be applied directly to the skin. Prewrap has been used successfully when patients are limited to a medium or low activity level.

DISPLAY 21-3
Longitudinal Arch Strapping Technique

Tape: 1-in athletic tape

Taping Position: Patient is supine on the treatment table, with their foot over the edge, ankle dorsiflexed to neutral.

Taping Technique: Place two anchor strips circumferentially just proximal to the metatarsal heads (apply lightly). Begin the first diagonal strip of tape on the medial side of the foot, just proximal to the head of the first metatarsal. Angle the tape posteriorly around the heel, then crossing the plantar surface, and return medially near the origin of this strip (**Fig. A**). Place the second diagonal strip of tape on the lateral side of the foot, just proximal to the head of the fifth metatarsal. Tape under the foot, around the heel, and up the lateral side toward the origin of this strip (**Fig. B**). Continue alternating strips in the same pattern until the "fan" is filled in (**Fig. C**). Tie down the entire procedure by placing plantar strips over the previous strips by starting on the dorsolateral aspect of the foot; continue under the arch, and finish on the dorsomedial aspect of the foot. Leave a gap on the top of the foot; bridge this by placing short strips of tape across the gap (**Fig. D**) and (**Fig. E**). Each strip of tape should overlap the previous strip by approximately ¼-inch.



resting length. Mobilization of the plantar fascia has statistically the best long-term results (see **Self-Management 21-7**). If this stretch increases heel pain, the exercise may be modified to passive toe dorsiflexion in the non–weight-bearing position up to the painful range.[73]

Long-term resolution of symptoms of plantar fasciitis can only be achieved by addressing the physiologic and/or anatomic impairments directly affecting the biomechanics of the plantar fascia. If pronation is straining the plantar fascia, and a stiff talocrural joint and/or short gastrocnemius–soleus complex are contributing to the pronation, mobilization to the talocrural joint or stretching of the gastrocnemius–soleus complex is indicated. The clinician should note, however, that simply stretching the gastrocnemius has not been demonstrated to significantly decrease plantar pain.[82] In conjunction with mobilization and stretching, strengthening the tibialis anterior and extensor digitorum is critical to maintain and utilize dorsiflexion range during functional activities. If intrinsic muscle weakness is contributing to loss of longitudinal and transverse arch support, strengthening can be initiated to promote dynamic stability against excessive pronation. In addition, lower extremity alignment, muscle flexibility, muscle performance, and movement patterns must be assessed for extrinsic pronatory factors. Functional exercise and proprioceptive training should be initiated to reduce pronatory forces and improve talocrural dorsiflexion. The patient might practice step ups onto a 12 inches box with their involved limb, and practice controlling pronation through the foot as the ankle moves through its available dorsiflexion ROM. This could be progressed by increasing the speed or angle of step up, or increasing the hold time in single limb balance on the box.

SELF-MANAGEMENT 21-7
Plantar Fascia Step Mobilization

Purpose: Restore normal resting length of plantar fascia.

Position: Standing with the toes extended against the vertical part of a step and the heel on the floor.

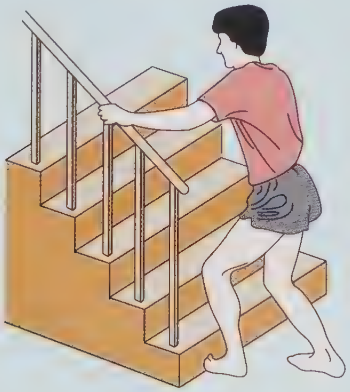
Movement Technique: Slowly bend the knee above the toes you are stretching back. Keep your arch from rolling in.

Dosage:

Duration: ______________________

Repetitions: ______________________

Frequency: ______________________



Posterior Tibial Tendon Dysfunction

The tibialis posterior tendon is the primary dynamic stabilizer of the medial longitudinal arch.[83] During open chain mechanics, the tibialis posterior inverts and plantar flexes the foot, whereas during closed chain mechanics, it decelerates subtalar joint pronation in the loading response phase and supinates the subtalar joint in the midstance and terminal stance phases.[84] Its contraction serves to elevate the medial longitudinal arch, which "locks" (supinates) the midfoot and assists the foot converting to a rigid lever for propulsion. This action allows the gastrocnemius muscle to act with much greater efficiency during gait.[83]

The mechanism of posterior tibial tendon dysfunction is usually excessive subtalar joint pronation and results in acquired flatfoot deformity. However, the tendon can be strained because of poor physical condition, training errors, or by excessive physical activity. This dysfunction is most common in females who are obese, in their fifth and sixth decade of life, and lead sedentary lifestyles.[85] The least common mechanism of injury is an eversion ankle sprain. Symptoms are commonly located at the distal one-third of the medial tibia or inferior and posterior to the medial malleolus resulting from a zone of hypovascularity that correlates with the region of tendon pathology.[85] Typical symptoms include tenderness to palpation along the tendon, pain and/or weakness with resisted inversion and plantar flexion, and pain with closed chain pronation. Walking can become painful if accompanied by excessive pronation. Running, cutting, or jumping may also be impaired because of the posterior tibialis' role during the deceleration phase of these activities. The patient may note feeling increasingly unstable at the ankle, indicating altered proprioception, strength, and coordination.[85]

Treatment

As with plantar fasciitis, a primary goal of treatment in the acute phase is to control pain with appropriate medications and therapeutic modalities. Arch or navicular strapping is beneficial to control end-range pronation, thereby decreasing the strain on the tibialis posterior. Low-intensity, high-repetition, open chain plantar flexion and inversion exercises in a pain-free range should be initiated early in the rehabilitation process to control pain and promote tissue remodeling. In the subacute phase, resistance may be introduced to open chain strengthening, and closed chain strengthening exercises should commence as tolerated. For example, the patient can practice progressive weight transfer on the affected foot while actively stabilizing the medial longitudinal arch, preventing excessive pronation. This may be progressed to single leg balance. The strength of proximal musculature (hip abductors and hip extensors) is critical to absorb ground reaction forces in the early stance phase of gait; they should be assessed and reeducated as indicated to minimize distal pronatory forces in weight bearing. Given the tibialis posterior's role during gait, eccentric and concentric strengthening may yield positive results, though this has yet to be substantiated in the literature.[86] Assess intrinsic and extrinsic pronatory factors and use orthotic therapy and functional exercise as indicated for long-term resolution of symptoms.[87]

Short leg casting with non-weight bearing for 4 to 6 weeks may be necessary for patients with evidence of a partial tear, signified by delayed heel varus with toe raises and weakness.[85] Posterior tibial tendon dysfunction is resistant to conservative treatment and often involves surgery because of the progressive nature of the disorder.[85,88] However, at present there is no method to determine which patients will respond most favorably to conservative intervention and which will ultimately require surgery.

Medial Tibial Stress Syndrome

Although MTSS is one of the most common lower leg injuries sustained in sports, its mechanism remains unknown.[89] It likely involves a stress reaction by the crural fascia or bone along the posteromedial portion of the tibia most commonly associated with the insertion of the soleus.[90] Some authors have suggested that MTSS is a consequence of repetitive stress that fatigues the soleus and overloads the bone-remodeling capabilities of the tibia,[91] but histological studies are needed to confirm this theory. Proposed risk factors include increased pronation, forefoot varus, a positive navicular drop test, high body mass index, hard or inclined running surfaces, and inappropriate footwear. Training errors account for 60% of patients in the research literature. MTSS is one of the most common overuse injuries in the athletic population, especially females.

Patients may report a dull ache along the middle or distal posteromedial tibia which occurs with exercise.[3,90,91] Initially, the pain may occur at the beginning and end of activity; with continued training, the pain increases in severity and duration.[3,91] Positive physical findings include tenderness to palpation of the middle to distal tibia and pain with heel raises, resisted dorsiflexion, plantarflexion, and/or inversion.[91] Dorsiflexion ROM is not a significant contributor to symptoms. While stiff plantar flexors are a feature of this condition, this should be considered a consequence rather than a cause.

Prevention of MTSS is difficult as the causal factors remain unknown. Methods which show promise in the literature include use of shock-absorbent and pronation-control insoles and graduated running programs. Nonspecific strengthening exercises, stretching, sports compression stockings, low-energy laser treatment, and leg braces have not been shown to have an effect.[89] Some research suggests a relationship between dynamic thorax and hip stability and altered limb movements that are associated with MTSS development. Interventions to improve strength and coordination of the entire kinetic chain may yield more successful outcomes. Therapeutic exercise should focus on improving the strength and endurance of the soleus and other weak ankle invertors to resolve any imbalance with the evertors, as well as strengthening weak proximal musculature. Footwear or training alterations may also be necessary. For example, individuals who exercise daily should commit to at least 1 day per week to a form of cross-training that unloads the tibia and allows bone remodeling to occur, such as a pool workout.

Achilles Tendinosis

Despite its large cross-sectional area, the Achilles tendon is particularly susceptible to degeneration and injury approximately 2 to 6 cm above its insertion into the calcaneus due to a poor blood supply.[92] The blood supply decreases with age, increasing the risk of rupture.[93]

Degenerative pathology of the Achilles tendon is one of the more common tendon injuries of the lower extremity.[94–100] It is especially prevalent among persons participating in running and jumping sports, given the high ground reaction forces involved. The tendon functions eccentrically to control the heel as it lowers to the ground upon landing, as well as during the late midstance phase of gait to slow the advancing tibia. Strain is particularly high when walking or running uphill, when the tendon must slow the tibia eccentrically while propelling the body uphill concentrically, with the ankle in extreme dorsiflexion. Intrinsic factors contributing to injury include BMI, gastrocnemius–soleus and hamstring stiffness or shortening,[91] and forefoot varus.[101] Extrinsic factors include training errors, type and fit of footwear, and running surface.

Pain is elicited with loading and/or direct palpation to the tendon and crepitus may occur with active ankle motion.[91] Symptoms may increase with passive talocrural dorsiflexion as a result of Achilles tendon stretch; dorsiflexion ROM may also be diminished. There may be visible edema along the length of the Achilles, as well as tendon thickening secondary to increased collagen deposition.

Treatment of Achilles tendinosis should follow the guidelines in Chapter 11. Stretching of the gastrocnemius–soleus complex is essential to increase the length over which the tendon loads can be dispersed. Stretching is recommended only after talocrural joint mobility is restored; otherwise, excessive tension will be placed on the Achilles if talocrural motion is absent. Stretching should be performed with the knee straight to isolate the gastrocnemius, and with the knee bent to isolate the soleus, while maintaining a neutral foot position (see Fig. 21-14).

Strengthening exercises are an important intervention but should only be introduced following resolution of an acute pain episode or symptom flare to avoid exacerbating the patient's condition. If a patient is unable to tolerate weight-bearing activities, an aquatic-based intervention may be appropriate until symptoms decrease; this allows the patient to maintain cardiovascular health while exercising the Achilles in a safe environment.[102] See Chapter 16 for further details. The strengthening program is eventually progressed to eccentric activities such as controlled lowering from a plantar-flexed to dorsiflexed position. Use of a decline board may assist these exercises[101] (**Evidence and Research 21-5**).

EVIDENCE and RESEARCH 21-5

Eccentric Loading Programs for Achilles Tendinosis

Eccentric calf strengthening in patients with painful chronic Achilles tendinosis has previously resulted in significantly better outcomes when compared to concentric strengthening, though only 45% of patients respond favorably to this intervention.[95,103–105] Eccentric exercises may also decrease tendon thickening, possibly indicating a resolution of abnormal collagen deposition described earlier.[106] However, to date, there are no studies which have documented an improvement in tendon structure following a course of eccentric loading exercises.[107]

The speed and load should also be gradually increased to appropriately and progressively challenge this muscle group (see **Self-Management 21-8**), as forces of 2.5 times the body weight act on the tendon during normal gait.[101] Given the size of and functional demands on the Achilles tendon, the patient may likely experience a more favorable outcome with a mix of plyometrics and heavy load training if a goal is to improve tendon cross sectional area. Most Achilles loading recommendations specify the patient perform exercise repetitions to pain provocation, and the physical therapist can provide education to help appropriately manage patient expectations and promote program adherence.

SELF-MANAGEMENT 21-8
Hop-Down Drills

Purpose: Increased balance and coordination during dynamic movement, impact loading, and controlled lengthening of the Achilles

Position: Standing on a small step of about 4 in.

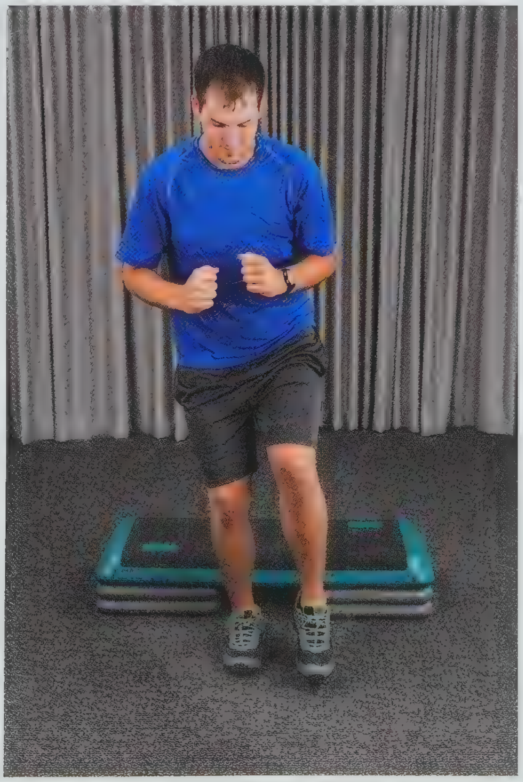
Movement Technique: Level 1: Hop down onto both feet, controlling the landing.

Level 2: Hop down, landing on a single leg.

Dosage:

Repetitions: ______________________________

Frequency: ______________________________



Postoperative Management

Achilles Tendon Rupture

The typical patient sustaining an Achilles tendon rupture is a middle-aged male active in recreational or competitive athletic activities. Signs of chronic degeneration are observed in most ruptured tendons, although the majority of ruptures occur without any preexisting complaints.[108] At the time of rupture, the patient complains of feeling as if she or he had been kicked in the back of the leg, despite the fact that most ruptures are the result of noncontact injuries. A defect may be palpable and the Thompson test result is positive.

Achilles tendon ruptures may be treated conservatively with immobilization in a cast or cast boot for up to 12 weeks. The effects of immobilization and the extent of the damage to the Achilles tendon must be considered when planning interventions; prolonged immobilization will have deleterious effects on gastrocnemius–soleus length, strength, and size. ROM activities to restore the length of the gastrocnemius–soleus complex and the mobility of the talocrural joint are necessary.

Although Achilles tendon rupture is a relatively common injury, discussion continues regarding whether surgical or nonsurgical treatment is the best management.[109] Recent studies have suggested improved outcomes and superior strength in operatively treated patients, with a decreased rate of re-rupture compared to a nonoperatively managed cohort.

Early, active rehabilitation is associated with better outcomes after surgical repair. Rehabilitation activities should commence with non–weight-bearing plantar flexion and progress to closed chain and eccentric activities as similarly outlined for Achilles tendinosis. The ability to perform a single full range heel rise is correlated with a more rapid return to preinjury physical activity levels, whereas fear of movement is correlated with a worse outcome. Physical therapy is critical to improve muscle performance and reduce fear associated with activity so that the patient can achieve a positive outcome.

Total Ankle Arthroplasty

TAA is a relatively new procedure which still requires significant evidence regarding the best surgical technique, prosthesis, and rehabilitation strategy. The surgery was initially developed to provide an alternative to ankle fusion with the inherent advantage of preserving joint motion. However, early efforts failed to appropriately reproduce the triplanar motion of the talocrural joint and lead to excessive complications.[110] Newer generation prostheses have improved outcomes, though the median survival rate of the component parts is 90% at 10 years—much lower than for total hip or knee arthroplasty.[111,112] Surgical complications include prosthesis loosening, infection, bony nonunion or fracture, and persistent pain and stiffness.[110]

Despite these limitations, the popularity of TAA continues to grow. Individuals indicated for the procedure include those with a history of painful rheumatoid or osteoarthritis that limits ROM and functional mobility. In general, most patients who undergo TAA have a good outcome, with the main postsurgical difficulty of limited dorsiflexion[110] (**Evidence and Research 21-6**).

EVIDENCE and RESEARCH 21-6

Total Ankle Arthroplasty Versus Arthrodesis

While the stimulus for its development was in part dissatisfaction with ankle arthrodesis, the TAA procedure remains challenging due to the unique morphology of the ankle.[113,114] In the research literature, clinical outcomes of both procedures were very satisfactory after 5 years postoperatively,[115] though the complication rate for TAA is higher[116] and the revision rate is roughly twice than of arthrodesis.[116] TAA has potential to normalize gait mechanics more than fusion due to its preservation of ankle dorsiflexion,[117] but research finds no significant difference in sporting/recreational activities or functional outcome in patients who underwent either procedure for treatment of end stage ankle arthritis.[116,118]

As with other forms of joint replacement, treatment in the initial postoperative phase should focus on reducing inflammation with manual therapy, cryotherapy, compression, and patient use of an assistive device. Return to full weight bearing is primarily dependent on the surgeon's recommendations and patient tolerance. Stretching of the gastrocnemius–soleus complex is recommended, but talocrural dorsiflexion may primarily be limited by the replaced talocrural joint. A heel wedge may be appropriate to enable functional mobility and appropriate gait mechanics until full dorsiflexion is achieved, but the patient should be aware that they may not fully gain this motion under current technological limitations. Rehabilitation should progress to improving strength of the proximal, as well as extrinsic and intrinsic foot and ankle, musculature. Balance and equilibrium reactions should be retrained as outlined previously in this chapter.

ADJUNCTIVE INTERVENTIONS

A therapeutic exercise program for the ankle and foot can be enhanced with the use of supportive devices. Adhesive strapping, wedges and pads, biomechanical foot orthotics, and sole or heel lifts can help control excessive compensation and promote early return to functional activity. The supportive devices are an adjunct to a thorough exercise program and, if used independently, may be less successful. In many situations, the converse is also true.

Adhesive Strapping

The use of adhesive strapping is beneficial in stabilizing end range of joint motion or improving neuromuscular control. Athletic tape or Leukotape may be utilized, depending on the degree of control desired or the anticipated duration of wear. Strapping should improve the patient's symptoms, and if symptoms increase, the strapping should be removed immediately. Approach any taping with caution if the foot is swollen. The foot must be properly prepared before adhesive strapping is applied to enhance support and decrease the risk of skin irritation. Display 21-2 provides guidelines for preparing the foot for adhesive strapping. The patient must be instructed to remove the strapping slowly by pulling the tape backward on itself. Quick jerking movements and excessive skin distraction with tape removal could pull superficial skin layers off.

Longitudinal arch strapping is valuable when excessive pronation is deemed a primary stressor. The longitudinal arch strapping technique presented in Display 21-3 is designed to decrease soft-tissue strain caused by excessive subtalar joint pronation. Many additions and variations of supportive foot strapping can be explored, such as the navicular strap detailed in **Display 21-4**.

Wedges and Pads

Medial heel wedges, longitudinal arch pads, and metatarsal pads are placed in a shoe or on a flat insole to decrease soft-tissue strain. Medial or varus heel wedges are thicker medially and

DISPLAY 21-4

Navicular Strap Technique

Tape: 1½ inches athletic or Leukotape

Taping Position: Patient is supine on the treatment table in long or short sitting.

Taping Technique: If using Leukotape, begin with Cover Roll and finish with Leukotape. Apply athletic tape directly to skin. The foot should be in a neutral or slightly relaxed position. Apply tape over the lateral plantar surface of the foot or over the most lateral aspect of the dorsal surface of the foot and draw the tape medially (**Fig. A**). Gently pull the tape over the medial longitudinal arch, directly crossing the navicular tuberosity. Continue to wind the tape over the dorsal surface of the foot, crossing approximately over the anterior talocrural joint (**Fig. B**), and finishing over the posterolateral distal leg. This process may be repeated twice per foot/ankle to improve midfoot support.

A

B

taper laterally. They are made of firm rubber and used with the philosophy of controlling excessive calcaneal eversion, decreasing the degree of subtalar joint pronation. Longitudinal and metatarsal arch pads are made of felt or foam rubber. The metatarsal pad is placed directly proximal to the symptomatic metatarsal head. Medial wedges, longitudinal arch pads, and metatarsal pads are most successful when used in conjunction with adhesive strapping. Longitudinal arch and metatarsal pads can be taped on top of foot strapping for precise positioning. The medial wedge can be secured in a shoe with the use of double-faced tape.

If symptoms are relieved and performance is improved through adhesive strapping and supportive pads and the patient has exhausted all intrinsic solutions, a biomechanical orthotic may be indicated.

Biomechanical Foot Orthotics

It is beyond the scope of this text to provide a detailed description of orthotic evaluation and prescription. This section describes the purpose of orthotic devices, the general fabrication method, the concept of posting, and therapeutic exercise prescription to augment orthotic prescription.

A biomechanical foot orthotic is a device that attempts to control dysfunction by controlling the subtalar joint near its neutral position. **Display 21-5** describes the general purposes of a foot orthosis.[119] An orthotic with posting decreases the compensation caused by the individual's structural abnormality.

A foot orthotic is composed of a shell, which conforms to the contours of the foot, and posting material, which tilts the shell according to the angulation and degree of control desired.

The shell is fabricated from an impression of the foot taken while the subtalar joint is maintained in a non–weight-bearing neutral position. The shell encompasses the heel, fits closely to the arch, and ends immediately proximal to the metatarsal heads. The shell can be made of a variety of materials, ranging from a flexible foam to a semirigid thermoplastic. Generally, the more rigid shells are indicated for the foot requiring motion control. Flexible accommodative shells are used for arthritic conditions, diabetes, and the hypomobile foot. Body weight is also a deciding factor when choosing a shell's rigidity. A heavy individual may require a more rigid shell for more adequate motion control without rapid material breakdown.

Orthotic posting is prescribed from the findings of a biomechanical evaluation of the entire lower extremity. Posting material is added to the shell's undersurface to conform to the foot and ankle angles, as specified below:

- Rearfoot posting is placed under the heel of the shell
- Forefoot posting runs under the metatarsal area to the end of the shell
- Medial or varus posting for a subtalar, forefoot, or tibial varum abnormality
- Lateral or valgus posting for a subtalar, forefoot, or tibial valgum abnormality

In combination with proximal strengthening, foot and ankle exercises such as calf stretching, arch lifts, and single-leg standing balance drills can help prepare the foot before orthotic therapy, which requires a break-in period of 1 to 6 weeks. During the break-in period, the orthotics are worn intermittently, perhaps as little as 1 to 2 hours per day, with a 1-hour progression each day. The break-in period can be accelerated based on orthotic tolerance and nature of the injury. Open chain exercises established before orthotic wear should continue. Closed chain exercise in the orthotics should be progressed as tolerated. Initially, patients can be instructed to actively supinate off of the orthotic and slowly lower onto it. Static weight-shifting drills can be progressed to exercise involving higher ground reaction forces. Athletic activity should not begin until light activity is well tolerated.

Foot orthotics must be reassessed for wear and breakdown, as periodic refurbishment or upgrading may be necessary. During orthotic reassessment, the patient's foot and function should also be reexamined. Alignment resulting from anatomic impairments does not change, but the patient's ability to control their compensation may improve. Alignment resulting from physiologic impairments may change. Day-to-day orthotic wear and wear for various activities may be adjusted. The reassessment schedule varies with each individual, ranging from 1 week to 1 year after the break-in period.

DISPLAY 21-5
Purposes of a Foot Orthosis

1. To even the distribution of weight-bearing forces
2. To reduce joint strain
3. To control foot motion at the subtalar and midtarsal joints, including magnitude, end range, and rate
4. To balance intrinsic foot deformities if necessary

Heel and Full Sole Lifts

Heel lifts can be helpful in the treatment of foot and ankle dysfunctions related to limited motion of the talocrural joint. A lack of 10 degrees of talocrural joint dorsiflexion can result in compensatory subtalar joint pronation during midstance and propulsion. A heel lift places the talocrural joint in a few degrees of plantar flexion at midstance (**Fig. 21-17**). This increases the available range of dorsiflexion and decreases the abnormal compensation.

Heel lifts can be used in the acute phase to decrease strain on the Achilles tendon, talocrural joint, and subtalar joint. Early ambulation with less pain increases independent function and enhances the effects of an exercise program. The goal is to normalize the impairment and remove the heel lifts.

FIGURE 21-17 A heel lift is used to increase the range of dorsiflexion at midstance.

If a heel lift is necessary, the following information can guide the proper amount of lift to prescribe.

- A patient with 0 degrees dorsiflexion may require a ¾- to 1-inch heel lift. Less severe limitations can be treated with smaller lifts.
- A ¼- to ⅜-inch lift can be placed inside the shoe. The lift depends on shoe style and fit.
- All or some portion of the lift can be added to the sole of the shoe by a shoe repair service.
- A lift of the same height should be added to the uninvolved extremity to avoid creating a leg length discrepancy.

Heel lifts are commonly used for correction of leg length discrepancies, but should be isolated for use in equinus contractures or temporarily to relieve foot/ankle strain. Full sole lifts are more appropriate for the treatment of leg length discrepancies, because the heel is in contact with the ground for only a short period in the gait cycle. After the loading response phase is completed and the foot enters the midstance phase, the forefoot is in contact with the ground. If the lift is only in the heel, the foot functions as if it is descending a small step after the forefoot contacts the ground. The full sole lift eliminates this problem. However, the disadvantage of the full sole lift is that it can occupy excessive room within the shoe. Typically, if a lift beyond ⅛ in is recommended, it should be added to the outside of the shoe. The prescription of a sole lift should be considered carefully, because an apparent leg length discrepancy often is functional and not structural.

Please refer to Chapter 19 for a detailed description of functional versus structural leg length discrepancy. A functional leg length discrepancy often can be treated with therapeutic exercise intervention, focusing on alignment and movement impairments throughout the kinetic chain. The use of a lift for a functional leg length discrepancy can capture and reinforce the alignment impairment rather than resolve the impairment (**Selected Intervention 21-1**).

SELECTED INTERVENTION 21-1

For the Lower Quadrant

See Case Study No. 1.

Although this patient requires comprehensive intervention as described in previous chapters, only one exercise prescribed in the final stage of recovery is described.

ACTIVITY: Lunging ball drill

PURPOSE: Improve balance, proprioception, and agility

RISK FACTORS: 10 weeks after second-degree sprain of the right calcaneofibular ligament

SUBSYSTEMS OF THE MOVEMENT SYSTEM: Neural subsystem

STAGE OF MOTOR CONTROL: Skill

POSTURE: Standing in "ready" position with knees flexed

MOVEMENT: Step forward and lunge as ball is tossed toward you

SPECIAL CONSIDERATIONS: Be sure foot lands in a good position and that it is in good alignment with respect to the knee, hip, pelvis, and spine.

DOSAGE

Special Considerations

Anatomic: Calcaneofibular ligament

Physiologic: Late-stage recovery from grade II sprain

Learning Capability: Good body awareness and coordination, should be no trouble

Repetitions/sets: To form fatigue, pain, or 20 to 30 repetitions, up to three sets

Frequency: Every other day

Sequence: Following warm-up of light activity and stretching

Speed: Functional speed

Environment: Home with a partner

Feedback: Initially in clinic with mirror and verbal feedback, tapered to no mirror in home environment

FUNCTIONAL MOVEMENT PATTERN TO REINFORCE GOAL OF SPECIFIC EXERCISE: Play basketball with same form

EXPLANATION OF CHOICE OF EXERCISE: Chosen as skill-level activity to prepare patient for return to basketball. Patient will require excellent balance, proprioception, and agility to return to basketball without recurrent ankle sprain. High repetitions of this exercise for 2 to 3 weeks should prepare patient for basketball without recurrent injury.

LAB ACTIVITIES

1. Perform resisted ankle dorsiflexion, plantar flexion, inversion, and eversion using a variety of resistive bands. Perform exercises in long-sitting and short-sitting positions and while standing on one leg. What are the most likely substitutions in each position?
2. Instruct a laboratory partner in correct lower extremity standing posture.
3. Perform the following exercises, maintaining subtalar neutral position and exaggerating pronation. Observe the differences in alignment throughout the lower extremity:
   a. Wall slide
   b. Single-leg wall slide
   c. Step down
   d. Standing on a minitramp
   e. Stair stepper, forward and backward
4. Consider the patient in Case Study No. 1 in Unit 7. Design a rehabilitation program for this athlete in the early, intermediate, and late phases. Instruct your patient in the exercise program, and have your patient perform all exercises.

KEY POINTS

- Common lower extremity anatomic impairments include subtalar varus, forefoot varus, and forefoot valgus.
- The foot and ankle examination must include a subjective history and evaluation of the weight-bearing and non–weight-bearing foot. Relationships of the lower extremity joints must be evaluated.

- Common physiologic impairments at the foot are mobility loss, loss of force or torque production, impaired posture and movement, pain, and impaired balance and coordination.
- The therapeutic exercise program must consider the kinetics and kinematics of the foot during gait, as well as consider proximal musculature length and performance to ensure appropriate coordination of mechanics throughout the kinetic chain.
- Adjunctive agents may be necessary to treat structural impairment or to prevent secondary problems associated with physiologic impairments.

CRITICAL THINKING QUESTIONS

1. Consider Case Study No. 1 in Unit 7. How would the treatment program differ if the patient was
   a. A competitive runner
   b. A landscaper walking on uneven surfaces
   c. An elderly individual who is a community walker
   d. A recreational golfer
2. Consider again Case Study No. 1 in Unit 7. The patient has progressed well with your interventions and demonstrates full ankle ROM and extrinsic muscle strength. However, her balance remains faulty. How would you modify your treatment to both address her balance and help her return to basketball? How would you progress the balance program as she improves?
3. Consider Case Study No. 9 in Unit 7. Theorize about potential relationships between this patient's plantar fasciitis, her thigh pain, and other symptoms. Describe a comprehensive treatment program for this individual.
4. Consider again Case Study No. 9 in Unit 7. The patient's thigh pain has improved moderately but has plateaued. Assuming her posture and hip muscle strength is improving and she is regularly performing her home program, what other factors might you consider addressing to drive further symptom resolution?

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Functional Approach to Therapeutic Exercise for the Upper Extremities

UNIT 6

CHAPTER

22

The Temporomandibular Joint

LISA M. FLEXNER • DARLENE HERTLING

The temporomandibular joints (TMJs) connect the mandible to the cranium and are the only two moving joints in the head. They work together with the cranium, jaw, cervical spine, dental arches, muscles of mastication, teeth, tongue, and associated neurovascular tissues and are known as the stomatognathic system. The TMJs and proper functioning of the stomatognathic system are critical to basic functions such as eating and talking. The TMJ is a weight-bearing joint, with joint compression occurring every time the teeth come in contact. Temporomandibular joint dysfunction (TMD) affects between 5% and 12% of the population, with some studies suggesting that the number may be as high as 26%.[1–3] It is 1.5 times more likely to occur in women than in men, and onset occurs in younger adults (18 to 44 years old) more than in children or the elderly.[2,4,5] It may also be referred to as craniomandibular dysfunction or orofacial pain.

Understanding TMD depends on thorough examination and evaluation, determination and treatment of the source of symptoms, and addressing contributing factors to the condition. The source may be myogenous and extracapsular; arthrogenous and intracapsular; or referred from other structures.[6,7] Common sources of referred pain include mandibular fractures, trigeminal neuralgia, neoplasms, otologic sources, and cardiac issues. The underlying cause for myogenous and arthrogenous problems may be postural dysfunction in the cervical and thoracic spine, such as forward head posture (FHP) affecting occlusion of the teeth, or it may be due to parafunctional activities such as grinding of the teeth or gum chewing. Treatment of TMD should address the person as a whole, taking into account the musculoskeletal relationships, the performance of functional activities, and the influence of physical and emotional stress on this system. Understanding how the TMJ relates to the patient's body structure and function is key to treatment planning, decreasing the patient's pain, and improving their quality of life.

REVIEW OF ANATOMY AND KINESIOLOGY

This section contains a brief summary of the key structures and relevant kinesiology of the TMJ.

The Temporomandibular Joint Structures

The bones most commonly associated with the TMJ are the mandible and the temporal bone of the cranium, which articulate directly to create the joint. A biconcave fibrocartilage disk sits between the convex condylar process of the mandible (the floor of the joint) and the temporal bone (the roof). From anterior to posterior, the articular surfaces of the temporal bone are the articular tubercle, articular eminence, mandibular fossa, and posterior glenoid spine; the disk will articulate with different parts of the temporal bone as the jaw opens and closes. The disk divides the joint into two cavities, which compensates functionally for the incongruity of the two opposing joint surfaces and effectively creates two articular surfaces (**Fig. 22-1**). The joint is synovial, and both bony surfaces are covered with vascularized fibrocartilage, unlike the hyaline cartilage in most synovial joints.[8] This fibrocartilage structure allows for greater force attenuation and the possibility of repair and remodeling. The disk is also fibrocartilage; it consists of three portions with varying vascularity and innervation (**Fig. 22-2**).

The ligamentous structure of the joint capsule is thin and loose, which allows for great mobility but sacrifices stability. The capsule is attached to the disk anteriorly and posteriorly, but not on the sides. This allows the disk to translate anteriorly and promotes greater mouth opening. A posterior ligament attaches

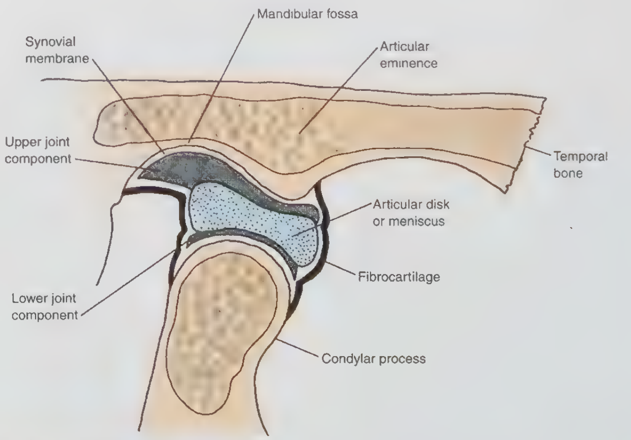

FIGURE 22-1 Articular structures of the TMJ in the closed position.

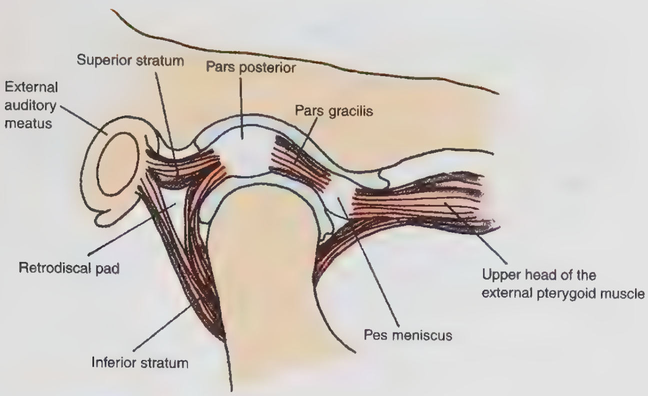

FIGURE 22-2 Sagittal section of the TMJ. The lateral pterygoid inserts into the mandibular condyle and the disk. The disk has three parts: (1) a thick anterior band (pes meniscus), (2) a thicker posterior band (pars posterior), and (3) a thin intermediate zone (pars gracilis) between the two bands.

the disk to the posterior aspect of the neck of the mandible, the bilaminar zone, and the posterior portion of the TMJ.[8–14] This ligament restricts anterior translation of the disk during mouth opening.

The innervated tissues of the TMJ are supplied by divisions of the trigeminal nerve (cranial nerve V), which also innervates the middle ear muscles. The auriculotemporal nerve is the major nerve innervating the capsular blood vessels, the retrodiskal pad, the posterolateral capsule, and the TMJ ligament of the TMJ. These tissues have an abundant supply of type IV articular pain receptors. Because branches of the auriculotemporal nerve supply the tragus, external acoustic meatus, and tympanic membrane, TMD is often associated with hearing problems, tinnitus, and vertigo. Buergers et al.[15] found that prevalence of tinnitus is eight times greater in those with TMD, and occurs ipsilaterally. The tensor tympani and tensor palati muscles may provide a musculoskeletal etiology for these auditory and vestibular issues, due to their shared innervation and proximity to the TMJ. Ren and Isberg[16] found a strong correlation between unilateral tinnitus and an ipsilateral anteriorly displaced disk in the TMJ.

Movement of the joint is guided by five key muscles on each side: the masseter (**Fig. 22-3**) and temporalis (**Fig. 22-4**) elevate the mandible; the digastric (**Fig. 22-5**) depresses the

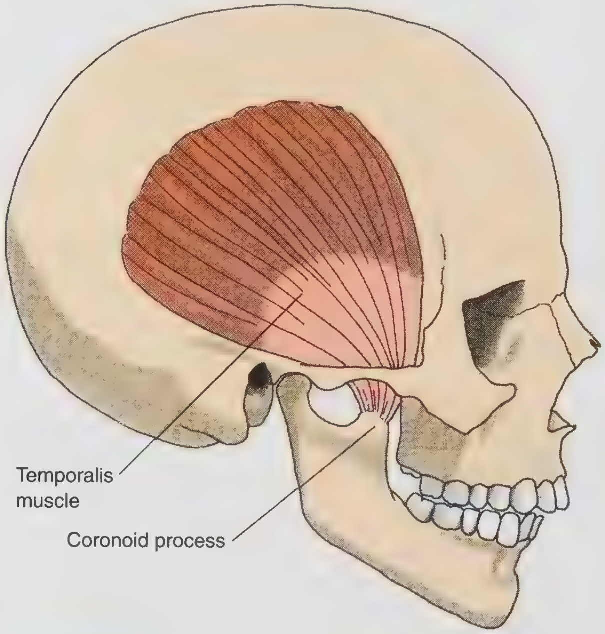

FIGURE 22-4 Temporalis muscle.

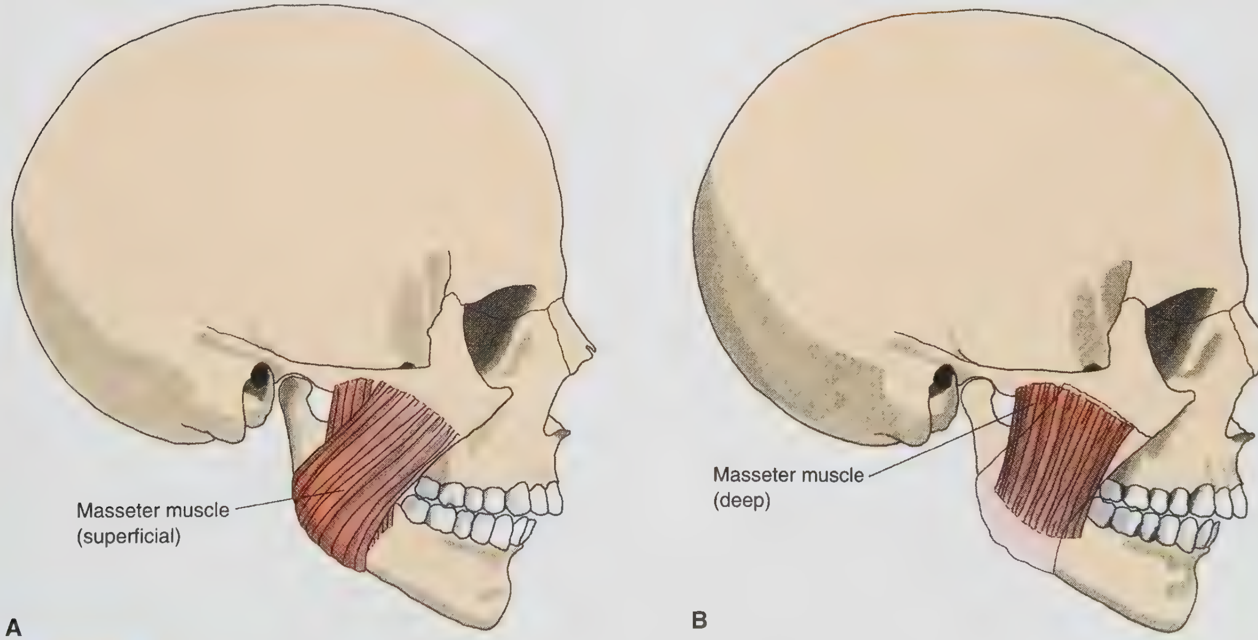

FIGURE 22-3 **(A)** Superficial and **(B)** deep layers of the masseter muscle.

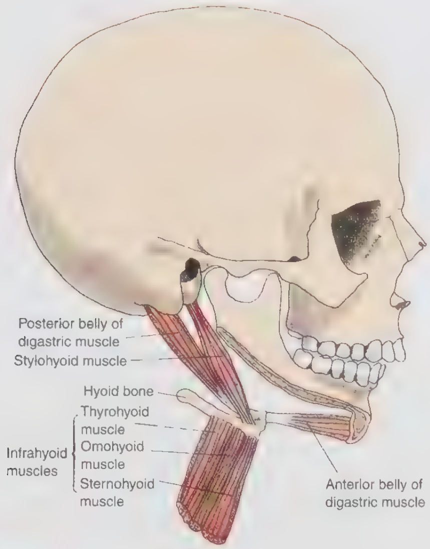

FIGURE 22-5 Hyoid bone and the digastric, stylohyoid, and infrahyoid muscles.

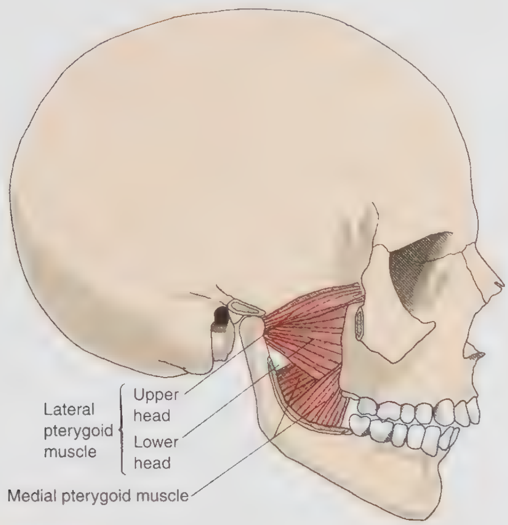

FIGURE 22-6 Medial and lateral pterygoid muscles.

mandible and elevates the hyoid, particularly in swallowing; the medial pterygoid (**Fig. 22-6**), which elevates and protrudes the mandible, and when working unilaterally will rotate the mandible to the contralateral side; and the lateral pterygoid (Fig. 22-6), which also protrudes and rotates the mandible. The lateral pterygoid also directly inserts into the articular disk and helps control the disk's movement during mouth opening and closing.

Associated Structures

Upper and lower teeth contact (occlusion vs. malocclusion) will directly affect the distribution of compressive forces acting on the TMJs. The suprahyoid and infrahyoid muscles and their interaction with the digastric and the hyoid bone can affect both speech and swallow function and head and neck posture (Fig. 22-5). When functioning appropriately, the infrahyoids

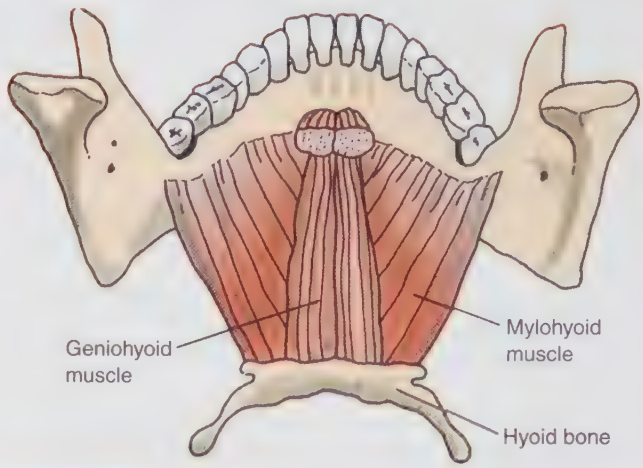

FIGURE 22-7 Mylohyoid and geniohyoid muscles viewed from above and behind the floor of the mouth.

stabilize the hyoid bone, which creates a stable base from which the suprahyoids can contract and move the mandible for chewing and talking (**Fig. 22-7**). The position of the upper cervical spine may alter mandibular position and masticatory muscle tone, affecting pain, occlusion, and TMJ function.[17]

Kinesiology

The jaw has three basic osteokinematic movements, with six degrees of freedom: depression/elevation, protrusion/retrusion, and lateral excursion to either side. These basic cardinal-plane movements can be combined to produce an infinite variety of mandibular motions. During opening and closing, the convex surface of the condylar head must move across the convex surface of the articular eminence. The biconcave disk moves forward with the condylar head on opening to increase joint surface contact between the two convexities and returns to its posterior position on closing to allow for full occlusion.

Arthrokinematically, the accessory movements of the TMJ are rotation (spin of the condylar head), anteroposterior translation, and lateral glide to either side.[11] Gliding movements occur in the upper cavity of the joint, whereas rotation or hinge movements occur in the lower cavity. Gliding and rotation are essential for opening and closing the mouth. Accessory movements most often restricted because of periarticular tissue tightness and disk displacement are lateral glide, translation, and distraction. According to Kraus,[12] of these accessory movements, loss of translation causes the most limitation of osteokinematic movement of the mandible and is more difficult to restore.

The normal range of mandibular opening is 40 to 50 mm; minimum functional opening is 40 mm for most activities. The first 25 mm of opening should take place in the lower portion of the joint, through rotation of the condylar head against the inferior surface of the disk. The additional 15 mm of movement is translation in the upper cavity, as the superior surface of the disk moves anteriorly across the articular eminence.[18] Normal lateral excursion is 10 mm (5 mm to each side), and protrusion is 4 to 6 mm, or at least the ability for the incisors to meet. If the capsule is restricted bilaterally, the patient will have significant loss of lateral movements, limited protrusion, and decreased mouth opening. In unilateral capsular patterns of restriction,

Patient-Related Instruction 22-1

TUTALC

To remind yourself of the resting position of the tongue, mouth, and jaw, use the acronym "TUTALC"

- Tongue Up—Place the front of the tongue on the hard surface just behind your upper teeth.
- Teeth Apart—Let your teeth separate slightly (less than a finger's width)
- Lips Closed—Keep your lips together and breathe through your nose

Allow the muscles in your face and neck to relax in this position. Practice throughout the day; after a week or two, you may find yourself already resting in the TUTALC position.

contralateral excursions are most limited and the mandible will deviate toward the restricted side in a C-curve motion.

The TMJ has two close-packed positions. The anterior position occurs when the disk and condyle translate forward toward the articular eminence during maximal opening; the posterior position is in maximal retrusion, when the mouth is closed, the teeth are clenched, and the condylar head is translated posteriorly, maximally compressing into the posterior elements of the joint. The rest (loose-packed) position for the TMJ is with the teeth 4 mm apart, sometimes termed "freeway space." To maintain the TMJ's resting position with minimal muscle activation, the tongue should remain in its postural resting position. The anterosuperior tip of the tongue should lie in the area against the hard palate, just posterior to the back side of the upper central incisors; this position should be discussed with and demonstrated to the patient.[19,20] The complete functional resting position for the mouth and jaw is: tongue up, teeth apart, and lips closed. The patient can be taught the acronym "TUTALC" to help remember this position (**Patient-Related Instruction 22-1**). When the tongue, teeth, and lips are in this position, the mandible is stabilized against gravity with minimal muscle activation. If not, the masseter and temporalis must contract to hold the jaw against gravity, increasing muscle tone and potentially causing clenching, which close-packs the TMJ.

Proper resting position of the tongue, in addition to helping maintain normal posturing of the mandible and axial spine, enhances normal swallowing patterns and makes daytime clenching more difficult.[21] Instructing the patient to maintain TUTALC helps to achieve the resting position of the jaw and tongue and overcome parafunctional and functional muscle hyperactivity.[22]

Cervical spine posture and muscle imbalances are frequently associated with TMJ symptoms. Functionally, the TMJ, the cervical spine, and the articulations between the teeth are intimately related (**Fig. 22-8**). Muscles attach the mandible to the cranium, the hyoid bone, and the clavicle. The cervical spine is, in essence, interposed between the proximal and the distal attachments of some of the muscles controlling the TMJ.[10] The balance between the flexors and the extensors of the head and neck affects and is affected by the muscles of mastication and the suprahyoid and infrahyoid muscles.[23] Dysfunction

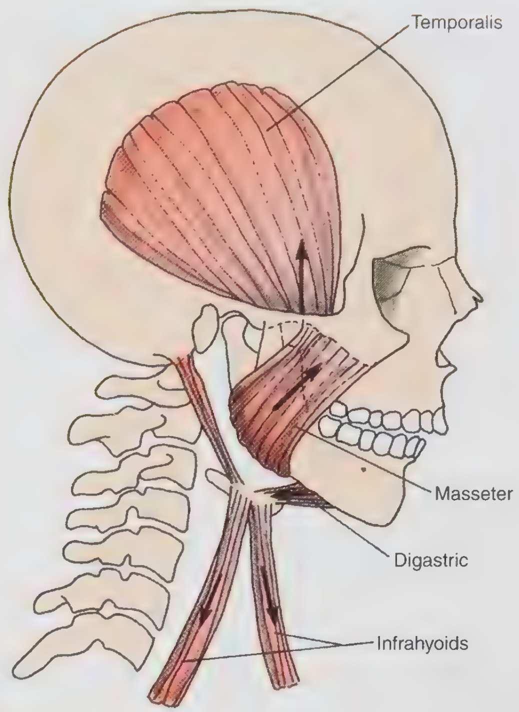

FIGURE 22-8 A lateral view of the head, neck, and mandible showing the muscular forces that flex the head. The infrahyoid muscles depress the hyoid bone; the suprahyoids depress the mandible. The muscles of mastication elevate the mandible and stabilize it against gravity.

anywhere in this system can easily disturb this balance. The neuromusculature of the cervical and masticatory regions actively influences the function of mandibular movement and cervical positioning.[24–26]

Cervical posture change affects the mandibular path of closure, the mandibular rest position, masticatory muscle activity,[22,23,27] and occlusal contact patterns. As discussed in Chapter 23, FHP increases the gravitational forces on the head. To correct for visual needs, the head typically tilts backward (posterior cranial rotation), the neck flexes over the thorax, and the mandible migrates posteriorly (**Fig. 22-9A**).[24] The posterior cervical muscles are shortened and forced to contract excessively to maintain the head in this position, while the anterior submandibular muscles are stretched, resulting in a retraction force on the mandible and an altered occlusal contact pattern. The retruded mandible may then require excessive mandibular shuttling (i.e., excursions) between opening and closing for functional activities such as chewing and eating, which may lead to hypermobility of the TMJ from overstretching of the capsule.[28]

In the presence of an FHP with no significant posterior cranial rotation (Fig. 22-9B), the suprahyoids shorten while the infrahyoids lengthen, leading to a decrease in the freeway space. The hyoid bone is repositioned superiorly, and the degree of elevation is proportional to the decrease in the cervical lordosis or the increase in the FHP.[29,30] Hyperactivity of the suprahyoids produces a depressive force on the mandible. According to Mannheimer and Rosenthal,[28] when combined with hyoid anchoring by means of the infrahyoids, the net mandibular repositioning effect is one of retraction and depression with increased contact in the molar region (see **Building Block 22-1**).

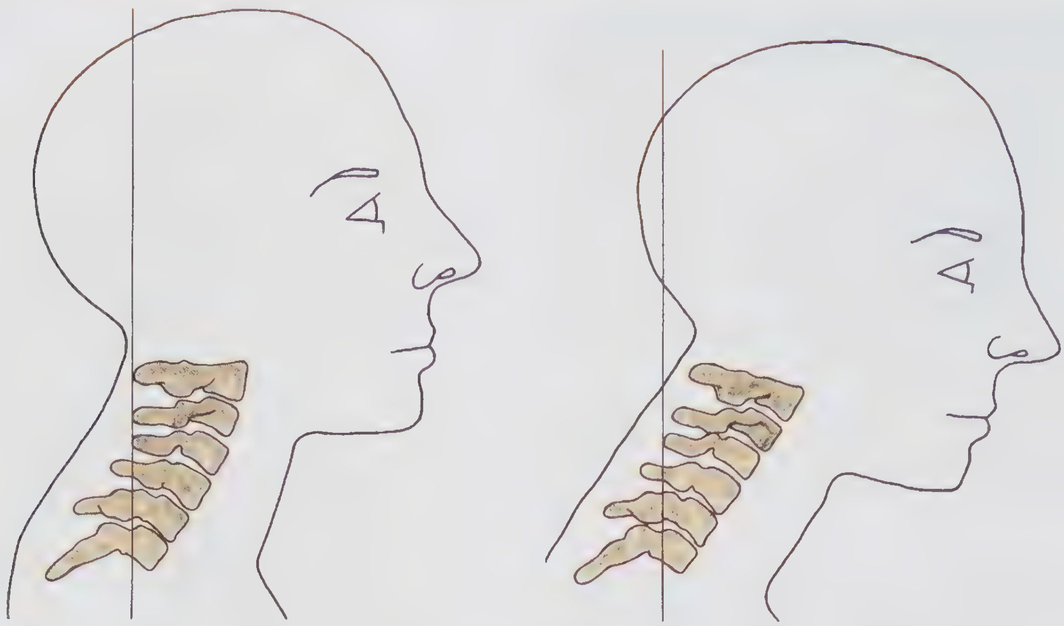

FIGURE 22-9 Types of forward head: **(A)** increased cervical lordosis with posterior cranial rotation (PCR) and **(B)** total flattening out of the cervical lordosis without PCR.

BUILDING BLOCK 22-1

How might a FHP affect tongue position and swallowing? Why is it important to address swallowing function in patients with temporomandibular joint and muscle disorders (TMD)?

Another contributing factor to TMD is mouth breathing. The dysfunctional patterns of the mouth-breathing syndrome constitute a chain reaction of body adaptation to abnormal breathing patterns. Various investigations have shown that postural relationships change to meet respiratory needs.[20,31] Breathing through the mouth facilitates FHP, a low and forward tongue position with resulting abnormal swallowing pattern, and increased activity of the accessory muscles of respiration (i.e., sternocleidomastoids, scaleni, and pectorals).[20,32,33] This pattern is perpetuated by decreased activity of the diaphragm and hypotonicity of the abdominal musculature.[20]

EXAMINATION AND EVALUATION

A thorough evaluation of the TMJ includes all components of the stomatognathic system, including the cervical spine. This assessment assists the therapist in determining the cause of the dysfunction and the influence of other factors and in designing an effective treatment plan. This section will discuss examination specific to the TMJ; for more information on evaluation of the cervical and thoracic spine, see Chapters 23 and 24 (**Case Study 22-1**).

CASE STUDY 22-1

The patient is a 21-year-old college student with complaints of a 6-week history of limited opening and right-sided jaw pain. Present symptoms include limited opening, right jaw pain, and difficulty with speaking, chewing, and brushing teeth due to pain. History includes a 3-year history of right TMJ clicking with occasional pain. The patient reports that she has pain and described it as a dull ache, which worsens with chewing, yawning, and talking. Pain is reported on the visual analog scale (VAS) at 2/10 at rest, and it will increase to 5/10 with function. Aggravating factors include talking, chewing, yawning, brushing teeth, sleeping position, and clenching. Alleviating factors include heat, rest, and ibuprofen (600 mg) for pain. 24-hour report: the patient reports increased pain upon waking in the morning and following meals. The patient reports difficulty finding a comfortable sleeping position due to pain, reporting mild sleep disturbance of 1- to 2-hours sleeplessness. The patient's medical and dental history is noncontributory, and she takes oral contraceptives in addition to the ibuprofen. Management to date included an evaluation by student health services, who recommended scheduled ibuprofen (600 mg three times a day [t.i.d.]), soft diet, warm compresses, and referral to therapy.

On opening, the patient demonstrates 25 mm of opening, with pain at end range. No clicking or crepitation is noted. Lateral excursion is 10 mm to the right and 4 mm to the left with pain at end range. Deflection to the right is noted on opening. She reported tenderness with palpation of the right TMJ at the joint line and with palpation of the masseter on the right. Joint play assessment demonstrates decreased mobility of the right TMJ in all planes. The patient demonstrates a FHP; swallowing and breathing functions are normal.

Subjective History

A comprehensive patient history helps to direct the objective evaluation. The client should provide detailed information about the onset of symptoms, incidence of joint locking, presence of joint noise, history of surgery and trauma, and medical history. Pain should be described in terms of location, intensity, frequency, time of day, and activities that reproduce it. The therapist should investigate associations with headache, tinnitus, vertigo, or hearing dysfunctions. Medical screening should be performed for issues that contribute to or refer to the TMJ, such as rheumatologic illness, fracture, neoplasia, otologic problems, and visceral referral patterns (particularly cardiac).

DISPLAY 22-1

Examples of Parafunctional Activity

Gum chewing
Bruxism/tooth clenching or grinding
Pipe smoking
Thumb sucking
Tongue thrusting
Nail/cuticle biting
Pen/pencil chewing
Mouth breathing
Resting chin on hand (e.g., to study)

Functions and Parafunctions

Oral functions such as talking, chewing, and swallowing should be thoroughly discussed and evaluated. A term found in TMJ management is "parafunction," which means using the body part for some function other than its primary functions (i.e., eating, drinking, and speaking). Gum chewing and tooth grinding (bruxism) are common; other examples are listed in **Display 22-1**. Stress has been linked to an increase in parafunctional habits.[34–36] Clients should be asked about their level of psychosocial, environmental, and postural stress, and asked if they notice an increase in clenching or other parafunctional habits when under stress. The type of job a patient has can provide information about postural parafunctions and the effect on the TMJ. For example, picture the different stresses placed on the TMJ by a student slouching to study on the couch versus a musician who must hold a violin between her chin and shoulder. Use of a functional outcome measure such as the Jaw Functional Limitation Scale (JFLS) may be helpful in evaluating these patients and tracking outcomes (**Display 22-2**).[37]

DISPLAY 22-2

Jaw Functional Limitation Scale[35]

For each of the items below, please indicate the level of limitation **during the last month**. If the activity has been completely avoided because it is too difficult, then circle "10." If you avoid an activity for reasons other than pain or difficulty, then leave the item blank.

		No Limitation										Severe Limitation
1.	Chew tough food	0	1	2	3	4	5	6	7	8	9	10
2.	Chew hard bread	0	1	2	3	4	5	6	7	8	9	10
3.	Chew chicken (for example, prepared in oven)	0	1	2	3	4	5	6	7	8	9	10
4.	Chew crackers	0	1	2	3	4	5	6	7	8	9	10
5.	Chew soft food (for example, macaroni, canned or soft fruits, cooked vegetables, fish)	0	1	2	3	4	5	6	7	8	9	10
6.	Eat soft food requiring no chewing (for example, mashed potatoes, apple sauce, pudding, pureed food)	0	1	2	3	4	5	6	7	8	9	10
7.	Open wide enough to bite from a whole apple	0	1	2	3	4	5	6	7	8	9	10
8.	Open wide enough to bite into a sandwich	0	1	2	3	4	5	6	7	8	9	10
9.	Open wide enough to talk	0	1	2	3	4	5	6	7	8	9	10
10.	Open wide enough to drink from a cup	0	1	2	3	4	5	6	7	8	9	10
11.	Swallow	0	1	2	3	4	5	6	7	8	9	10
12.	Yawn	0	1	2	3	4	5	6	7	8	9	10
13.	Talk	0	1	2	3	4	5	6	7	8	9	10
14.	Sing	0	1	2	3	4	5	6	7	8	9	10
15.	Putting on a happy face	0	1	2	3	4	5	6	7	8	9	10
16.	Putting on an angry face	0	1	2	3	4	5	6	7	8	9	10
17.	Frown	0	1	2	3	4	5	6	7	8	9	10
18.	Kiss	0	1	2	3	4	5	6	7	8	9	10
19.	Smile	0	1	2	3	4	5	6	7	8	9	10
20.	Laugh	0	1	2	3	4	5	6	7	8	9	10

Used with permission Ohrbach R, Larsson P, List T. The Jaw Functional Limitation Scale: development, reliability, and validity of 8-item and 20-item versions. J Orofac Pain 2008;22:219–230.

An abnormal tongue position, with the tongue resting behind the lower teeth, is often accompanied by tongue thrust and other parafunctional habits.[20,38,39] Tongue thrust occurs with protraction of the tongue against or between the anterior teeth, altering swallowing sequence and leading to excessive masticatory muscle activity.[12,37] Although tongue thrust is more common in children, it also occurs in adults, where it is referred to as an acquired adult tongue thrust.[12] It is theorized that tongue movement and positioning in the oral cavity are influenced by dysfunctional mobility and positioning of the cervical spine[18] (see **Building Block 22-2** and **Evidence and Research 22-1**).

BUILDING BLOCK 22-2

In Case Study 22-1, the patient demonstrates a FHP with no significant PCR. How does the presence of a FHP affect her tongue and jaw function?

EVIDENCE and RESEARCH 22-1

Ergonomics as Parafunction: TMD and Musicians

While the prevalence of TMD is around 10% in the general population, ergonomic demands may increase this rate. For instance, playing-related pain in the teeth or jaw occurs in 19% to 47% of musicians, and localized TMJ pain in 15% to 34%, depending on instrument group. Vocalists and musicians who play brass instruments, violin, and viola are most likely to report TMJ pain, due to the positions of the head, neck, and jaw required to play these instruments.[40,41]

Screening Exam for the TMJ

A local screening exam for the TMJ should include: range of motion for vertical opening, lateral excursion, and protrusion; joint function assessment for rotation and translation; joint play; and muscle tests for length, strength, and coordination/motor control. The therapist should also assess the mandible, hyoid, and TMJ and note their resting positions, palpate the soft tissue structures of the neck, and evaluate the patient's oral function, and patterns of occlusion, swallowing, and respiration, as these will have direct influence on the TMJ. Finally, regional screening including cervicothoracic movement, atlantoaxial stability, posture, and medical screening for referred pain of non-musculoskeletal origin and for systemic hypermobility will help inform the treatment plan.

THERAPEUTIC EXERCISE FOR COMMON IMPAIRMENTS OF BODY FUNCTIONS

A treatment plan cannot be determined without a thorough examination and evaluation of the diagnosis, activity limitations, and participation restrictions. Certain causes of mandibular dysfunction, particularly those stemming from disorders of the mandible or cranial bone—aplasia, dysplasia, hypoplasia, hyperplasia, fractures, and neoplasms—may not be appropriate for physical therapy interventions, while jaw pain of nonmechanical origin warrants referral for medical management.[42] Therapeutic exercise interventions should address specific impairments that directly relate to activity limitations and participation restrictions to increase overall function of the TMJ.

Mobility Impairments

Hypomobility

Etiology The primary mandibular hypomobilities seen in the clinic may be intra-articular, with the restriction due to the joint capsule or articular structures, or myogenous, occurring in the muscles extrinsic to the joint.[7] Arthrogenous temporomandibular dysfunctions that can contribute to mandibular hypomobility are ankylosis (fibrous or bony); arthropathies involving the periarticular tissue (capsule) and structural bony changes (e.g., osteophytes); disk displacement (i.e., acute disk displacement that does not reduce); and inflammation or joint effusion. Myogenous hypomobility is due to masticatory muscle disorders such as myofascial pain, muscle splinting, myositis, spasm, contracture, and neoplasia.[31] Differentiating between intra-articular and myogenous causes of hypomobility will help with appropriate treatment planning and exercise choices.

Hypomobility of either type may lead to capsular fibrosis, a result of the intermolecular cross-linking adhesions of collagen fibers. It most commonly accompanies one or some combination of three situations: resolution of an acute articular inflammatory process, such as may occur after a whiplash injury; a chronic, low-grade articular inflammatory response, often due to overloading the joint from parafunctions like bruxism; or, immobilization such as after surgery or fracture.

The hypomobile jaw may or may not be painful. If painful, the pain is felt over the side of involvement, with possible reference into areas innervated by cranial nerve V. Pain increases during functional and parafunctional movements of the mandible, with the pain pattern dependent on the source of the restriction (myogenous vs. arthrogenous). If significant capsular shortening exists, the mandibular opening is less than functional, and the patient presents with a capsular pattern of restriction.

Treatment Treatment for the hypomobile jaw typically begins with gaining tissue extensibility through soft tissue mobilization and joint mobilization. The gains are maintained with a series of passive and active stretches. Motor control into the new ranges must be developed in order to restore functional movements to the jaw. Strength and stability can then be progressed, finally moving into higher-speed motions and transfer from conscious motor control to subconscious performance during daily movements. Patient education is a significant part of the rehabilitation program throughout, including instructions on proper posture, maintaining the normal rest position of the tongue and jaw ("TUTALC"), and avoiding aggravating factors.[43]

Mobilization of the involved soft tissues can decrease muscle tone, which will facilitate stretching techniques and joint mobilization procedures, making them more tolerable and effective. Effective soft tissue mobilization by therapist and patient is a primary intervention for myogenous hypomobility. Static

FIGURE 22-10 **(A)** Interoral distraction. The clinician's thumb is positioned to apply a distraction force. **(B)** Lateral glide. The clinician's thumb is positioned on the lingual side of the teeth to apply a lateral glide force. **(C)** Intraoral translation (ventral glide). The clinician's index and third fingers are positioned to apply translation.

stretches, dynamic movements, and strengthening exercises are used to promote mobility, motor control, and strength for both myogenous and arthrogenous restrictions. Joint mobilization techniques are used to further enhance capsular extensibility in arthrogenous limitations. These may be performed initially by the therapist intra-orally or extra-orally, with the patient instructed in self-mobilization procedures for the TMJ including distraction, medial glide, and translation (**Figs. 22-10** to **22-12**).[12,21,44,45]

Most patients with hypomobility impairment require a home program of active ROM exercises, self-mobilization, and a passive stretching program with tongue depressors or a device such as the Thera Bite Jaw Motion Rehabilitation System (ATOS Medical

FIGURE 22-11 Extraoral articulation techniques are performed with the patient sidelying on the noninvolved side with the head supported on a pillow. **(A)** Extraoral medial glide. Gentle oscillatory mobilizations are performed over the lateral pole of the condyle in a medial direction with the thumbs. **(B)** Extraoral protrusion. Gentle oscillatory mobilizations are performed over the posterior aspect of the condyle in an anterior direction.

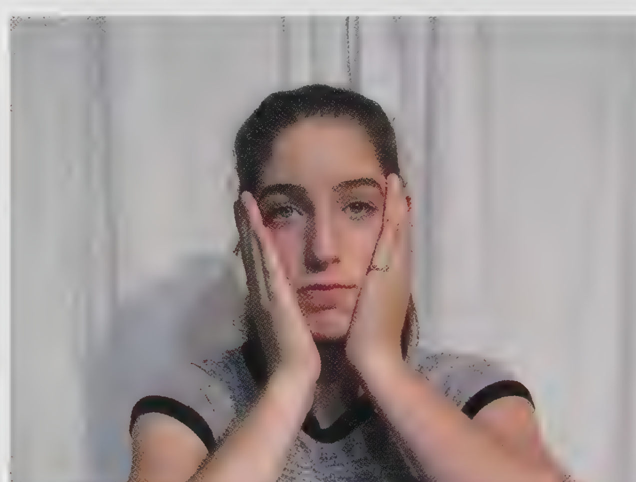

FIGURE 22-12 Self-distraction may be performed by the patient by gently squeezing the face and pulling forward and downward on the mandible. The elbows should rest on a firm surface, or the patient should hold the forearms firmly against the chest. To enhance the mobilization techniques, active participation by the patient is encouraged. The patient actively opens or closes the mouth using minimal muscle contraction, and after relaxing, additional distraction can be applied.

FIGURE 22-13 Stack tongue depressors between teeth for passive stretch.

AB, Hörby, Sweden) to maintain and facilitate tissue extensibility. Passive stretch, also known as prolonged static stretch, may be used by placing stacked tongue depressors horizontally between the upper and the lower incisors, adding layers as able to increase the mandibular opening (**Fig. 22-13**). As the range of motion increases, the patient can gradually increase the number of tongue depressors until he or she can open far enough to insert the knuckle of his or her index and middle fingers between the anterior teeth. Another simple method of self-stretch is to use the thumbs crossed over the index fingers, actively opening the jaw, and applying gentle overpressure with fingers until a stretch is felt (**Fig. 22-14** and **Self-Management 22-1**).

Post-isometric relaxation techniques (PIRs) can be very effective in managing myogenous restrictions of the TMJ. These techniques are similar to muscle energy and proprioceptive neuromuscular facilitation (PNF) exercises. PIRs use active

SELF-MANAGEMENT 22-1
Mandible Self-Stretch

Purpose:	Stretch the soft tissues of the mouth and jaw to improve mouth opening.
Start Position:	Sit comfortably in good posture. Place index fingers of both hands on lower teeth, with thumbs on upper teeth, trying to get as far back in the mouth as possible.
Movement Technique:	Actively open mouth as far as possible. While opening the mouth, press your fingers apart to add extra pressure to the stretch.
Dosage:	Hold stretch 15 to 60 seconds. Relax and repeat. Perform daily.

FIGURE 22-14 Mandibular opening self-stretch (see Self-Management 22-1).

muscle contractions at various intensities from a precisely controlled position in a specific direction against a counterforce to facilitate motion.[46] The muscle being targeted is placed in a stretch position. The patient is then cued to isometrically contract against gentle resistance at approximately 20% of MVC, then relax. During the relaxation phase, passive stretch is applied[47] (See **Patient-Related Instruction 22-2** and **Evidence and Research 22-2**).

Patient-Related Instruction 22-2

Post-Isometric Relaxation Techniques

Mouth opening (**Fig. 22-15**)	Sit at a table with one elbow on the table, and your forehead propped on that hand. Place the fingers of your other hand on your lower teeth. Open your mouth until you feel a stretch. Breathe in, open as wide as possible, as if yawning. Resist with your fingers as you try to close your jaw; don't let your jaw move (isometric contraction). Hold for a few seconds. Breathe out and relax, stretching mouth further open.
Lateral pterygoid (**Fig. 22-16**)	Lie on your back. Place your thumbs on the front of your chin. Press the chin forward into your thumbs, resisting with gentle force. Breathe in and hold for a few seconds. Breathe out and relax, letting the chin drop back toward the throat for a stretch.
Digastric (**Fig. 22-17**)	Sit at a table with one elbow on the table, and your chin propped on that hand. Wiggle the bone in your throat side to side—your therapist will teach you how. Place your thumb on the side of the bone that is more tense. Open your mouth against the resistance of your hand on your chin. Breathe in and hold for a few seconds. Breathe out and relax, while you gently press the bone in your throat to the opposite side for the stretch.

FIGURE 22-15 Post-isometric relaxation technique for mandibular opening (temporal, masseter, and medial pterygoid muscles).

FIGURE 22-16 Post-isometric relaxation technique of the lateral pterygoid.

FIGURE 22-17 Post-isometric relaxation technique for the digastric muscle.

EVIDENCE and RESEARCH 22-2

Post-Isometric Relaxation Exercises

In a study of 244 patients and across 351 muscle groups, the PIR technique produced immediate pain relief in 94%, lasting pain relief in 63%, and lasting relief of point tenderness in 23% of the sites treated. Patients who learned how to do the technique on themselves had the best long-term outcomes.[45]

Active stretch exercises into newly gained ranges of motion help maintain mandible mobility as well as facilitating motor control. The patient should be encouraged to open and close the mouth throughout the day. Active protrusion and lateral excursions (with or without tongue depressors positioned between the teeth) can be used to actively mobilize the mandible in other directions (**Fig. 22-18**).

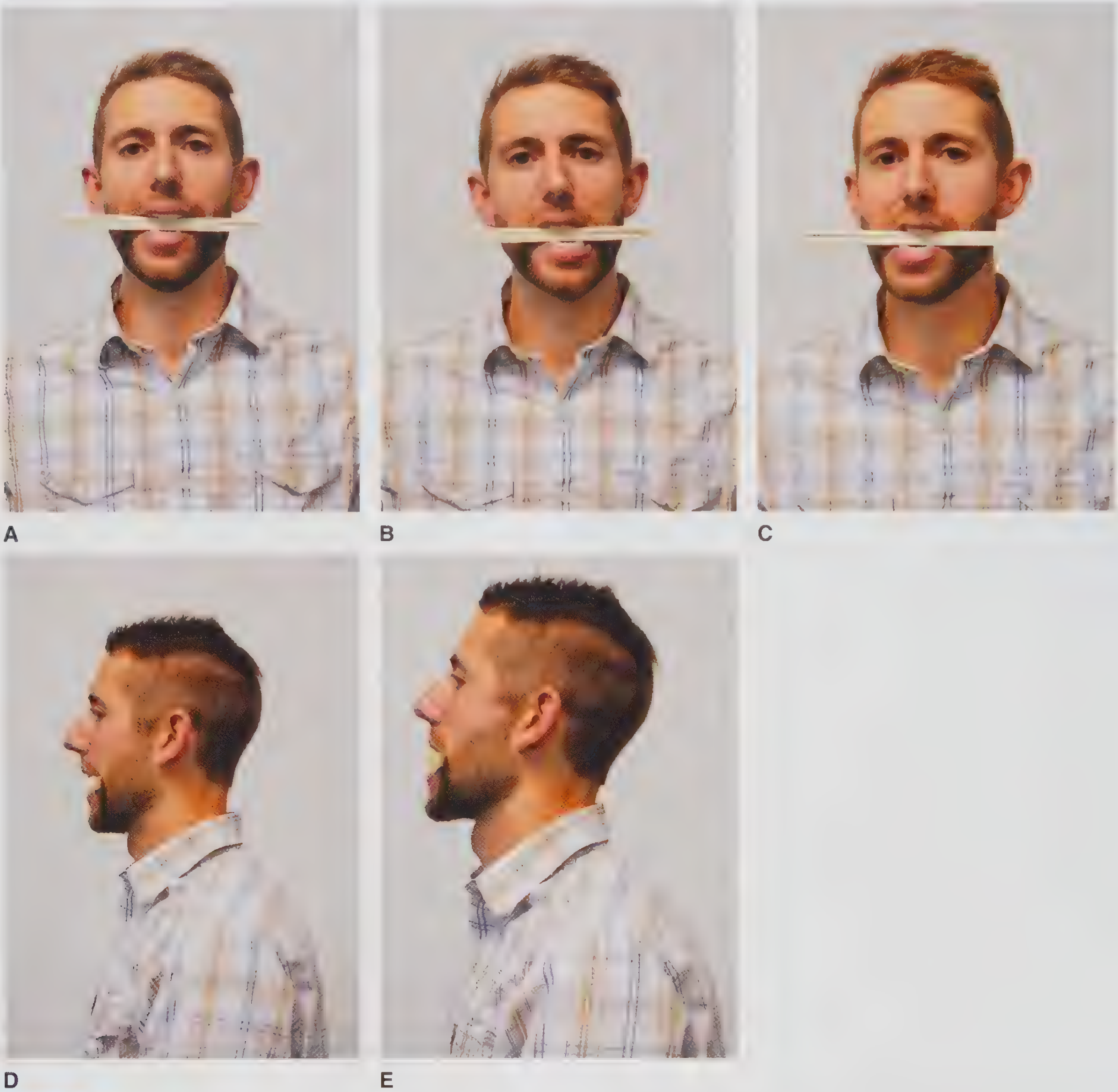

FIGURE 22-18 Active exercise to increase mandibular lateral excursions and protrusion. The patient is given enough tongue depressors to place between the teeth to allow for approximately 10 to 11 mm of opening **(A** and **D)**. The patient is then asked to protrude the mandible at this opening to improve translation **(E)**. The patient may also be instructed to protrude and glide the mandible to one side to improve translation of one side **(B** and **C)**.

Once movement has been restored, the patient needs to learn motor control and coordination into the newly available range. Functional kinetic exercises developed by Klein-Vogelbach[48,49] develop this motor control, helping the patient learn to move the TMJs freely and with precision in all directions. In normal TMJ activity, the mandible moves while the head remains stationary. If movement at the TMJ is restricted, Klein-Vogelbach suggests it may be helpful to reverse these roles and move the head over a stable jaw, transmitting the active movements to the upper cervical spine joints (i.e., atlantooccipital and atlantoaxial joints). The therapist can instruct the patient to move head-on-jaw, rather than jaw-under-head, as an exercise for motor control. Note that the therapist should screen the upper cervical spine to ensure full and safe function prior to beginning these exercises.

Begin practicing these exercises in the clinic, with the therapist stabilizing the mandible and then teaching the patient how to do so at home. While the patient sits with good vertical alignment, the therapist or the patient provides fixation of the mandible; the fingers of both hands should grasp the mandible. Exercises include opening and closing of the mouth, lateral deviations, and protrusion and retrusion (**Fig. 22-19**). These precise and unfamiliar movements of the TMJ must be performed at low intensity and slowly, because the body is learning movements that it does not need in normal motor behavior.[47] These head-on-mandible exercises are

FIGURE 22-19 Functional kinetic exercises moving the proximal lever (the head). **(A)** Opening: with the mandible stabilized, the patient extends the head (the tip of the nose moves cranially and dorsally). The joints of the upper cervical spine extend, and the mouth opens, moving through the TMJs. **(B)** Closing: the patient flexes the head (the tip of the nose moves caudally and ventrally); the joints of the upper cervical spine flex and the mouth closes. **(C** and **D)** Lateral movements: with the mandible stabilized, rotate the atlantooccipital and atlantoaxial joints of the cervical spine, allowing the upper teeth to slide laterally on the stabilized mandible. The movement causes lateral translation in the TMJ contralaterally and medial translation ipsilaterally. **(E)** Protrusion: with the mandible stabilized, retract the cervical spine, bringing the upper teeth dorsal (posterior) to the lower teeth for relative mandibular protrusion and TMJ anterior translation. **(F)** Retrusion: with the mandible stabilized, protract the cervical spine, bringing the upper teeth ventral (anterior) to the lower teeth for relative mandibular retrusion and TMJ posterior translation.

then followed up with normal mandible-under-head motions to assess progress and maintain function. Progress the Klein-Vogelbach exercises by placing the head in an inverted position (**Fig. 22-20**). The therapist should ensure the patient is safe and comfortable in this position. By changing the position of the head, opening of the mouth is performed against gravity. The suprahyoids must now contract concentrically to open the jaw, while the masseter and temporalis fire eccentrically to control speed; closing is assisted by gravity, with the suprahyoids firing eccentrically.

Hypermobility

Etiology While the cause of bilateral hypermobility is unknown, unilateral hypermobility can occur as a compensatory reaction to hypomobility of the contralateral side. Other potential predisposing factors range from joint laxity to psychiatric disorders to skeletal disorders.[50] Investigations suggest that systemic hypermobility (i.e., ligament laxity) may be closely related to TMJ hypermobility, and other investigations suggest disk displacement and osteoarthrosis.[48,51,52] Parafunctional habits in childhood such as

FIGURE 22-20 Opening the mouth against gravity, with the long axis of the body inverted.

prolonged bottle-feeding, thumb sucking, and pacifier use may contribute to hypermobility of the TMJ in the adult.[20] Many adult patients also present with a history of habitually opening their mouths excessively wide when yawning or eating.

Believed to be the most common mechanical disorder of the TMJ, hypermobility is characterized by early and excessive anterior translation of the mandible.[53] In cases of hypermobility, translation occurs within the first 11 mm of opening rather than the last 15 to 25 mm. Excessive anterior translation results in laxity of the capsule and ligaments, particularly posteriorly. The breakdown of these structures may lead to disk derangement in one or both TMJs. Ultimately, impairments such as loss of motion and arthritic changes may occur, leading to loss of function.

Treatment Patient education regarding joint function, the reason for the symptoms, and activity modification is key to successful management of hypermobility. Once the patient begins to attend to and limit provocative activities in daily life, therapeutic exercises are likely to be more effective.

Teach and Reinforce Resting Position For the therapist to teach control of the jaw muscles, the patient must first recognize the resting position of the mandible: lips closed, teeth slightly apart, and the tongue on the hard palate (Patient-Related Instruction 22-1). The patient should breathe in and out through the nose and use diaphragmatic breathing.

Temporomandibular Rotation and Translation Control The patient starts by learning to limit TMJ mechanics to condylar rotation. Initial training uses an active technique with the index finger and thumb monitoring and guiding the movement. The patient begins in the TUTALC position and uses the fingers to monitor both mandibular movement and joint motion. As the patient begins to open the mouth, they monitor for movement quality, speed, and rotation in the joint, stopping as soon as translation begins (**Self-Management 22-2**). The patient may also use a mirror to watch for normal tracking and to ensure that the tongue stays elevated and the jaw does not deviate from the midline. The exercise is progressed by decreasing tactile input (**Fig. 22-21**), lowering the tongue, and finally increasing speed.[12] Kraus found this a useful technique in reducing symptoms associated with inflammatory disorders such as synovitis and capsulitis and when inflammation coexists with hypermobility, hypomobility, or excessive parafunctional activities (see **Building Block 22-3**).[12]

SELF-MANAGEMENT 22-2
Rotation Motor Control

Purpose: To restore proper "tracking" to the TMJ, to improve rotation, to limit early translation through an active assisted technique, and to decrease or eliminate clicking, cracking, popping, or excessive movement occurring in the TMJ.

Cues: Carefully monitor the movement of the TMJ, feeling for rotation and stopping the movement if translation (forward sliding) begins.
Use a mirror for visual feedback. The tongue should stay on the roof of the mouth and the jaw should move straight down the midline without deviations.
Exercise should be performed slowly and rhythmically in pain-free range.

Start Position: Sit on a firm chair, close to the front edge, with feet on the floor hip-width apart.
Sit with good posture, including a neutral pelvis, lumbar, thoracic, and cervical spine alignment.
Use supports as needed to achieve this neutral posture. For instance, you can sit against a wall to support your back, place towels behind your head to get a neutral neck position, or sit on a folded towel for neutral pelvis and lumbar spine.

Movement Technique: Keep the tongue on the roof of the mouth.
Place one index finger on the TMJ.
Place the opposite thumb and index finger lightly on the tip of the chin. Allow the lower jaw to drop down and back, guiding the movement with your thumb and index finger on the chin. STOP when you feel the jaw begins to move forward (translation).

Dosage: Sets/Repetitions: Repeat this exercise five times
Frequency: Do five times per day.
As you are able to open more and move more smoothly, perform throughout the day, such as whenever you are in front of a mirror.

Progression: Level II: Repeat exercise with tongue still on roof of mouth, but without the finger and thumb on the chin (Fig. 22-19).

Level III: Remove tongue from roof of mouth and open the jaw with controlled motion. Allow the finger and thumb on the chin to guide and assist.

Level IV: Control jaw opening without support either from the tongue or the finger and thumb on the chin.

Level V: Add speed as you perform all the above versions of the exercise, but stay focused on opening without allowing translation.

SELF-MANAGEMENT 22-2
Rotation Motor Control (*continued*)

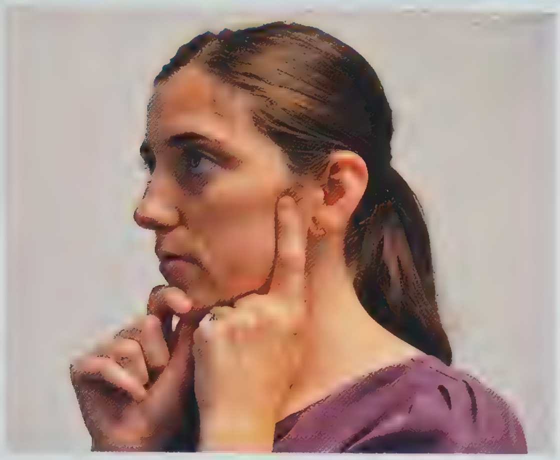

FIGURE 22-21 Neuromuscular reeducation for rotation and translation control (see Self-Management 22-2).

BUILDING BLOCK 22-3

Why is it important to teach the normal resting position of the tongue to patients with TMD? How would you teach this to a patient?

Muscle Performance Impairments

Etiology Muscle imbalances, including asymmetric weakness of the muscles controlling one TMJ with normal strength on the other side, may be due to many factors. Disuse, habit, and parafunctional activities may play a role, for instance if the patient habitually chews only on one side of the mouth. Impairments of muscle performance may also be caused by trauma or surgical procedures. Restoring muscle balance both around a single joint and symmetrically between both TMJs is important for long-term success.

Treatment Strength and stabilization exercises may be initiated concurrently with or after motor control exercises to develop TMJ rotation and translation control. These exercises are designed to strengthen the jaw muscles and balance the strength and function of the right and the left TMJs. Dynamic exercises may be used in the management of painless clicking, after a painful episode is resolved, and when the click is not caused by a displaced articular disk.[54] Strengthening exercises are also indicated after surgical interventions and for a variety of other TMJ dysfunctions and disorders.

Isometric or Static Exercises PNF techniques such as the alternating isometrics and rhythmic stabilization may be used to build isometric strength. Light pressures are applied to the jaw with the index finger and thumb on either side of the mandible. The patient maintains the TUTALC position while applying gentle pressure for 6 to 10 seconds in varying directions (see **Self-Management 22-3**). Motion in each direction is repeated

SELF-MANAGEMENT 22-3
Mandible Stabilization and Strength

Purpose:	To improve muscle strength and muscular stability of the jaw and TMJ and to help improve normal positioning of the jaw at rest and on opening.
Cues:	Use gentle resistance—a 2 on a scale of 0 to 10, where 10 is maximum resistance. Do not allow the jaw to move while applying pressure. Monitor exercise and movement in mirror if needed.
Start Position:	Sit in good posture (head, neck, and back). Let jaw and mouth drop slightly open with teeth apart.
Movement Technique:	Place index finger at desired resistance point. Apply gentle pressure (2 out of 10) in varying directions, changing the placement of your finger each time to fire different muscles. Sideways at the left or right side of the jaw (alternate) Up toward the ceiling Back/in toward the throat Diagonally toward the left or right ears (alternate)

(*continued*)

SELF-MANAGEMENT 22-3
Mandible Stabilization and Strength (*continued*)

Hold each position for 10 seconds; do not increase pressure over time.

Dosage: Sets/Repetitions: ______________

Frequency: ______________

Progression: Level II: open mouth further, approximately one knuckle width apart, and repeat the exercise (**Fig. 22-22**).

Level III: Repeat the exercise, opening mouth almost as wide as it will go (maximum mouth opening).

FIGURE 22-22 Isometric stabilization exercises. First one and then two knuckles are placed between the upper and lower teeth **(A)**. The knuckle or knuckles are removed, keeping the teeth apart. Apply gentle pressure to the lower jaw laterally **(B)**, posteriorly **(C)**, and/or superiorly **(D)** to stabilize in the desired direction (see Self-Management 22-3). Not all patients are progressed to the two-knuckle-width opening.

several times to exercise various muscles and stimulate neuromuscular awareness. Progression is by repeating the exercise at increasing interincisal distances.

PNF techniques resisting isometric opening strengthen the lateral pterygoids and suprahyoids and promote relaxation of the mandibular elevators (i.e., temporalis and masseter) through reciprocal inhibition. This technique may then improve maximum oral opening measurements.[55,56]

Isotonic or Dynamic Exercises Dynamic exercises are performed against manual resistance as the patient moves the mandible through the available range of motion. Exercises include resisted opening, closing, and lateral movements (**Figs. 22-23** to **22-25**). Open-close movements are initially limited to about 15 mm of opening (i.e., width of one knuckle) to strengthen motion during the rotation phase of opening without allowing anterior translation. The patient should be reminded not to push the jaw forward during the opening movement and to allow the jaw to open in an arc toward the throat. Lateral movements are limited to about 5 mm to train normal ROM. Resisted movements should initially be performed with slow, controlled movement, increasing speed as the patient is able while maintaining normal rotation/translation relationships and avoiding deviation from midline. ROM should be limited to pain-free, click-free movements (see **Building Block 22-4**).

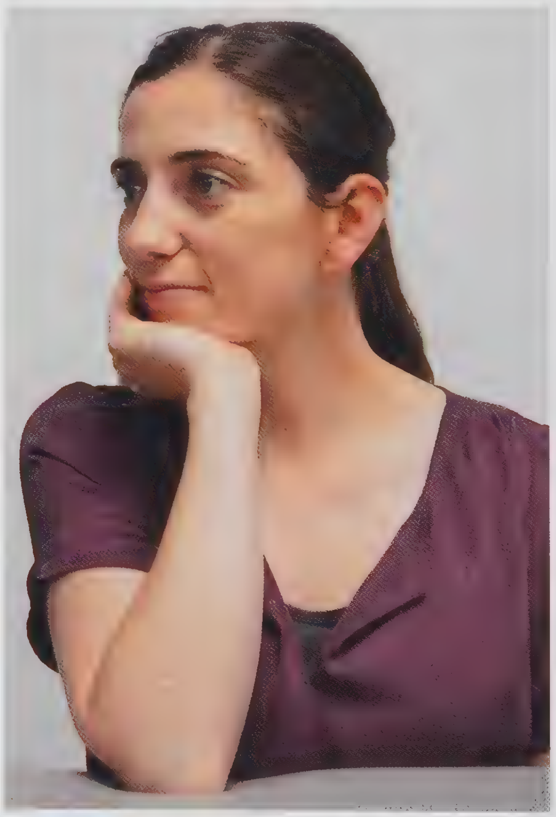

FIGURE 22-23 Dynamic strengthening exercise. Resisting against the right lateral force provided by the patient's right hand strengthens the left lateral pterygoids. Resistance is provided by placing the palm against the chin with the arm stabilized (i.e., the elbow resting against a firm surface or with the arm held firmly against the chest).

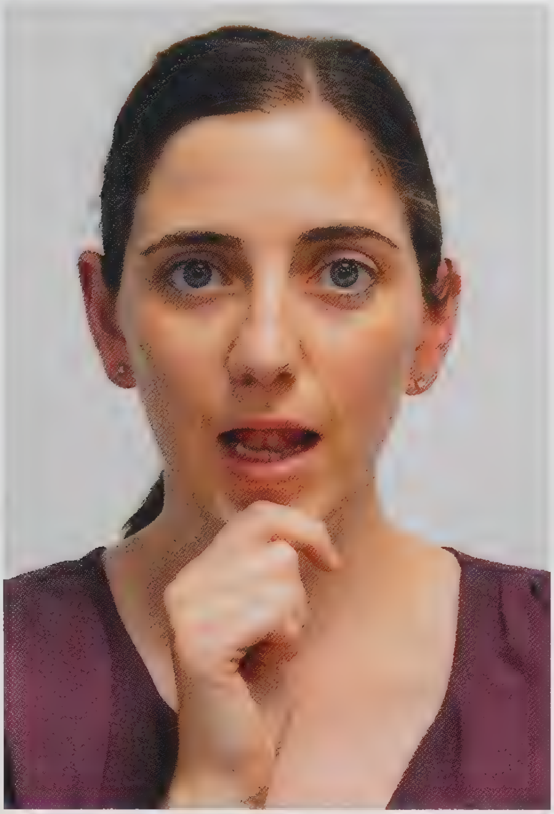

FIGURE 22-24 Resisted concentric opening at the midline is performed by the closing force provided by the therapist's or the patient's hand. Emphasis is placed on straight, midline mandibular depression and protrusion with the tongue on the hard palate. To avoid provoking pain or clicking, opening should be restricted to <20-mm interincisor separation.

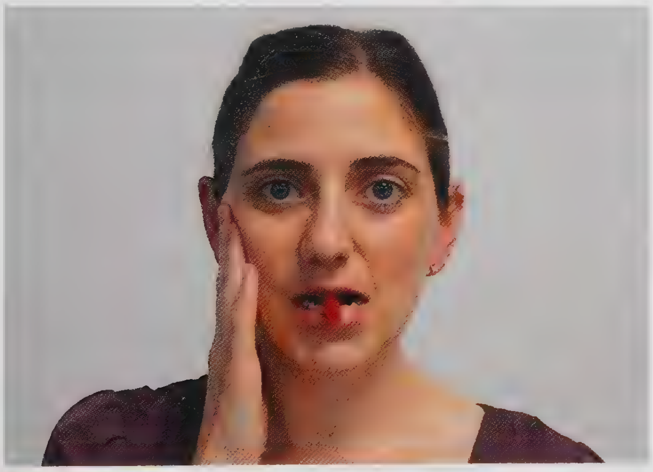

FIGURE 22-25 Lateral deviation of the mandible. Tubing is maintained with the frontal incisors at an end-to-end position. Active exercises are performed by rolling it side to side. A mirror should be used for visual feedback to ensure that no retrusion occurs.

BUILDING BLOCK 22-4

A patient demonstrates 55 mm of vertical opening with early and excessive translation noted on opening. What is the movement fault for this patient? What exercises would you teach to help correct this fault?

Posture Impairments

Etiology

FHP with resultant rounding of the shoulders can produce dysfunction of the craniocervical and temporomandibular systems. To restore balance to the system, patients must address excess tension, head and shoulder girdle alignment, jaw and tongue position, and respiratory pattern. This section will focus on postural impairment interventions specific to the TMJ. For more information and general exercise instructions to alleviate FHP, please refer to Chapter 23.

Treatment

Neuromuscular Relaxation Training Effective self-regulatory and neuromuscular relaxation training involves development of habits of attention, bringing conscious awareness to tension in the face and jaw. With regular practice, this is eventually transferred to subconscious performance during everyday activities. Various relaxation procedures that employ physical and mental exercises to increase awareness have been devised.[57–59] Any of these relaxation techniques may be integrated into biofeedback-assisted attention training.

Progressive relaxation involves a structured isometric approach that asks the patient to contract the muscle of interest, and then relax that muscle.[60,61] It may also use a reverse approach, in which the muscles are passively stretched and then relaxed.[62,63] Autogenic training employs adaptive mental imagery.[64,65] The verbal content of the standard exercises is focused on the neuromuscular system (e.g., heaviness of the limbs), the vasomotor system (e.g., warmth of the limbs, coolness of the forehead), and slowing of the cardiovascular system and respiratory mechanisms.

Yoga, meditational mantra, and diaphragmatic breathing techniques may be helpful in management of TMD.[66–69] Approaches which focus on integrated functions of the tongue, jaw, and breathing, including the use of sensory awareness techniques[65,70–73] and sensory-motor learning exercises,[74–79] may be particularly valuable for these patients.

Head, Neck, and Shoulder Postural Exercises A significant aspect of the therapy for the head, neck, and shoulder is a postural exercise program. The principles proposed by Kendall et al.[80] and Sahrmann[81,82] are beneficial for these patients (see Chapters 9, 17, 23–25). Cue the patient to avoid flattening of the cervical curve and excessive cranial flexion (**Fig. 22-26**). Therapists may also use a variety of movement reeducation approaches to attain balanced posture, alignment, structure, and function. Therapeutic approaches include a variety of methods, such as Aston Patterning,[83,84] the Alexander Technique,[68,69,85] the Feldenkrais Method,[73–77] tai chi,[86–88] and Trager Psychophysical Integration,[82] which use sensory, kinesthetic, and proprioceptive feedbacks to the body-mind system. A TMJ sensory awareness CD, part of the Intelligent Body CD/DVD series, has been developed based on the Feldenkrais Method for home use (Feldenkrais Movement Institute, Berkeley, CA).

Conscious practice must transfer to the subconscious level for long-term success. To facilitate this, it is often helpful for the patient to practice awareness exercises directed at restoration of the neutral resting position of the head, neck, tongue, jaw, and shoulder girdle throughout the day. The RTTPB system (relaxation, teeth apart, tongue on the palate, posture, and breathing) proposed

A B

FIGURE 22-26 Cervical posture. **(A)** Forward head with PCR: line between forehead and chin angled posteriorly. **(B)** Neutral position: line between forehead and chin is nearly perpendicular to the floor.

by Ellis and Makofsy[19] expands on the TUTALC concept, and is one way to help the patient remember and practice frequently. This helpful acronym addresses the common imbalance seen in the upper quadrant (see **Building Block 22-5**).

BUILDING BLOCK 22-5

Your patient has a history of asthma and allergies. How may this affect his or her jaw symptoms?

Mandibular and Tongue Postural Exercises Once the patient is familiar with the TUTALC position, additional mouth, jaw, and tongue posture exercises may be added to the program. Tongue push-ups may be used as an initial exercise to strengthen the tip of the tongue and familiarize the patient with correct placement.[37] The tongue tip is pointed and pressed against the hard palate, just behind the upper teeth, held and then released, and the exercise is repeated. Increase challenge by instructing the patient to "cluck" the tip of the tongue repeatedly against the hard palate at increasing speed.[42] The patient may also practice the sounds made by the letters T, D, L, and N, all of which raise the tip of the tongue to the hard palate. Words such as "Ted," "dad," "love," and "nut" can be practiced, working to add force to activate the tongue muscles.[37]

Swallowing and Respiratory Impairments

Etiology

A commonly overlooked problem in patients presenting with TMJ and craniocervical disorders is an altered swallowing sequence, which is associated with tongue thrust swallow and/or abnormal breathing. In abnormal breathing, such as mouth breathing, the tongue usually rests against the lower teeth, the teeth are apart, and the mouth remains open. This position is maintained during abnormal swallowing, causing the tongue to thrust forward. Persons who swallow abnormally usually bring their tongues forward to meet the glass or cup when taking a drink, and excessive lip activity may be evident. The hyoid bone may elevate on swallowing, and abnormal contraction of the suboccipital musculature may occur.[89]

Intervention

Funt and colleagues[37] have proposed a way of altering this abnormal swallowing pattern. The patient is instructed to drink from a cup or glass. While doing so, the patient bites the back teeth together, puts the tongue "to the spot" on the anterior palate directly behind the upper incisors, siphons the water in between the teeth, and swallows (**Fig. 22-27**). As water is siphoned during the initial phase of swallowing, the tip of the tongue should return

FIGURE 22-27 Swallowing exercise. As water is siphoned during the initial phase of swallowing, the tip of the tongue should return to its resting position. When successful, the patient will be able to swallow repetitively without movement of the facial muscles.

to its resting position without putting pressure on the posterior teeth. When this is accomplished, successive sips of water may be taken and swallowed without any movement of the facial muscles. Because a tongue thrust habit is usually well rooted, this exercise should be practiced several times daily. Once the patient is comfortable with using the new swallowing pattern for all eating and drinking activities and has learned proper posturing, he or she should begin to monitor all swallowing activities and become aware of the rest position of the tongue throughout the day, in order to assess transfer of the exercise to the subconscious level.

Proper diaphragmatic breathing is also important to normal TMJ function.[64,68,70,90–92] For more information on respiratory training techniques, please refer to the section on diaphragmatic breathing in the Thoracic Spine chapter.

The Rocabado 6 × 6

A well-known series of exercises proposed by Rocabado[93] attempts to address the multifactorial nature and management of mechanical jaw pain. Patients will often find these exercises during Internet searches for information, so the physical therapist at minimum should be aware of and able to discuss them. It includes exercises addressing the relationships between the structures of the stomatognathic system, tongue position, and diaphragmatic breathing practice (**Self-Management 22-4**). While not well validated in formal study, these exercises are generally accepted clinical practice and may provide a good starting point for exercise (**Evidence and Research 22-3**).

SELF-MANAGEMENT 22-4
Rocabado 6 × 6[91]

Purpose: To learn a new postural position, fight the soft tissue memory of the old position, restore the original muscle length–tension relationships, restore normal joint mobility and restore normal body balance.

Movement Technique:

1. Practice tongue rest position
   - Make a clucking sound with the tongue six times
   - Find normal resting position (TUTALC)
   - Diaphragmatically breathe through the nose while the tongue is in the resting position for six breaths
2. Control TMJ rotation on opening
   - Tongue on roof of mouth and open six times (see Self-Management 22-2)
3. Stabilize the mandible against resistance
   - Apply light resistance to opening, closing, and lateral deviation with the jaw in a resting position (see Self-Management 22-3), holding each position for 6 seconds
4. Upper cervical flexion (nodding)
   - Nod head slightly up and down (approximately 15 degrees) six times
5. Lower cervical retraction
   - Tuck your chin slightly back toward throat and hold 6 seconds.
6. Shoulder girdle retraction
   - Pull your shoulder blades back and down toward opposite hip pockets and hold 6 seconds

Dosage: Sets/Repetitions: Do each exercise in the series six times.
Frequency: Perform the series six times per day.

EVIDENCE and RESEARCH 22-3

Does the 6 × 6 Series Work?

In a randomized double-blind controlled study, Mulet et al.[94] evaluated whether the 6 × 6 exercise series proposed by Rocabado added value to a self-care based program (self-care only vs. self-care + 6 × 6). They found that jaw pain and neck pain intensity showed a statistically and clinically significant improvement within both treatment groups, and there was no difference between groups. There was no clinically or statistically significant change in head posture for either group. In this study, therefore, the addition of the 6 × 6 exercises did not change the outcomes compared to self-care alone, nor did they alter head posture during the 4-week study.

THERAPEUTIC EXERCISE FOR COMMON DIAGNOSES

In the typical physical therapy setting, the most common disorder of the TMJ is dysfunction involving the capsule and intra-articular structures. Some of the more common intra-articular diagnoses of the TMJ are reviewed in the following sections. Remember to consider the possibility of more serious pathologies and refer to an orofacial medical specialist (MD or DMD) for further investigation and management if appropriate.

With any TMJ issue, the therapist should remember to consider the cervical spine's influence, including the suprahyoid-infrahyoid length–tension relationship and its influence on tongue physiology and the resting position of the jaw.[95,96] Treatment of the cervical spine, based on the evaluation findings, may be directed at postural corrective exercises for the head and neck, releasing myofascial restrictions, restoring joint mobility, or providing segmental stabilization exercises for hypermobile segments.[97] Refer to Chapter 23 for more information (**Evidence and Research 22-4**).

EVIDENCE and RESEARCH 22-4

Effect of Head Position on TMJ Mechanics and Pain

Twenty-nine TMJ patients were evaluated for maximum mouth opening (MMO) and pressure-pain threshold (PPT) in neutral, retracted, and forward head positions. Significant differences were found in both MMO and PPT between the three positions. Mouth opening was greatest in the forward head position, and lowest in craniocervical retraction. PPT was highest for neutral position, and worst in FHP. These findings support the biomechanical relationship between the craniocervical region and the temporomandibular joint; they also support the theory that patients may be more sensitive to pain in different craniocervical postures.[17]

Capsulitis and Retrodiskitis

Etiology

Overloading of the joint from bruxism, excessively hard chewing, trauma, strain, or infection may cause an inflammatory response in the fibrous capsule, synovial membrane, and retrodiskal tissues. This condition is called capsulitis. Parafunctional habits can alter the normal pattern of masticatory behavior and lead to asymmetric muscle activity, altered muscle length, and mandibular malalignment. Overload problems are often related to emotional stress which is correlated with increased muscular tone and excessive muscular activity.[32–34]

Retrodiskitis occurs with encroachment of the condyle on the articular disk. This may directly cause inflammation or may exacerbate an existing inflammatory condition. It can occur gradually, as a result of chronic repetitive microtrauma when the condyles are displaced posteriorly because of anterior disk displacement, or by acute external trauma to the chin, forcing the condyles posteriorly into the retrodiskal tissues.

Persistent, subtle changes in joint kinematics may cause muscular imbalance between the elevators and the depressors and produce abnormal stresses sufficient to result in improper loading of the articular cartilage. This pattern can lead to potential fatigue failure and possible arthritic changes in the articular cartilage. Repeated overload leads to microtrauma and an inflammatory reaction in the capsule, the peripheral parts of the disk, and the lateral pterygoid insertion. The overfatigued lateral pterygoid's ability to control disk movement during jaw movements can be upset and result in disk derangement and damage.[30]

Signs and symptoms of capsulitis include pain at rest that intensifies during functional maximum contact of the teeth (e.g., chewing) and parafunctional movements of the mandible (e.g., bruxism). Pain occurs on the side of involvement in the area of the TMJ, with possible reference of pain into areas innervated by cranial nerve V. Impairment resulting from capsulitis ranges from minor joint restriction to total immobility.

Signs and symptoms of retrodiskitis include constant pain and palpable tenderness posterior and lateral to the joint. Pain is usually increased by clenching or by moving the mandible to the affected side, which permits the condyle to press against the inflamed tissue. With swelling, the condyle may be forced anteriorly, resulting in acute malocclusion. When an object such as a bolus of food is placed between the teeth on one side, it can cause increased compression of the contralateral TMJ, as the teeth come closer together on the nonfood side. This can increase pressure in an inflamed joint, causing more pain, so—although it may be counterintuitive—the patient should be advised to chew on the involved side.[98,99]

Treatment

The therapist's choice of treatment depends on the cause and the acuity. An acute injury caused by a single traumatic event will initially make use primarily of passive interventions to decrease pain and inflammation and maintain or improve range of motion. This program may include limited mandibular function, mild analgesics, ice, and moist heat or ultrasound. Because hemarthrosis may occur in an acutely traumatized joint, measures should be taken to prevent ankylosis, with gentle, cautious movement of the joint. In the case of direct trauma such as a blow to the chin, make sure to eliminate the possibility of fracture prior to treatment.

Retrodiskal or capsular inflammation due to chronic microtrauma warrants use of more active interventions. The goals of therapy are to reduce inflammation, decrease joint compression, and alter the parafunctional activities contributing to the perpetuation of the problem. Placement of a joint-stabilization splint may reduce bruxism and decrease pressure on the joint.[100] Surface electromyography (SEMG) is often beneficial in the treatment of diurnal parafunction.[101,102] Maintaining the mandibular rest position via the TUTALC postural cue also reduces joint pressure; with the teeth apart and the lips closed, the mandible is supported in the loose-packed position of the TMJ.

After inflammation, pain, and muscle guarding are under control, a program of stretching and muscular reeducation should be instituted. The techniques discussed in the "Hypomobility" section help to restore muscle length and increase capsular extensibility. Functional kinetic exercises and strengthening and stabilizing exercises can assist in muscular reeducation and relaxation.

Internal Derangement of the Disk

Etiology

Malocclusion (i.e., overclosure of the mouth with backward displacement of the condyle) or trauma may cause derangement of the disk. Macrotrauma or repetitive microtrauma to the disk may cause tears in the capsular attachments to the disk, particularly the thin posterior ligamentous structures. This allows the disk to migrate from its normal anatomic position, typically displacing anteriorly or anteromedially. Two general classifications of this disorder are recognized: the anteriorly displaced disk that reduces during joint translation and the anteriorly displaced disk that does not reduce during joint translation.[103] These two conditions may be independent and persist indefinitely or may be one of the stages in the continuum of a disease process that leads to degenerative joint disease.[104]

Among the various theories regarding the cause of disk derangement are excessive pressure on the joint from clenching or trauma; incoordinate contraction of the two bodies of the lateral pterygoid so that the disk snaps over the condyle rather than following the movement smoothly and coordinately when the mouth is open; deterioration of the disk and cartilaginous surfaces; and stretching of the joint ligaments by frequent subluxation.[98,105,106]

Joint sounds, particularly clicking, are considered hallmarks of disk derangement. The frequency and quality of clicking or other sounds and their association with specific functional movements and pain often help to provide important clues regarding the condition of bony and soft tissues within the joint. Clicking may occur in one or both joints, and it may or may not be associated with pain. Various types of clicking noises have been observed during sagittal opening, including an opening click, an intermediate click during the opening phase, and an end-range click at full opening.

An opening click is believed to be caused as the posteriorly and superiorly displaced condyle passes over the posterior portion of the anteriorly displaced disk. This reduces the anteriorly displaced disk, bringing the condyle back into its normal position in the concave articular surface beneath the disk (**Fig. 22-28**).[104] This

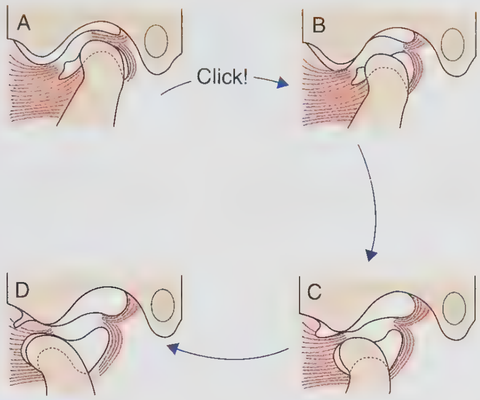

FIGURE 22-28 Mandibular depression (opening) with anteriorly displaced disk with reduction. **(A)** TMJ with the mouth closed, disk displaced anterior to the condyle. **(B)** Early in the translatory cycle, the condyle rides up on the posterior disk material, relocating the disk and causing a click. **(C, D)** Normal joint motion allows complete opening.

reduction is often accompanied by a concurrent palpable jarring of the joint. The timing of the click correlates with the severity of the derangement. A click occurring early in jaw opening indicates a small degree of anterior disk displacement; a click occurring near maximal opening suggests farther anterior displacement. Mandibular ROM is usually normal in disk displacement with reduction, and the amount of vertical opening may be greater than normal.[98]

A second, quieter click may also be detected during closing, as the condyle slips behind the posterior edge of the band of the disk, leaving the disk displaced anteriorly and medially. Clicking can worsen with time as the posterior ligamentous attachments become further stretched and damaged. In addition to clicks produced during mandibular opening, clicks may be produced by eccentric movements. These clicks may result from structural changes in the disk or incoordinate function of the parts of the joint. Inconsistent clicking during other parts of opening is probably caused by internal derangement of the disk.[107]

The sign of an anterior disk dislocation that does not reduce is the absence of joint noises combined with reproducible restrictions during mandibular movements. These restrictions are caused by the disk remaining anterior to the condyle and blocking translatory glide. This limits condylar translation in the affected joint, which restricts mouth opening. This is often referred to as a "closed lock."[108–110] A restricted maximum opening of 20 to 25 mm is the most obvious sign of an acute anterior disk displacement without reduction. Additionally, the mandible will sharply deflect to the affected side at end range, as the contralateral side continues to translate forward. Lateral excursion to the contralateral side is limited, particularly if the disk is displaced anteromedially. Over time, the closed lock may partially or even fully resolve and a more normal range may be achieved as the posterior disk attachments continue to stretch and tear.[103,111,112]

Pain due to disk derangement may be felt in the region of the TMJ on the side of involvement, with possible reference of pain into areas innervated by the trigeminal nerve (cranial nerve V). Pain increases or is altered during functional and parafunctional movements of the mandible. Most patients with chronic anterior disk displacement without reduction report a prior history of clicking and occasional locking, suggesting the disk initially reduced itself (**Evidence and Research 22-5**).

EVIDENCE and RESEARCH 22-5

Disk Morphology and Displacement

To investigate if disk morphology correlates with displacement, 218 TMJs (109 patients) were reviewed on MRI. A normal temporomandibular disk is biconcave. Imaging showed that anteriorly displaced disks that reduced were more likely to be round, hemiconvex, or biconvex, while nonreducing disks were more likely to be folded. This suggests that the type of displacement correlates with the severity of the morphologic change of the disk.[113]

Treatment

Techniques used to improve mandibular opening may be helpful in decreasing joint restrictions caused by anterior disk displacement with and without reduction. In the case of a nonreducing disk, it is important to limit intercisal opening to approximately 30 mm to protect the retrodiskal tissue from being overstretched.[87] Management of disk derangements may best be accomplished by normalization of muscle tone and function. When pain or hindrance of function is significant and therapeutic intervention and appliances are unsuccessful, consultation with an oral surgeon is indicated (see **Building Block 22-6**).

BUILDING BLOCK 22-6

What would your diagnosis and treatment plan be for the patient in the case study?

Temporomandibular Joint Clicking In a study of young adults, Au and Klineberg[52] found that clicking was a reversible condition that could be treated successfully with noninvasive isometric exercises (see Self-Management 22-1). This suggests that there may be a neuromuscular cause for many TMJ clicking problems not caused by internal derangement. In the absence of obvious malocclusion, simple exercises designed to allow controlled joint movement under load with simultaneous activity of the extensor and flexor muscles operating about the joint have been found to alleviate the annoying problem of TMJ clicking. Gerschmann[114] found that lower jaw movement protrusion/retrusion exercises done with a pencil placed between the teeth while performing chewing exercises with the pencil could decrease clicking in about 2 weeks (**Fig. 22-29**).

Anteriorly Dislocated Disk with Reduction An anteriorly dislocated disk with reduction may be treated with an anterior repositioning appliance or a nonrepositioning appliance. These are prescribed and fit by a dentist specializing in the treatment of TMD. Physical therapy modalities such as heat and ice help to decrease pain and muscle guarding, enhancing the effectiveness of the appliance. The patient and physical therapist should begin by instituting a home program to identify and decrease the incidence of parafunctional activity. The patient should be instructed in self-cueing techniques to monitor and decrease parafunctional frequency. These techniques may include: checking the position of the tongue and mandible frequently throughout the day; visual cues, such as a clock or a sticky-note

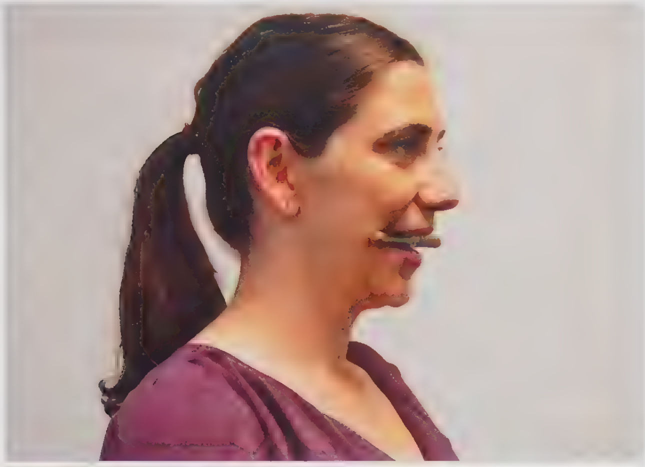

FIGURE 22-29 Chewing the pencil exercise. A soft cylindrical rod (1.5 to 2 mm) is placed horizontally at the back of the mouth. The patient is instructed to bite on the rod with a grinding movement so that the object moves forward and back with the mandible.

placed where the patient will see it; and a timer or reminder set on the patient's phone or computer. When the patient recognizes clenching or other parafunctional activity, he or she is cued to take a deep breath, exhale, and return the tongue and mandible to their resting positions. The patient may also benefit from education and exercises in facilitating relaxation of muscle tone of the jaw and cervical muscles, such as those discussed in the sections on Neuromuscular Relaxation Training.

Anteriorly Dislocated Disk Without Reduction Therapeutic modalities and soft tissue mobilization techniques, such as myofascial release and massage, can be used to treat impairments. A joint mobilization technique of distraction (i.e., caudal glide) combined with translation (i.e., protrusion) may help relocate an anteriorly displaced disk that otherwise blocks opening (Fig. 22-10A and C). If joint mobilization techniques successfully relocate the disk, proceed immediately with the treatment plan for an anterior disk dislocation that reduces.

Degenerative Joint Disease/Osteoarthritis

Etiology

Osteoarthritis of the TMJ, also called degenerative joint disease, is considered primarily a disease of middle or older age. Osteoarthritis alters the weight-bearing surfaces of the TMJ, often leading to secondary inflammation of the capsular tissue. The joint space narrows, with spur formation and marginal lipping of the joint. There is often erosion of the condylar head, articular eminence, and fossa.[30] Advanced joint disease may lead to atrophy of associated muscles. Some causes of this degenerative process include repetitive overloading and internal derangement of the disk. Moffett et al.[115] demonstrated that injury to the disk is usually followed by osteoarthritic changes on the condylar surface, which is followed by similar bony alterations on the opposing surface of the fossa. The clinical features of osteoarthritis are similar to those of other forms of joint dysfunction. Typically, pain and crepitus occur during mandibular motions; crepitus remains even once other symptoms resolve. Most persons experience some restriction of mandibular movement, although not necessarily in a capsular pattern.

Treatment

The primary therapy for DJD is directed at symptom management. Interventions may include pharmacologic management, physical therapy, and/or surgery. Conservative management includes active ROM exercises, mobilization techniques, and stretching, as discussed in the "Hypomobility" section. Graded exercises involving a few simple movements performed frequently during the day are often prescribed as a home treatment. Joint protection techniques, such as avoidance of excessive opening and parafunctional habits, and proper resting position of the tongue and mandible should be taught. Surgical intervention is reserved for patients with advanced bony changes within the joint and may include joint debridement and/or arthroplasty.

Postoperative Physical Therapy Following Surgical Intervention

Overview

Rehabilitation of the TMJ following surgical intervention can take 6 months to 1 year, and physical therapy is considered key to successful outcomes. The oral surgeon may refer the patient for a preoperative physical therapy consult, which is the therapist's opportunity to help set the patient up for postoperative success. Patient education and patient adherence are critical to successful postoperative treatment. At the preoperative visit, patients may be made aware of the surgical procedure and what to expect postoperatively. Patients should be instructed in techniques of pain control and the reduction of swelling (e.g., cryotherapy, transcutaneous electrical nerve stimulation [TENS], diaphragmatic breathing) to be used immediately after surgery. Active and passive exercises to be started after surgery can be explained and practiced at the preoperative appointment.

Postoperatively, physical therapy procedures initially consist of interventions designed to decrease inflammation, edema, reflex muscle guarding, and pain. The patient's diet is often limited to soft foods for up to 3 months, depending on the extent of surgery and possible scar growth. Again, the home exercise program is the most significant part of the patient's rehabilitation program.

Postoperative Arthroscopic Surgery

Arthroscopic surgery is indicated for diagnosis and treatment of intracapsular derangement and joint adhesions.[116] Patients are seen in physical therapy as soon as 24 to 48 hours after surgery.[117] At the postoperative appointment, the physical therapist reevaluates the patient to determine changes in pain patterns, sensation, occlusion, active motions, and evidence of intracapsular or extracapsular swelling. The therapist should make sure to discuss any postoperative protocol with the surgeon.

In most postoperative procedures, an immediate goal is to maintain the interincisal opening achieved under anesthesia by the surgeon.[87] Postoperative adhesions between the articular surfaces and the disk may occur if mobility is not maintained. Intraoral joint mobilization techniques may include distraction and lateral glides (Fig. 22-10). These techniques are designed to inhibit reformation of adhesions, decompress the TMJ, enhance synovial lubrication, promote muscle relaxation, and restore functional ROM.[12,118] Joint mobilization techniques must be performed gently and slowly within the pain-free range. They are usually done on the uninvolved TMJ as well, to prevent developing hypomobility due to disuse. Self-distraction (Fig. 22-12) may be taught to the patient if appropriate.

Studies by Osborne[119,120] and Salter[121] have shown that constant mobility after joint trauma or surgery usually lyses blood clots, forestalling organization into connective tissue. Following the surgeon's protocol as the primary guide, the therapist may choose from exercises for hypomobility, motor control, condylar rotation without translation, and mandibular stabilization. The typical postarthroscopic surgical patient is followed up for 5 to 7 weeks.[87]

If hypomobility develops as healing progresses and the problem is attributed to capsular restriction, ultrasound treatment in combination with home exercise may be more effective than home exercise program alone (**Evidence and Research 22-6**).[122] If hypomobility is attributed to fascial restriction or muscle dysfunction, refer to the techniques discussed in the sections on myogenous hypomobility and neuromuscular relaxation training.

EVIDENCE and RESEARCH 22-6

Ultrasound Enhances Home Exercise Program

While ultrasound alone is not effective in TMJ management,[123] it may enhance the efficacy of a home exercise program. In a recent study, two intervention options were investigated. The first group received home exercises with patient education and information about parafunction, while the second received intervention plus 5 days a week of ultrasound to the TMJ and masticatory muscles. Pain decreased and mouth opening improved in both cases, but the addition of ultrasound resulted in a statistically significant improvement over home exercise alone.[122]

Postarthrotomy Surgery

The most common indication for postarthrotomy surgery is a derangement of the disk that has not responded to conservative management. Arthrotomy (i.e., open joint) procedures vary, depending on the existing pathology and the technique of the maxillofacial or oral surgeon. Surgical options include disk plication and partial or total discectomy with grafts or without replacement. The degree of disk deformation and the health of the intercapsular disk attachments dictate the feasibility of the plication.

The patient is typically seen within the first 3 to 4 days postoperatively to administer appropriate anti-inflammatory modalities and to begin active or passive ROM, depending on physician protocol.[124] Most surgeons request that only active motion without resistance be used during the first 3 days after surgery, due to concern that passive mobilization may disrupt healing and cause surgical failure.[87] Once cleared by the surgeon, additional exercises may be included. These may include exercises for hypomobility, motor control, and stabilization and strength.

Physical therapy after a disk plication procedure is based on an understanding of revascularization and healing of the involved tissues. The greatest change in vascularity and healing occurs in the second and third week after surgery, and complete healing occurs in 6 weeks.[125] If a disk has been reconstructed or retrodiskal tissue repair performed, motion may be quite limited, initially allowing only condylar rotation. Splint therapy is usually an integral part of the patient's overall treatment.

ADJUNCTIVE THERAPIES

Many other interventions are available to the physical therapist for management of TMJ dysfunction. In a systematic review published in 2006, McNeely et al.[126] found some level of support for postural training, manual therapy, exercise, acupuncture and dry needling, biofeedback, and low-level laser therapy, but not for pulsed radiofrequency energy or TENS.

Therapeutic modalities such as ice or heat can help to decrease pain and muscle guarding. Soft tissue mobilization techniques may include deep pressure-point massage,[127] friction massage,[128] acupressure,[129] strain–counterstrain,[130] craniosacral therapy,[121–133] and myofascial release or manipulations.[87,134,135] Massage of the temporalis and inferior to the masseter decreases myofascial tone and may allow the therapist or patient to more easily stretch the surrounding soft tissue.[118] Ultrasound in conjunction with active motion or prolonged static stretch may be effective in increasing extensibility of the capsular tissues.[120,136]

SEMG of the muscles of mastication is used routinely by some dentists and therapists as part of the diagnosis and treatment of TMD and has been comparatively well studied. Muscle hyperactivity, spasms, and imbalance have been suggested in the literature for many years to be major features of TMJ disorders, although supporting evidence is mixed.[137–139] Records of SEMG activity before and after therapeutic intervention have been used to document changes in muscle function and have been cited as proof that the treatment was successful.[140–142] Most researchers agree that SEMG can measure a behavioral event such as bruxism or clenching.[143,144] With portable SEMG devices, relaxation of the masticatory muscles may be attained by the patient through biofeedback at home or work. A few controlled studies have shown significant reduction in diurnal masseter muscle activity by using diurnal biofeedback.[75,99] Nocturnal biofeedback exercise can produce a significant decrease in the frequency and duration of nighttime bruxism,[145–149] but the benefits of this treatment did not last long, and a return to pretreatment SEMG levels was observed as soon as biofeedback stopped.[144,145] Ultimately, though, at least one systematic review indicates that SEMG in combination with cognitive-behavioral therapy is an efficacious treatment, and SEMG alone is probably also effective.[150]

KEY POINTS

- The relationships of the head, neck, tongue, teeth, and jaw, collectively called the stomatognathic system, require a thorough evaluation and integrated treatment approach addressing both structure and function.
- Contact between the top and bottom teeth leads to weight bearing through the TMJ. Repetitive contact from parafunctional habits such as bruxism or job requirements can lead to overuse, structural changes, and pain in the joint.

LAB ACTIVITIES

1. Outline a conceptual model of musculoskeletal TMJ dysfunction and its sequelae. How might an untreated myogenous hypomobility progress over years and decades?
2. List nine generic treatment goals appropriate for treatment of a patient with musculoskeletal pain and dysfunction of the TMJ.
3. Provide an initial treatment plan with at least two exercise progressions, using the goals identified in question no. 2 for the following:
   a. Lateral pterygoid muscle spasm without capsular restriction
   b. Restricted joint play in a capsular pattern
   c. A closed-lock restriction

- Any deviation from neutral in upper cervical spine, including FHP, affects the position of the mandible, tongue, and hyoid. Long-term postural habits alter mandibular rest position, swallowing function, breathing pattern, and muscle balance.
- Proper positioning of the tongue on the roof of the mouth helps to maintain normal resting position of the mandible and promotes normal swallowing function.
- Hypomobility of the TMJ may result from various conditions involving the bones, muscles, joint capsule, retrodiskal tissue, or disk. Treatment seeks to decrease inflammation and pain and increase motion and function.
- Hypermobility of the TMJ is characterized by early and excessive translation of the mandible. Treatment seeks to increase joint proprioception and retrain motion, limiting translation through controlled motions and stabilization exercises.
- Hypermobility is usually bilateral; however, it may occur unilaterally as a result of hypomobility in the contralateral joint.
- In the case of a nonreducing disk, it is important to limit interincisal opening to approximately 30 mm to protect the retrodiskal tissue from being overstretched.
- Most studies show conservative management is the treatment of choice for TMD, but surgical intervention may be indicated if conservative methods fail. Postoperative rehabilitation can take 6 months to 1 year. Therapeutic intervention should begin as soon as possible to administer appropriate anti-inflammatory modalities and to begin active or passive ROM, following the surgeon's preferred protocol. A key postoperative exercise is teaching the patient to open the mouth with the tip of the tongue on the hard palate to facilitate joint rolling and inhibit early translation.
- Systematic reviews suggest that exercise and posture training are the physical therapist's most effective tools for managing TMD, with manual therapy also somewhat effective. Encourage patients to be actively engaged in their treatment plan and emphasize the home program as the most significant part of their rehabilitation program.

CRITICAL THINKING QUESTIONS

1. Describe:
   a. The resting position of the TMJ, considering jaw, teeth, tongue, and other associated structures.
   b. The osteokinematic and arthrokinematic motions available to the TMJ
   c. The relationship of the cervical spine and the TMJ
   d. The muscular control necessary for normal TMJ motion
2. Differentiate between:
   a. The motions available in the upper and lower joint components of the TMJ
   b. Signs, symptoms, and evaluation findings for myogenous versus arthrogenous TMD
   c. The classic signs of anterior disk displacement with reduction and an anterior disk displacement that does not reduce
3. Describe (in order) the major elements of the exercise prescription for:
   a. Hypomobility
   b. Hypermobility

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CHAPTER

23

The Cervical Spine

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Therapeutic exercise interventions are crucial in the rehabilitation of any cervical spine disorder, particularly those of a recurrent or chronic nature. However, exercise programs designed for the treatment of the cervical spine cannot function in isolation. Because of the close relationship between the cervical spine, thoracic spine, shoulder girdle, and temporomandibular joint (TMJ), a complete and successful examination, evaluation and therapeutic exercise program must also address impairments in adjacent regions that contribute to activity limitations and participation restrictions. This chapter briefly reviews cervical spine anatomy and kinesiology and provides guidelines for examination and evaluation. Therapeutic exercise interventions are described for common impairments of body structure and functions and common diagnoses affecting the cervical spine.

REVIEW OF ANATOMY AND KINESIOLOGY

A detailed description of the anatomy and biomechanics of the cervical spine is beyond the scope of this chapter, and the reader is directed to other texts for this information.[1–3]

The cervical spine is composed of two functional units: the craniovertebral (CV) complex and the middle to lower cervical spine. The two units are different in structure and biomechanics, but act together to enable the large range of motion (ROM) available in the cervical spine while concurrently supporting and protecting the vital structures found in this region. One important function of the cervical spine is to place the head in space for the vital functions of sight, hearing, and feeding.

The CV complex includes the atlantooccipital (AO) and atlantoaxial (AA) joints. The biomechanics of the CV complex are governed by the articular surfaces, the complex ligamentous system, and, to a large degree, the intricate specialized muscular system.

Laxity of the CV ligamentous system results in increased motion of this complex. Signs and symptoms, such as headache, dizziness, vision complaints or altered face sensation are most likely the result of overreactivity of the articular and muscle receptors. In addition, these signs and symptoms along with more sinister complaints such as quadrilateral symptoms, ataxia dysarthria, dysphagia, or drop attacks could be related to pressure on the cervical cord or vertebral artery insufficiency.

The midcervical spine consists of the region from the C2–C3 intervertebral segment to the C7–T1 segment. Each mobile segment of the midcervical spine consists of several joints, including the paired zygapophyseal and uncovertebral (UV) joints and the interbody (disk) joint.

Panjabi[4] divided the full ROM of an intervertebral segment into two parts (**Fig. 23-1A**); the neutral zone, which is the portion of the ROM that produces little resistance from the articular structures and the elastic zone, which consists of the portion of the ROM from the end of the neutral zone up to the physiologic limit of motion. The entire cervical spine, particularly the CV region, has a large neutral zone of motion. Because of the lack of tension in the capsular or ligamentous system in this middle part of the range, there is less passive control and the muscular system must be recruited to actively control the motion in the neutral zone. If there is damage to the ligamentous system, resulting in an increased neutral zone, dynamic muscular control becomes even more important (Fig. 23-1B).

The cervical nerve roots exit from the intervertebral foramen above the vertebra, with the exception of the C8 nerve root, which exits below the 7th cervical vertebrae. The C1 nerve root exits through the osseoligamentous tunnel formed by the posterior AO membrane, which puts it at risk of impingement. As the cervical nerve roots exit the intervertebral foramen, they are surrounded by several structures, including the zygapophyseal and UV joints, cervical disk and bony pedicle.

Degenerative changes affecting any of these structures may diminish the foramen size and alter nerve function. Cervical roots 4 through 6 have strong attachments to the transverse processes. The dural sleeve at each level forms a plug that protects the nerve and cord from traction forces. Tension in

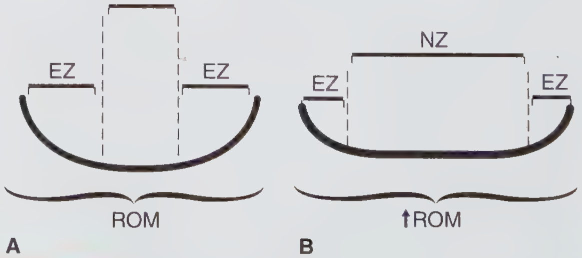


FIGURE 23-1 Neutral zone. **(A)** Normal. **(B)** Hypermobile. EZ, elastic zone; NZ, neutral zone; ROM, range of motion.

the neuromeningeal structures may produce tension on the cervical vertebrae.

Muscles

The musculature of the cervical spine is complex, and anatomy texts[2] should be consulted for descriptions of origins and insertions and their actions.

Table 23-1 lists the muscles of the CV complex and their actions. These muscles enable the specific, fine movements of the head on the neck that are required for sight, hearing, and balance. They are richly supplied with mechanoreceptors, which are integral to the muscles' strong proprioceptive function and are implicated in the production of dizziness in patients with dysfunctions of this region. The upper cervical flexors are crucial in obtaining and maintaining optimal postural balance of the head on the neck. Several long muscles, such as the sternocleidomastoid, link the head directly to the trunk.

The muscles of the midcervical spine, arranged as elsewhere in the spine, consist of slips traversing a variable number of segments. **Table 23-2** lists these muscle groups and their actions. In individuals with forward head posture (FHP), the deep anterior cervical musculature lengthens and becomes functionally weak, and conversely the posterior group tends to shorten.

As in other regions of the spine, the muscle system can be grouped into three layers: deep, intermediate, and superficial. The deep groups tend to be single segmental muscles that function as local stabilizers of the spine rather than prime movers. These muscles tend to become weak or inhibited in pathological states. The intermediate groups are multisegmental but still attach into each segment. They also stabilize the spine, particularly during movement. They often become facilitated or overactive. The superficial muscle groups have little, if any, segmental insertions and function to move and balance the head on the trunk. They generally become overactive and tight, and have a tendency toward protective spasm, resulting in inhibition of the deeper muscle groups. Despite this overactivity, the intermediate and

TABLE 23-1

Craniovertebral Region Musculature

MUSCLE	ACTION
Rectus capitis posterior minor	AO joint extension
Rectus capitis posterior major	CV complex extension and ipsilateral rotation
Superior oblique	AO joint ipsilateral side flexion and extension
Inferior oblique	AA joint ipsilateral rotation
Rectus capitis lateralis	AO joint ipsilateral side flexion
Rectus capitis anterior	AO joint flexion

CV, craniovertebral; AO, atlantooccipital; AA, atlantoaxial.

TABLE 23-2

Midcervical Musculature

	ACTION			
MUSCLE	FLEXION	EXTENSION	ROTATION	IPSILATERAL SIDE FLEXION
Longus colli	X	NA	MC–bilateral	MC–bilateral
Longus capitis	X	NA	Ipsilateral–MC	NA
Scalenes (elevates first or second rib)				
Anterior	X	NA	Contralateral–MC	X
Medius	MC	NA	NA	X
Posterior	NA	MC	Ipsilateral–MC	X
Sternocleidomastoid	X (midC)	X (CV)	Contralateral	X
Trapezius upper fibers	NA	X	Contralateral	X
Levator scapula	NA	X	Ipsilateral	X
Splenius, capitis, and cervicis	NA	X	Ipsilateral	X
Spinalis, capitis, and cervicis (inconsistent–blends with semispinalis)	NA	X	NA	NA
Semispinalis, capitis, and cervicis	NA	X	Ipsilateral	NA
Longissimus, capitis, and cervicis	NA	X	Ipsilateral	X
Iliocostalis cervicis	NA	X	NA	X
Interspinalis (most distinct in cervical spine)	NA	X	NA	NA
Multifidus	NA	X	? direction–MC	MC
Rotators (inconsistent)	NA	X	Ipsilateral	MC
Intertransversarii (most distinct in cervical spine)	NA	NA	NA	MC

MC, minimal contribution; NA, no action; X, active; ? direction: debate on direction of action superficial layers are often found to be weak when tested via manual muscle test.

Deep Cervical Flexors

The deep neck flexors (DNF) include rectus capitis anterior minor, longus capitis, and longus colli. These muscles function as deep segmental stabilizers of the cervical spine. Contraction of these muscles decreases the cervical lordosis. Longus colli has been shown to be active bilaterally as a stabilizer during talking, coughing, swallowing, and rotation/side flexion motion of the head and neck. The deep anterior segmental muscles have been shown to weaken and lose their endurance capacity in various types of cervical spine dysfunction, thus producing loss of dynamic stability.

Suprahyoid and Infrahyoid Muscle Groups

The suprahyoid and infrahyoid muscle groups are primarily involved in the functions of swallowing, speech, mastication, and the TMJ. These muscle groups are discussed in Chapter 22. This muscle group can also assist in flexion of the cervical spine. However, they are inefficient and produce excessive shear forces at the TMJ. Dysfunction of these muscle groups can have a significant effect on cervical posture as well as the TMJ; as such, they should be assessed in persons with chronic neck conditions.

Scalene Muscle Group

Of particular clinical interest is the scalene muscle group. These muscles have a tendency to become dominant neck flexors, especially the anterior scalene, and are also often overused during a poor pattern of apical respiration. Because of the angle of pull, increased muscle activity creates compressive and lateral forces on the intervertebral segment. Because of its insertion onto the first and second ribs, the increased activity can elevate these ribs. This elevation decreases the space available in the thoracic outlet, which can eventually lead to the symptoms of thoracic outlet syndrome (TOS). Adaptive shortening of this group also can impinge on the cervical nerve roots as they travel between the anterior and middle scalenes.

Sternocleidomastoid Muscle

With FHP, the sternocleidomastoid muscle (SCM) tends to shorten, increasing the compression load on the cervical spine. It is a prime mover of CV extension and head on trunk flexion, but the movement pattern it produces causes substantial amounts of anterior translation of the spine. When flexing the head forward on the trunk, it may increase cervical lordosis. A study by deSousa[3] demonstrated sternocleidomastoid activation in both cervical extension and flexion.

Cervical Extensors

The deep segmental stabilizers in the posterior aspect of the spine are the posterior suboccipitals, multifidus, and interspinalis. The middle layer of the erector spinae, specifically semispinalis cervicis and longissimus cervicis, also have segmental insertions and likely act primarily as stabilizers, as suggested by Conley et al.[5] The cervical extensors also play a role in producing and controlling rotation. These muscles have been shown to both shorten and weaken in the presence of cervical dysfunction, possibly secondary to shortening with a FHP, or reflex inhibition from underlying joint pathology and pain. The more superficial erector spinae muscles tend to extend the head on the trunk. As mentioned previously, SCM is also an upper cervical extensor and increases the cervical lordosis.

Levator Scapula and Upper Fibers of Trapezius

Several muscles create movement in both the cervical spine and shoulder girdle. The levator scapula and the upper fibers of the trapezius originate at the scapula and have broad insertions into the cervical spine. Alterations in the shoulder girdle resting position change the length of these muscles, affecting the cervical spine as well. For example, a depressed scapular resting position lengthens the upper fibers of the trapezius muscle and produces a lateral translation and compression force on the cervical spine. These continuous translational forces on the cervical spine can eventually lead to hypermobility in certain planes of movement and subsequent restriction of motion in other planes.

EXAMINATION AND EVALUATION

Examination of the cervical spine should include evaluation of the entire spine, particularly the thoracic region, as well as the TMJ, and shoulder girdle complex. These regions directly influence the posture and mobility of the cervical spine. The clinician must have the knowledge and skills necessary to perform all the appropriate tests to diagnose impairments related to activity limitations and participation restriction in the cervical spine.

History and Clearing Tests

In addition to the questions included in any musculoskeletal subjective examination, some questions specifically address the cervical region. These questions are detailed in texts such as Grieve's *Common Vertebral Joint Problems*.[6] In addition, functional questionnaires provide an excellent baseline determination and can be used to monitor the progress of treatment over time. For example, the Neck Disability Index[7] provides a reliable and valid measure of cervical spine disability.[7]

Shoulder girdle tests should be performed on the patient if indicated by the subjective history and outcomes of postural alignment tests.

Physical Examination

Standing alignment should be assessed in all three planes. The examination includes the spinal curves (i.e., CV region, midcervical region, and cervicothoracic [CT] junction), pelvic alignment, and the scapular resting position.

Sitting alignment should also be evaluated in all three planes. The examiner should observe the patient for changes that occur from standing to sitting. In addition, supine alignment also is evaluated. Various motion tests are used to assess the patient's flexibility and ability to move in certain ways. The clinician should note which examination procedures recreate the patient's symptoms as well as identify impairments that directly relate to the patient's activity limitations. The clinician should assess the following:

- Active ROM
- Combined movements
- Foraminal compression tests
- Assessment of cervical spine passive mobility
  - Passive intervertebral movements
  - Passive accessory vertebral movements
- Stability tests
- Vertebral artery tests
- Neurologic testing
  - Dermatomes (sensation)
  - Myotomes (motor activity)
  - Deep-tendon reflexes
- Assessment of neuromeningeal extensibility
  - Upper limb neurodynamic test
    - Median nerve bias
    - Radial nerve bias
    - Ulnar nerve bias
- Muscle performance
  - Ability to recruit appropriate muscles
  - Strength and endurance assessment
  - Assessment of myofascial extensibility
    - Muscle lengths

THERAPEUTIC EXERCISE INTERVENTIONS FOR COMMON IMPAIRMENTS OF BODY FUNCTIONS

Any comprehensive therapeutic exercise program for the cervical spine must address the impairments that are directly related to activity limitations and participation restriction. This section describes exercise interventions for impairments of muscle performance (including endurance), mobility (i.e., hypomobility and hypermobility), and posture. Appropriate modifications may be necessary for some patients, depending on their signs and symptoms.

Impaired Muscle Performance

Etiology

Over the past two decades, many studies have investigated the motor dysfunction that is present in patients with neck pain. Regardless of the cause of the neck pain, both the flexors and extensors, deep and superficial, show deficits in strength, endurance and fatigability. In addition, these muscle groups show deficits in motor recruitment, with a tendency toward overactivity or dominance of the superficial muscles and inhibition of the deep stabilizing muscles (**Evidence and Research 23-1**). These deficits have been seen in patients with:

- Cervicogenic headache (CHA)[8]
- Mechanical neck pain[9]
- Osteoarthritis[10]
- Whiplash associated disorder (WAD)[11]

EVIDENCE and RESEARCH 23-1

Muscle Strength and Patterning Deficits

Studies of patients with CHA symptoms have found decreased maximal isometric strength and endurance of the short upper cervical flexor muscles compared with those of normal subjects.[8] A group of patients with mechanical neck pain also showed significant weakness of the neck flexor muscles compared with controls.[9] A study of patients with osteoarthritis showed more pronounced fatigue curves for anterior and posterior neck muscles than for the muscles of normal subjects.[10,12] This finding was more pronounced on the painful side of the neck.[13] Subjects with neck pain showed a decrease in EMG output of the DNF muscles during a craniocervical flexion test.[14] Patients with WAD show an inability to isolate and isometrically contract the DNFs as well as early and excessive activation of both the anterior scalene and SCM muscles.[11,15] Similar impairment of the extensors has also been found, although the effect seems to be greater on the flexors.[16,17]

Other findings include:

- Atrophy, fatty infiltration, and other histological changes in both flexor and extensor muscles (**Evidence and Research 23-2**)
- Timing delay in activation of the neck stabilizers during arm movement perturbations
- Excessive activity and delayed relaxation times of neck and shoulder girdle muscles post-activity (**Evidence and Research 23-3**)

EVIDENCE and RESEARCH 23-2

Muscle Changes

On real-time ultrasound and magnetic resonance (MR) imaging, atrophy of both multifidus and semispinalis capitus, the deep and intermediate groups, have been found in subjects with neck pain.[18-21] The atrophy was more profound on the side of the pain. Transition of muscle fiber type[22] as well as fatty infiltration of the deep anterior and posterior cervical muscles.[23-26] has been demonstrated in subjects with cervical pain, causing a loss of tonic function.

EVIDENCE and RESEARCH 23-3

Timing Delay and Relaxation Times

Falla et al.[27] found a timing delay for all cervical flexors, particularly the DNF group during arm movements, suggesting a lack of control of the neck with arm activities in patients with neck pain. During simulated keyboarding tasks, there is increased activation of upper fibers of the trapezius, SCM, and the anterior scalenes, but less activation of the cervical extensors.[28-31] This was more profound in patients with WAD as compared to patients with mechanical neck pain, with both being increased over controls. Following repetitive arm movements, relaxation times for the excessive muscle activity are prolonged in subjects with neck pain, again more noticeably in the WAD subgroup.[28,29,32-34] The superficial neck muscles also demonstrated increased relaxation times following a head lift.[32]

Changes in motor function have been shown to occur quickly after the onset of neck pain.[35] Despite complete resolution of symptoms, these motor impairments have been shown to remain and may contribute to the high recurrence rate of neck pain.

In a systematic review[36] of the conservative management of subacute and chronic mechanical neck pain, the authors found that the multimodal approach of a combination of manual therapy and exercise demonstrated strong evidence of benefit for long-term pain reduction, improved function, and positive global perceived benefit. There is also moderate to strong evidence supporting the use of strengthening, stretching, and proprioceptive exercises.[36–38] Several studies have shown improvements related to cervical exercise to be maintained over the long term of 1 to 3 years.[39–41] Patients receiving supervised and individually tailored exercise programs have been shown to achieve greater improvement than those instructed in an unsupervised home exercise program.[42,43]

Although it is clear that cervical exercise programs are an important and effective component in the management of neck pain, the most effective type of exercise has not yet been determined.[44] Various approaches of low load supported nod exercises, higher load head lift exercises and resisted exercises have all been found to be effective in terms of reducing pain and improving function, but not necessarily superior to each other.[45–49] Although higher loaded exercises do seem to be more effective in increasing overall strength,[48,50] lower load exercise has been shown to be superior for postural control and normalizing movement patterns.[51,52] The higher load programs may not be appropriate for patients with higher pain levels and irritability. Gains made with an exercise appear to be directly linked to the mode of that exercise (**Evidence and Research 23-4**). As such, it is important to include various types of exercise when designing comprehensive cervical rehabilitation programs.[53]

EVIDENCE and RESEARCH 23-4

Mode of Exercise

O'Leary et al.[53] compared three different modes of cervical exercise over a 10-week training time frame: a coordination task that used the Craniocervical Flexion Test protocol with a Pressure Biofeedback Unit to retrain motor patterning, a strength/endurance exercise group, and a mobility control group. All three groups achieved improvement in pain and disability, but each group improved predominately in the motor performance of their assigned mode of exercise, with only minimal change in the other domains.

Exercise dosage should be determined on an individual basis, depending on the characteristics of the patient's presentation; type of pathology, pain intensity, irritability, as well as the aim of the exercise; recruitment, patterning, strength, or endurance. A better response seems to occur when loads are initially very low (less than the weight of the head) and progressed slowly. An exercise is considered too difficult or is stopped when it produces pain, muscle tremors occur because of fatigue, or the exercise cannot be executed correctly. The endurance function of many of these cervical postural muscles should be emphasized by encouraging longer, sustained contractions.

Therapeutic Exercise Intervention

Deep Cervical Flexors The most common muscles to become weak with neck dysfunction are the deep, single segment cervical flexors. It is important to teach the patient to isolate these dynamic stabilizers without substituting with the more superficial muscle groups, such as the SCM and scalenes. The primary exercise to recruit these muscles is the DNF nod exercise of CV flexion, continuing segmentally into midcervical flexion. During this exercise, it is important to control the tendency to substitute with the overactive superficial flexors that would excessively translate anteriorly (see **Patient-Related Instruction 23-1**). If done initially in the upright position at the wall (**Fig. 23-2**), the exercise is gravity assisted, but the head must stay back in contact with the wall at all times to prevent any forward movement that would change the exercise into an eccentric contraction of

Patient-Related Instruction 23-1

How to Activate Your Cervical Core Muscles

What are the cervical core muscles?

The cervical core muscles work together to provide deep segmental stability of the cervical spine and maintain optimal posture of the head on the neck with dynamic extremity and trunk movements. They also enable specific, fine movements of the head on the neck. The cervical core consists of the deep cervical flexors at the front of the neck and the deep cervical extensors at the back.

How do you activate the cervical core muscles?

The cervical core muscles are the most common muscles to become weak for those who suffer from neck pain; therefore, it becomes very important to retrain them. It is important for you to learn how to isolate the cervical core muscles without substituting larger, superficial muscle groups. Cervical core recruitment must be mastered before using them with more challenging exercises.

Start in either a lying position with the head supported, or up against the wall with your head in contact with the wall. To contract the deep cervical flexors, gently nod the head so flexion occurs only at the junction between the head and the neck. Head motion should occur about an imaginary axis that runs through your ears. You can progress the movement down toward the middle of your neck, but do not lift your head up off the ground or away from the wall. Do not allow superficial muscles such as the sternocleidomastoid and scalene muscles to activate. Your therapist will instruct you in palpating for the superficial muscles.

Slowly return to the neutral position. Think about moving one vertebrae at a time. Do not allow superficial neck extensor muscles such as the erector spinae to activate by pushing your head back into the surface.

Practicing to activate the deep cervical core muscles in many different positions is important before learning to use them with dynamic activities. Usually, it is best to start to practice in either lying or upright against a wall, but you can practice cervical core activation in the following positions:

_________ Standing _________ Backlying _________ Sitting
_________ Quadruped _________ Walking

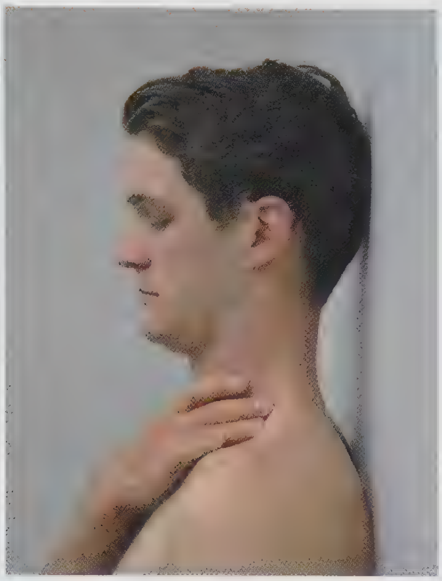


FIGURE 23-2 Standing deep neck flexor nod: for deep flexor muscle recruitment, the patient's hand palpates for unwanted superficial muscle activity as the head slides up the wall.

the cervical extensors. The retracted position also discourages the use of the SCM muscle. The patient is taught to palpate at the front of the neck for any unwanted contraction of the SCM or scalene muscles and to rest the tongue on the roof of the mouth to inhibit hyoid muscle activity.

The patient slowly nods the chin down, while sliding the back of the head up the wall. The nod is stopped at the furthest point in range that can be achieved without superficial activity, held for 10 seconds to encourage the endurance function, and is repeated 10 times. The assistance of gravity can be decreased by performing the exercise supine on an incline board, with difficulty increased by progressively tilting the board backward toward horizontal.

When this same nod exercise is performed with the patient supported in supine (**Fig. 23.3**), the DNFs work against the slight resistance of gravity theoretically making the exercise more difficult. However, this position is both well supported and non–weight bearing, so for some patients this might be more easily executed than at the wall, despite the gravity assist. The head is positioned in neutral, either resting on a pillow, or with a small folded towel placed under the occiput as needed to achieve a neutral posture. A small rolled towel can be placed under the hollow of the midcervical spine to support the normal cervical lordosis. As a low load recruitment exercise, the head nod is performed with no lifting of the head off the surface, with the patient again palpating anteriorly to ensure no superficial muscle activity. The patient is also instructed to avoid using a neck retraction strategy as compensation during this exercise. If the patient is unable to obtain much excursion of motion because of tight extensors or an extremely ingrained pattern of superficial recruitment, the exercise can be started in a more outer range of some extension, nodding toward neutral. Using eye motion to look down as the movement is initiated can also assist in correct muscle activation.

FIGURE 23-3 Supine deep neck flexor nod: deep flexor muscle recruitment, palpating for unwanted superficial muscle activity performed in lying with or without a pillow or towel roll.

The DNF nod exercise can also be performed in a prone position over an exercise ball or in the four-point kneeling (FPK) position. In this position, gravity draws the head forward into a position of upper cervical extension. The head is drawn back in line with the trunk and then the head nod motion is performed, while maintaining this position. This exercise recruits the upper cervical flexors only; gravity is assisting the lower cervical flexors in this position. If the patient maintains the retracted neutral posture of the spine while nodding, it is very difficult to substitute with SCM because this muscle protrudes the neck, and so this is a useful option for patients with very dominant SCM muscles.

Eventually, the patient should be progressed to higher load exercises to increase strength, rather than just recruitment. Auto-resistance, where the patient provides their own resistance to the exercise, can be applied to the head nod motion to increase the load. Resistance must be applied at such an angle to appropriately resist the head nod motion and not encourage a head forward translation movement (a shearing motion). Resistance under the chin rather than at the forehead can encourage the proper movement pattern. This is considered an easier progression than head lift exercises, as the auto-resistance can be graded to be substantially less than the weight of the head.

Further progression to strengthen the entire flexor group would add the weight of the head as resistance in several options of a head lift exercise in supine. An isometric neutral head lift (**Fig. 23.4**) can be performed by nodding the CV unit to neutral and then lifting the head off the surface to add the load. The neutral posture of the neck must be maintained using a balance of both deep and superficial muscles, not allowing dominant superficial muscles to cause an anterior translation. The patient no longer palpates the front of the neck, because the superficial muscles must now be active to lift the weight of the head against gravity. If there is proper balance between the deep and superficial muscles, the patient will be able to maintain the neutral CV position while holding the weight of the head.

As an alternate, a nod lift-off motion can be performed supported on a high incline (**Fig. 23-5**). The patient is instructed to nod to the point of CV neutral and then nod further to just lift the head off the supporting surface to take the weight of the head as resistance not allowing any anterior translation. The patient will progress to holding this sustained neutral position for 10 seconds, repeating 10 times and gradually working up to three sets. The exercise can be further progressed by gradually bringing the incline down toward the horizontal, as long as the patient can control the neutral posture of the neck.

FIGURE 23-4 Neutral head lift: for strengthening of the entire flexor synergy, the head is nodded to craniovertebral (CV) neutral and then lifted off the surface and held. The patient no longer palpates, because the superficial muscles have to be active to lift the weight of the head against gravity. A loss of CV neutral would indicate dominance of the superficial muscles over weak deep neck flexor muscles.

FIGURE 23-5 Incline nod lift-off: a nod lift-off motion can also be performed supported on a high incline. The patient is instructed to nod to the point of cervical spine neutral and then nod further to just lift the head off the supporting surface to take the weight of the head as resistance. The neutral posture of the neck must be maintained, not allowing dominant superficial muscles to cause anterior translation.

Another option is an isotonic exercise, such as performing a segmental flexion curl-up in supine. The head lift pattern should be segmental, starting at the head with a CV nod and continuing a curl-up into full flexion without lifting the thorax or shoulders off the surface (**Fig. 23-6**). The chin should remain tucked throughout the lift; if the chin comes forward, this is a sign of excessive anterior translation caused by relative dominance of SCM and scalenes over weaker DNFs. The ROM allowed depends on the muscle balance and the ability to continue the neck curl without anterior translation. A towel roll under the neck can be used as a fulcrum and provides feedback for the segmental motion pattern. A head nod into a flexion quadrant (e.g., flexion, side flexion, rotation to the same side) emphasizes contraction of the flexors more unilaterally and may be appropriate in cases of asymmetric weakness.

FIGURE 23-6 Segmental flexion curl-up head lift: isotonic strengthening of the full flexion synergy with bias toward the group. Starting with a craniovertebral nod, the patient continues to nod segmentally to full range of flexion, ensuring that the chin remains tucked throughout. A towel roll can be placed under the neck to act as a fulcrum to encourage the correct movement pattern.

The choice of head lift options is dependent on several variables, and there is not a fixed stepwise progression through the three options as different patients find some exercises more challenging than others. Some patients find that the isometric hold is easier to perform, while others find that moving through the range is less challenging than holding the sustained contraction. The lift on the incline is often easier as there is less gravity resistance than in supine. The segmental curl-up pattern adds another element of motor control that may be more challenging for some. As well as the type of motor function required (isometric vs. isotonic), the recruitment pattern of the deep and superficial muscles is also different, with the segmental curl-up head lift biasing toward greater contribution of the deeper muscles[54] (**Evidence and Research 23-5**). Identifying the patient's activity limitations and determining how the cervical muscles are utilized for that activity will dictate the type of muscle contraction that is the most appropriate for that particular patient.

EVIDENCE and RESEARCH 23-5

Choice of Head Nod/Lift Exercise

Cagnie et al.[54] used functional MR imaging to evaluate the recruitment patterns of longus capitus, longus colli, and SCM during three cervical flexor exercises: supported head nod, neutral CV head lift, and combined CV flexion with neck flexion (curl-up). During the head nod exercise, the longus capitus showed significantly higher recruitment than the other two muscles, with minimal activity in SCM, making this an excellent choice of exercise to isolate that DNF muscle. All three muscles were strongly activated during the neutral CV head lift action, suggesting that this higher load exercise trains the full flexor synergy more equally. There was significantly more activity in the two deep flexors compared to SCM during the combined nod and curl-up lift task showing preferential activation for the deep over the superficial flexors, although because of its larger cross-sectional area, SCM would still be considered the main contributor to lifting the head.

To increase the resistance of the exercise, an elastic band can be looped around the head. In sitting with the band secured behind the head, the patient adopts a neutral spine posture. While maintaining a neutral chin nod position, the patient leans forward at the hips, creating an isometric load to the cervical flexor muscle group (**Fig. 23-7A**). Alternatively, the patient can perform isotonic flexion against the band resistance, starting at the CV region and progressing segmentally down the cervical spine. The therapist must cue the patient to use a nodding action and to avoid anterior translation or shearing. In standing, a forward lunge can be used to increase the tension in the band and because of the additional balance challenge, there is a dynamic component to this exercise (Fig 23-7B).

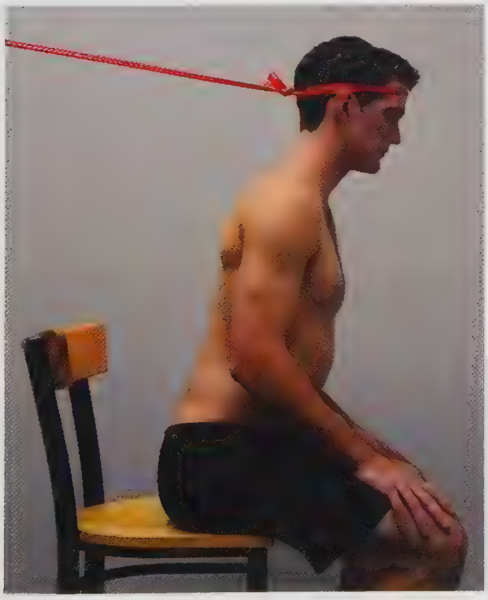
Table 23-3 outlines potential exercise progressions for the cervical flexor muscle group from low load recruitment of the deep stabilizer muscles to higher load strengthening of the full flexor synergy.

Cervical Extensor Muscles Both the deep and middle layers of the cervical extensors atrophy and decrease in strength and endurance in response to neck pain. The use of electrical muscle stimulation is effective in the initial stages of retraining, especially when the patient has a high level of pain that precludes resisted exercise. With the patient lying supine with the head supported, small electrodes are placed over the extensor muscles bilaterally at the vertebral level with poor segmental recruitment. Contraction should be a sustained tonic hold, and the patient can simultaneously perform a nod to obtain cocontraction of both the flexors and extensors.

A 'muscle energy' type technique (MET) can be used to encourage a localized contraction of the weak suboccipital or multifidus muscle at the involved segment as determined on assessment (**Fig. 23-8**). The patient can then be taught to apply auto-resistance to the contraction of a specific muscle. For example, a weak superior oblique muscle can be retrained by applying auto-resistance to AO joint side flexion into extension on the same side (**Fig. 23-9**). Contraction of the multifidus at the C4–C5 level can be obtained by pressure applied to the C4 lamina, as the patient attempts side flexion to the same side into extension. Schomaker et al.[55] found that resistance applied bilaterally at the vertebral arch of C2 was more effective in preferentially recruiting deeper rather than superficial extensors, as compared to pressure at the occiput or C5. Resistance to a nod-retract motion can be applied by gently pushing the head back into hands at the back of the head, a wall in standing or a pillow in supine.

A study by Mayoux-Benhamou et al.[56] suggested that the motions of return to neutral (RTN) from the flexed posture, and retrusion, are less likely to recruit the superficial extensors. If this motion is performed segment by segment, it is likely that the segmental extensors will need to be recruited. The patient starts in the forward flexed position and initiates the extension in the thoracic spine first, starting at the lower segments, and sequentially extending until the trunk is in an upright neutral position, avoiding overextension. As the motion moves into the cervical spine, the chin tuck position is maintained as the patient continues to extend segmentally, incorporating a component of slight posterior motion (**Fig. 23-10**). The patient should be cautioned to avoid excessive retraction of the neck as this is not the cervical neutral posture. Maintaining the CV region in flexion until the end of the motion will tend to inhibit the superficial capitis group of the erector spinae muscles. Tactile cues can be given at each level to encourage the segmental nature of the motion.

The extensor recruitment exercise can be progressed by performing the motion in the FPK position to initiate resistance against gravity (**Fig. 23-11**). The patient starts the exercise in the quadruped position with the head hanging into full flexion with the thorax dropped between relaxed scapulae. The patient is instructed to bring the thoracic spine to neutral. While keeping the chin tucked, the patient segmentally draws the head up in line with their body, starting at the lower cervical spine. The final step is to release the chin tuck to neutral, while still maintaining the head back in line with the body. This position is held for 10 seconds, before reversing the movement pattern. The FPK position



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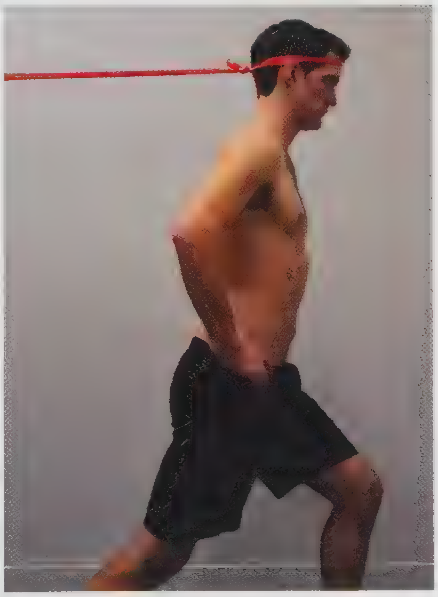

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FIGURE 23-7 Elastic band resisted exercises. **(A)** Isometric forward lean load, holding a neutral deep neck flexor nod and then leaning forward at the hips to increase tension. **(B)** Forward lunge, to add a dynamic perturbation component.

TABLE 23-3

Cervical Flexor Exercise Progressions

CERVICAL FLEXOR PROGRESSIONS			
EXERCISE	PURPOSE/AIM	MODIFICATIONS	POINTS
Low Load	Recruitment/isolation/pattern/ down-train superficial		Monitor superficial muscle activity—palpation 10 repetitions/hold 10/2×/d + additional practice throughout day
DNF nod: upright	Gravity assisted	Sit Stand	Head must stay in contact with the wall More difficult if poor posture—sitting position may help this
Supine	Slight gravity load	With pillow and roll No pillow No roll	Practice with PBU in clinic
FPK	Particularly useful to reduce SCM activity		Only activates the upper cervical flexors Also recruits cervical extensors to hold neutral neck posture
Light Load	Early strength for DNF		Reeducate the pattern/balance superficial + deep
Auto-resisted nod		Isometric Isotonic Hand—ball—spring system	Apply resistance under chin to encourage nod pattern Can be very light initially Can also progress to much stronger contraction
Higher Load	Strengthening of flexor synergy with DNF focus	**Choose order of progression individually dependent on which mode is easier to most difficult	No longer palpate superficial muscle activity Instead monitor excessive use causing chin poke or shift Work up to three sets of 10/1×/d
Incline nod lift-off	Isometric neutral hold—less gravity		Progress by lowering the incline
Neutral head lift	Isometric hold		A bit more flexed position than incline lift-off
Segmental flexion curl-up head lift	Isotonic, through range	With/without roll	Larger relative contribution of deeper muscles But need more motor control
External Load	Strengthening	Elastic, pulleys, free weights	Could use light band to be less load than head lift
Neutral forward lean	Isometric hold of neutral	Sit	Watch for anterior translation
Segmental neck flexion	Isotonic, through range	Sit Stand	Watch angle of band to encourage nod pattern
Forward lunge	More perturbations More functional		Start slow and controlled Increase speed Incorporate function—arm movements/ movement patterns

DNF: deep neck flexors; SCM: sternocleidomastoid; PBU: pressure biofeedback unit; FPK: four-point kneeling.

can be considered quite functional for those who lean forward in their jobs or for sports such as cycling. This exercise also encourages dissociation between the neck and thorax which may be difficult for those who have been adopting a protective bracing pattern. Prone on elbows is an alternate position to use. A similar exercise can be performed prone over an exercise ball and arm movements can be added to add a scapular stabilization component.

The exercise can also be performed into further extension of the cervical spine or into the extension quadrant position to target the muscles unilaterally. The chin remains relatively tucked as the head is lifted beyond neutral to prevent the collapse of the mid-cervical spine. Adding arm motion further challenges the maintenance of the cervical neutral posture and with multiple repetitions, would also reinforce the endurance requirements of these muscles.

Elastic band resistance can also be used to load the cervical extensors. The patient can perform a seated neutral lean back against the tension of a band, which is secured in front of them. Additionally, to increase load and add a dynamic component, the patient can perform a backward lunge as described for the cervical flexors.

Table 23-4 outlines possible progressions of exercises for the cervical extensor muscle group.

FIGURE 23-8 Therapist-directed deep extensor recruitment: with the patient sitting, the therapist palpates at the affected level as the patient recruits the segmental extensor against the localized resistance of the therapist.

FIGURE 23-9 Auto-resisted extensor recruitment: retraining a weak right superior oblique muscle by applying auto-resistance to atlantooccipital joint side flexion into extension on the same side.

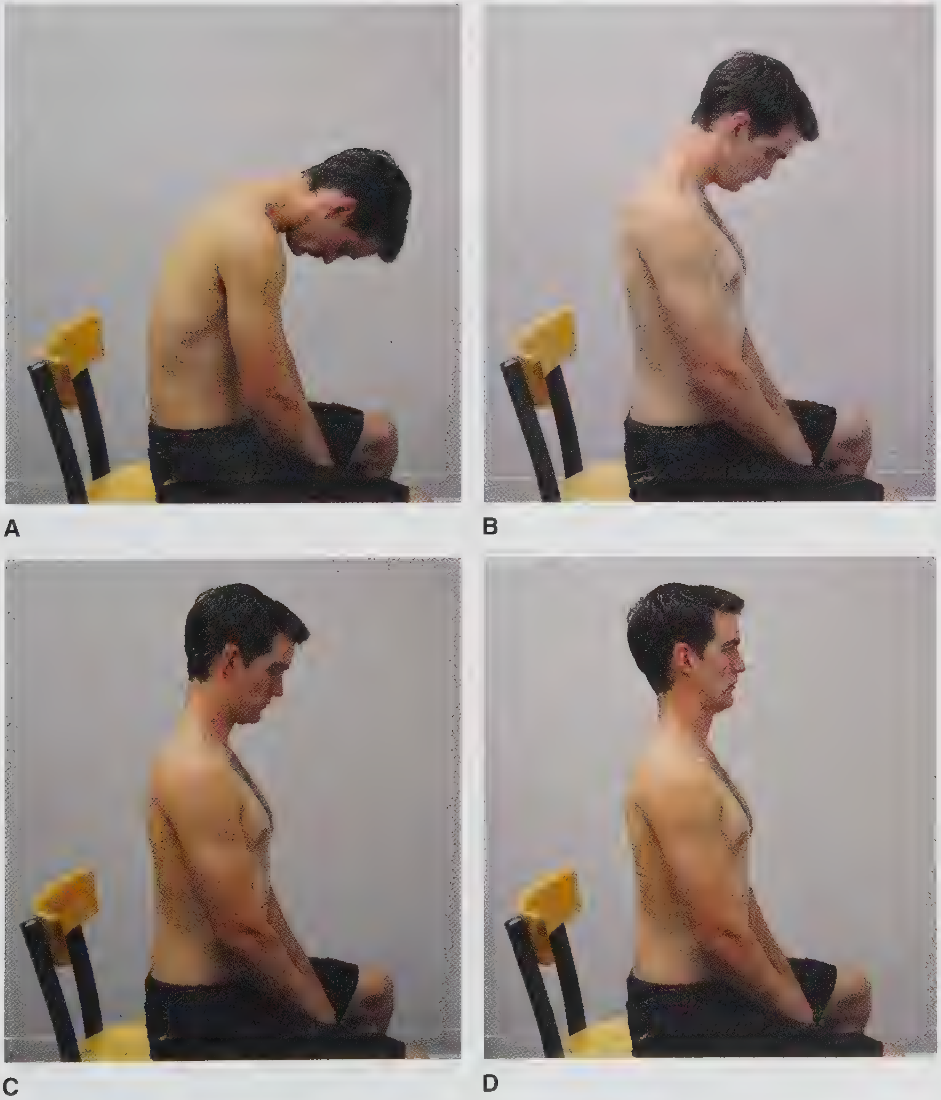


FIGURE 23-10 Return to neutral in sitting: segmental extension movement pattern to recruit the deeper extensors. **(A)** Start in the forward flexed position. **(B)** Keeping the head dropped forward and the chin tucked, initiate segmental extension starting at the mid to upper thoracic spine, lifting up through the sternum. **(C)** Keeping the chin tucked, continue the extension into the lower cervical segments, drawing the head and neck back in line with the trunk. **(D)** Lastly, the chin tuck is released to neutral while avoiding craniovertebral shearing. The pattern is reversed to lower the spine back down to the starting position.

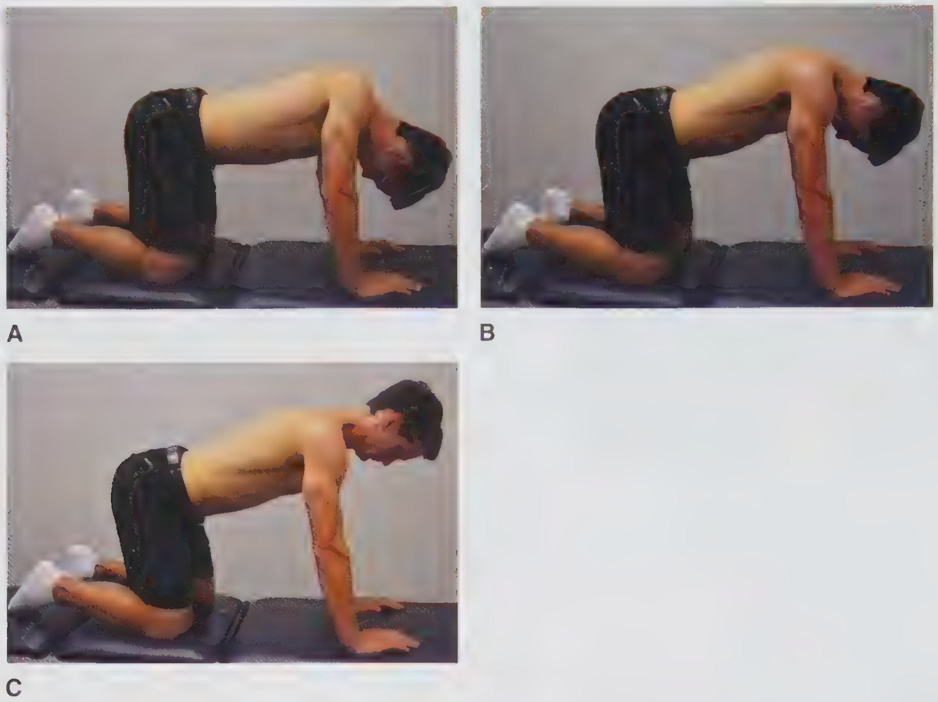


FIGURE 23-11 Return to neutral in four point kneeling (FPK). **(A)** Start position is in FPK with the head hanging and the thorax sagging between the scapulae. **(B)** The patient presses up between the scapulae to bring the thorax into a slight, neutral thoracic kyphosis. **(C)** Keeping the chin tucked the patient draws the head back in line with the trunk and then releases the nod to the neutral position, holding for 10 seconds. The movement pattern is then reversed back to the start position.

TABLE 23-4

Cervical Extensor Exercise Progressions

CERVICAL EXTENSOR PROGRESSIONS			
EXERCISE	**PURPOSE/AIM**	**MODIFICATIONS**	**POINTS**
In clinic options:	Teach patient how to find the extensors		Not as a mobilization—as a segmental muscle recruitment technique
MET			
EMS		+/− simultaneous nod	
Lower Load	Recruitment/isolation/pattern		
Auto-resisted		Segmentally Or a more general multisegmental quadrant motion	Resist at C2 has been found to recruit deeper rather than superficial layer
Resisted nod-retract	Less superficial activity with retract than tip back into extension	Hand/wall/into pillow	Push back pattern rather than tip back
RTN in sitting	Segmental extension followed by eccentric control on segmental flexion	Back on chair or at wall	
Higher Load	Strengthening of extensor synergy with deeper layer focus		
RTN in FPK	Adds scapular control and slight loading against gravity	On elbows On forearms on chair Over end of bed Forward lean on wall/counter	Achieve neutral, not over-retraction
Add extension lift	Focuses on lower cervical extensors, as controls tendency to collapse		Keep CV neutral as extend about an axis at C7—encourages deep vs. superficial
Ball extension lift-off	Includes scapular and thoracic strength	Over end of bed 45° arm lift to focus to scapular stabilizers	Starts with head and neck position, then scapula set, then thoracic extension

TABLE 23-4

Cervical Extensor Exercise Progressions (*continued*)

CERVICAL EXTENSOR PROGRESSIONS			
EXERCISE	PURPOSE/AIM	MODIFICATIONS	POINTS
External Load			
Isometric backward lean		Sit	
Hand hold band		In sit/stand At wall	Retract motion or extend elbows to add tension Watch that relaxation phase doesn't allow excessive anterior shear
Backward lunge	More perturbations More functional		Start slow and controlled—increase speed Incorporate function—arm movements/ movement patterns

RTN, return to neutral; FPK, four-point kneeling; MET, muscle energy type technique; EMS: electric muscle stimulation.

Rotation and Side Flexion Component By exercising into a quadrant position, the muscles that are primarily lateral flexors and rotators are also recruited. In supine, with the head offset on a foam wedge, the slope can be used to apply resistance to combined flexion, side flexion, and rotation of the cervical spine (see **Self-Management 23-1**).

The addition of pure rotation to the exercise in FPK (**Fig. 23-12**) further activates the suboccipital extensor muscles and can be particularly useful for those conditions related to the upper cervical spine such as CHA and dizziness **Table 23-5**.

Elastic resistance can be utilized to provide additional loading to this movement pattern. With the band held in hands placed on the wall, the head is drawn back into neutral, the elbows extended slightly to obtain the desired tension, and then the head rotated in a single plane motion to the right and then left (**Fig. 23-13**). The elbows can then be flexed to release the load and then the exercise repeated. As a true strengthening exercise, building to three sets of 10 repetitions would be appropriate.

In the sidelying position with the head supported on a pillow and a towel roll under the neck, these muscles can also be

SELF-MANAGEMENT 23-1
Side Flexor and Rotator Activation

Purpose: To activate and strengthen the neck side flexors and rotators on each side

Starting Position: Lie on your back with your head supported on the foam wedge. Knees are bent. Move the wedge so your head is resting off to one side on the slope of the wedge (**A**). You will immediately feel that you have to use your neck muscles on the side closest to the peak to hold your head in place.

Movement Technique: Perform a slight nod to activate the deep neck muscles. Hold this nod throughout the exercise.

Slowly, in a controlled fashion, lower your head down the slope to the end of range. Stop before there is any pain. Pause at the end of range, then slowly bring the head back up the slope, maintaining the slight nod throughout (**B**). Go past your center position, continuing up the slope of the wedge to the end of range. Again pause at this point. In a controlled fashion, bring your head back to midline. Relax from the nod position. This is one repetition.

Repeat for the designated number of repetitions, beginning with the pre-set nod for each.

Move the wedge over to have the head resting on the other side of the peak. Repeat the same sequence as above for the designated number of repetitions.

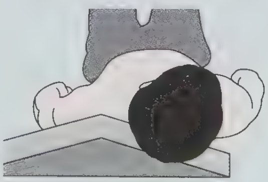
Dosage:

Set/repetitions: ______________________

Right: ______________________

Left: ______________________

Frequency: ______________________



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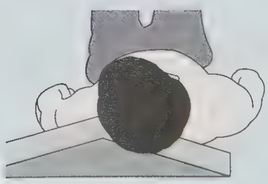

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FIGURE 23-12 Pure rotation in four-point kneeling: the patient first adopts the neutral spine position they were taught to achieve in Figure 23-11. Keeping the chin nodded to neutral, the patient performs isolated rotation to the right and then left, making sure not to collapse into side flexion or extension.

FIGURE 23-13 Elastic resisted pure rotation: holding the elastic band at the wall, the patient draws the head back to neutral, extends the elbows slightly to increase the tension, and then performs pure rotation, maintaining the neutral chin nod position throughout.

TABLE 23-5

Asymmetric Loading and Rotation Control Exercise Options

ASYMMETRIC LOADING AND ROTATIONAL CONTROL			
EXERCISE	**PURPOSE/AIM**	**MODIFICATIONS**	**POINTS**
Low Load			
Wedge pillow: peak	Non–weight bearing but some gravity load		Pre-set a neutral nod prior to rotation, maintained throughout motion
offset	Increase load against gravity	Can angle the pillow to alter amount of combined SF	
Auto-resist rotation	Early rotation loading—can be less than weight of head	Pure rotation Diagonal pattern Can also resist pure SF separately	Neutral nod first to encourage deep component Can start with very low load and progress as appropriate
Higher Load			
Pure rotation in FPK	Extensor/suboccipital focus		Excellent for CHA and CD
Pure rotation in incline nod lift-off	Flexor focus	Start with minimal decline and progress	Much more difficult than FPK—later progression
Diagonal segmental curl-up head lift	Isotonic through range combined flexion/rotation		Watch that the nod continues throughout
Diagonal extensor lift in FPK	Extensor through range extension/ SF/rotation		Watch for any midcervical collapse
SF head-lift in side lying	Isotonic through range strengthening	Use towel roll to encourage proper pattern	Neutral nod first to "set" the deeper muscle system
External Load—Elastic/Pulleys			
Rotation	Pure rotation control	Options: Lean back/forward and then pure rotation Rotation from side attachment Rotate and lean forward/back	Ensure cervical neutral is maintained throughout the exercise Pre-set neutral nod prior to each repetition Or held for multiple repetitions to gain endurance
Side flexion		Options: sideways lean Isotonic SF Sideways lunge	
General asymmetric	Challenges rotation control	Diagonal leans Diagonal lunges—forward/back/sideways Pull back with elastic in mouth—alphabet	

SF, side flexion; CHA, cervicogenic headache; CD, cervicogenic dizziness; FPK, four-point kneeling.

FIGURE 23-14 Side lying head lift: the patient starts in the side lying position, with the head supported on a pillow with a towel roll under the neck. The patient lifts their head toward the ceiling. The deeper muscles are emphasized by ensuring that the neck remains in contact with the roll while the head is lifted.

FIGURE 23-15 Elastic resisted rotation: standing sideways to the attached band, the patient begins with a pre-set neutral nod, then performs pure rotation against the resistance of the elastic. Having the knot of the band anterior rather than posterior will alter the angle of pull and change the emphasis on anterior and posterior muscles.

trained more specifically and at higher load. The head is lifted off the pillow, working against gravity. The roll is used as the fulcrum, and the deeper muscles can be emphasized by ensuring that the neck remains in contact with the roll, decreasing the amount of lateral translation taking place (**Fig. 23-14**). The desired movement pattern is pure side flexion as any rotation during the lift would suggest excessive recruitment of either SCM or scalenes

For both of these exercises, the patient is taught to perform a pre-set nod to activate the deep stabilizing muscles prior to any motion of the head. This would also encourage retraining of the appropriate timing of the motor pattern that is impaired with neck pain.

Again elastic band resistance can be used in sitting during sideways or diagonal leaning movements to produce asymmetrical loading. In addition, a sideways or diagonal lunge can be performed. Standing sideways to the attached band, with the knot at either the front or the back of the head, pure rotation movements can be practiced against load (**Fig. 23-15**).

See Table 23-5 for exercise options in this category.

Mobility Impairment

Impairment of mobility can be classified as hypomobility (i.e., reduced motion) or hypermobility (i.e., excessive motion). In the case of hypomobility, exercises are given to regain and maintain motion. For hypermobility, a stabilization exercise program is used to regain control of the excessive motion.

Hypomobility

Etiology ROM is often reduced in patients with neck pain regardless of cause. There is a decrease in ROM in patients with symptomatic WAD at 1 month post-accident, but this has recovered by 3 months in the subgroups that are classified as either mild or recovered.[57–59] In both the moderate and severe subgroups of WAD, the reduced ROM persists at 3 months. Decrease in ROM is present in subjects with CHA, but not in migraine or tension type headache. As such, a decrease in ROM may be used in the differential diagnosis. Reduction in motion as determined by the flexion-rotation test has been found to correlate highly with CHA related to AA joint rotation restriction.[60] Rosenfeld et al.[61–63] demonstrated that subjects who performed early active repeated rotation movements 10 times hourly, had less pain at both 6 months and 3 years, as well as better mobility and less sick time at 3 years.

Cervical mobility can be reduced for several reasons:

- Segmental articular mobility restriction
- Capsular thickening and contracture
- Degenerative bony changes
- Segmental muscle spasm
- Myofascial restriction
- Adverse neuromeningeal tension

Cervical mobility also can be affected by syndromes involving the shoulder girdle and thoracic spine, and treatment oftentimes requires interventions for impairments in those regions.

Therapeutic Exercise Interventions Even in the early stages of treatment for an acute neck condition, ROM exercises within the pain-free range can be taught for each of the restricted planes of motion. Care must be taken in teaching these exercises to ensure that the normal movement pattern is performed and that this pattern is reinforced with repetition. With the patient lying supine with the head supported on a pillow, the weight of the head is eliminated, decreasing the compression load. This position can be helpful for patients with painful neck motion. The use of rhythmic respiration during the exercise can aid in relaxation of the scalene muscles and create a pumping action to help reduce swelling. This activity can be progressed to rotation exercises with the head positioned on the peak of a foam wedge (**Fig. 23-16**). The amplitude of motion obtained is increased and there is some extension incorporated with the movement on rotation and flexion on return to midline. Once the patient can tolerate the compressive load from the weight of the head, ROM exercises can also be performed in the upright position.

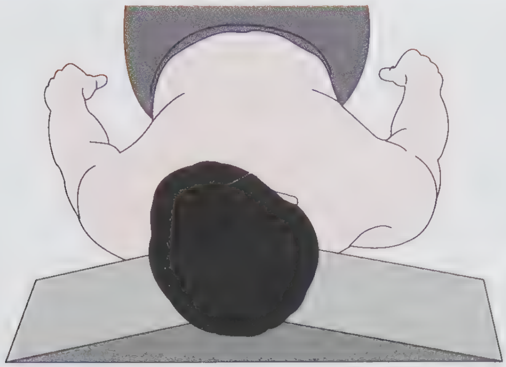


FIGURE 23-16 Foam wedge ROM exercises: allows gravity assisted non–weight-bearing motion, combining rotation and side flexion with flexion-extension.

If a mobility exercise into extension or the extension quadrant is being contemplated, the effects on articular, vascular, and neurologic tissues should be considered. Keep in mind that a considerable weight-bearing force is sustained by the articular facet and the intervertebral foramen is being compressed in these positions.

Segmental Articular Restrictions Segmental articular restrictions generally respond well to manual therapy mobilization techniques unless there is excessive degeneration of the bony structures (see Chapter 7). As the maintenance of the range gained with mobilization is often difficult, self-mobilization exercises are a useful adjunct to this treatment. The patient is taught to localize to the involved segment with his or her fingers or a towel support and perform a specific, sometimes multiplanar motion to mobilize the joint restriction as determined by mobility testing (see **Self-Management 23-2**). A specific AA towel rotation technique (**Fig. 23-17**) as proposed by Mulligan has been shown to be effective in increasing upper cervical motion and decreasing headaches.[64]

Muscle Extensibility Assessment of muscle length is necessary because of muscle imbalances and postural asymmetries that are unique to each individual. Janda[65] states that certain muscle groups in the cervical spine have a greater tendency to shorten. This may be related to the effect of the limbic system on these muscles, the large percentage of afferent fibers supplying these muscles, and the more tonic rather than phasic properties of many of these muscles. According to Janda,[65] the following muscles tend to shorten:

- Posterior suboccipital muscles
- Cervical superficial erector spinae muscles
- Scalenes (anterior, medius, posterior)
- Sternocleidomastoid
- Levator scapula
- Trapezius, upper fibers

A study of cervical musculoskeletal function in postconcussional headache[66] and CHA[67] showed a higher incidence of moderate muscle tightness compared to those with migraines or controls. This finding of tightness was not isolated to any one of the muscles tested (e.g., upper fibers of the trapezius, levator scapula, scalenes, upper cervical extensors), but it was most frequently identified in the upper cervical extensors. In subjects with CHA, many of these muscles were found to be of normal length. A study by Edgar et al.[68] showed a relationship between decreased neuromeningeal extensibility and decreased length of upper fibers of the trapezius, possibly as a protective mechanism. Patients with WAD showed greater electromyography activity of both their ipsilateral and contralateral upper fibers of the trapezius during repetitive upper extremity activity and were less able to relax that muscle following activity as compared with controls.[28] This may suggest that feelings of tightness in patients with cervical spine dysfunction may be more related to overactivity than to true shortening.

Alterations in resting posture may cause a muscle that is of normal length to be placed on tension because of the increased distance between the origin and insertion caused by the posture. For example, a depressed scapular resting position puts tension on the levator scapula, potentially reducing opposite-side flexion and rotation of the cervical spine. The neck motion can be regained immediately upon elevating the scapula, confirming that the tension on the levator scapula, resulting from the depressed position of the scapula, was contributing to the loss of neck ROM. Other muscles may adaptively shorten because of long-standing changes in posture. The sternocleidomastoid, for example, tends to adaptively shorten in response to FHP. When the head is brought back into a more normal position, the muscle may appear to be a tight band, inhibiting attempts to retrain optimal posture. Treatment of both cases consists of postural correction exercises. Chapter 25 illustrates taping techniques to correct scapula position and normalize length–tension properties of the cervical muscles that attach to the scapula (i.e., levator scapula and upper trapezius).

The posterior suboccipital muscle group can be lengthened by using the CV flexion head nod exercise at the wall (**Fig. 23-18**). The stretch can alternatively be localized by supporting the rest of the neck with clasped hands and further localized by side flexion away and rotation toward the tighter side.

Further neck flexion must be incorporated to obtain a stretch into the middle to low cervical erector spinae. CV flexion must be maintained throughout the exercise to maintain the stretch on the long superficial extensors. If any anterior translation is allowed, cervical lordosis is produced, which results in a shortening of these muscles. Performing this stretch with the trunk against the wall helps fixate the cervicothoracic (CT) junction (**Fig. 23-19**). Adding side flexion and rotation to the opposite side biases the stretch to the right or left side.

The scalene muscle group tends to shorten and become overactive, often reinforced by improper breathing patterns. Teaching proper diaphragmatic breathing while palpating the scalenes can decrease recruitment of this group as a secondary muscle of inspiration (see Chapter 22). Exercises designed to stretch this muscle must allow for adequate fixation of the first and second ribs, which can be achieved through manual or belt fixation. The scalene group is lengthened by side flexion away (**Fig. 23-20**). Slight rotation toward the affected side will focus the stretch to the anterior group, and rotation away from the effected side will bias the posterior scalene. Performing pure side flexion at the wall prevents the neck from collapsing into an FHP and will allow a more effective stretch. The patient must be instructed to stop at the point of tension, because the muscle pull can produce an unwanted lateral translation force on the cervical spine.

An effective method of regaining normal SCM length is to correct the FHP. Retraining the use of the deep cervical

SELF-MANAGEMENT 23-2
Self-mobilization for the Cervical Spine

Purpose: To maintain the range gained during treatment at a particular joint.

AO Joint

Starting Position: Sit tall in a chair with back support. Clasp your hands behind your neck with your little fingers just under the base of your skull. Stabilize the neck, but be careful not to drag the neck forward by pulling forward with your hands.

Movement Technique: Flexion on the right (**Fig. A**)

- Nod your head on your neck. The head must tip away (left) from the stiff side, and the chin must deviate toward (right) the stiff side. In other words, tuck your chin toward your armpit on the side of the stiff joint.

Extension on the right (**Fig. B**)

- Tip your head back on your neck over your fingers. Tip the head slightly toward (right) the stiff side and point the chin away from (left) the stiff side. In other words, point your chin toward the opposite elbow.

Dosage:

Hold: ________________________________ count

Repetitions: ________________________________

Frequency: ________________________________

AA Joint

Starting Position: Wrap your hands behind your neck with your little fingers resting at the level of the large bump at the top of the neck below the skull. Stabilize the neck, but be careful not to drag the neck forward by pulling forward with your hands.

Movement Technique:

- Keep eyes level as you rotate the head in the stiff direction, being sure not to let the rest of the neck move with the head.
- If instructed, bias the movement to the joint on one side or the other by
  - Tucking the chin into a bit of flexion as you turn, and slightly pull the supporting hand forward on the side you are turning to (**Fig. C**)
  - Tipping the chin slightly up as you turn, and hold back with the supporting hand on the side opposite to the direction you are turning to (**Fig. D**)
- Do not let the neck collapse as you turn the head; stay tall.

Dosage:

Hold: ________________________________ count

Repetitions: ________________________________

Frequency: ________________________________

Midcervical Joints

Starting Position: Find the stiff joint as instructed. It often will feel tender, or thick under your finger. Hold the bottom bone stable by pushing in gently with your fingers. Alternatively, place the salvage edge of a towel along the affected joint to stabilize it.

Movement Technique: Flexion

- Nod your chin forward until you feel a pull at the stiff joint. Tip the head away from the stiff side and rotate the head away (**Fig. E**). The movement to stretch the joint maximally will be off on the opposite diagonal.
- The fixing fingers should stabilize the bottom bone down toward the floor.
- You should feel a strong stretch on the side of the neck at the stiff joint.

Extension

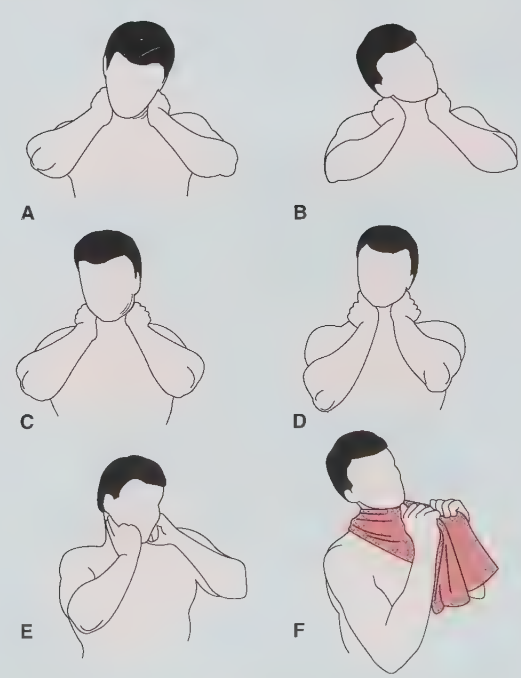
- Tip your head back over the stabilizing fingers or towel. The head should also tip and rotate to that same side on a diagonal (**Fig. F**).
- You can push in and up slightly with the fixating fingers.
- Focus the movement to the level that is stiff. Do not arch your whole neck back over the fingers.

Dosage:

Hold: ________________________________ count

Repetitions: ________________________________

Frequency: ________________________________



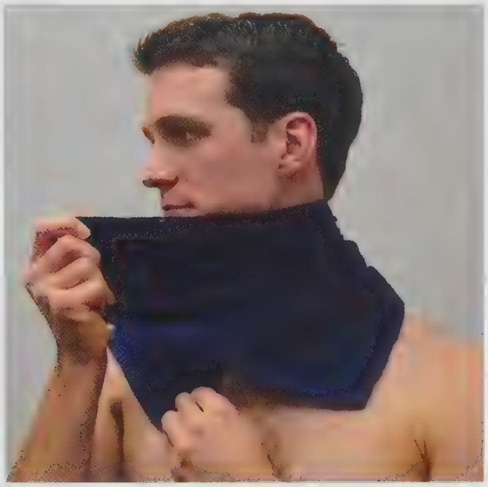


FIGURE 23-17 Atlantoaxial towel rotation self-mobilization: the edge of a towel is placed at the level of C2, the hands crossed with the towel positioned along the edge of the jaw. The towel is used to assist the head and neck motion in pure rotation. The movement should be pain free.

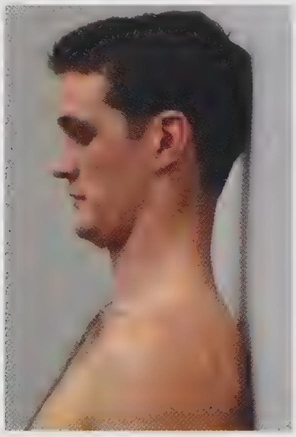


FIGURE 23-18 Posterior suboccipital stretch: using the craniovertebral flexion head nod exercise into full range with head staying on the wall.

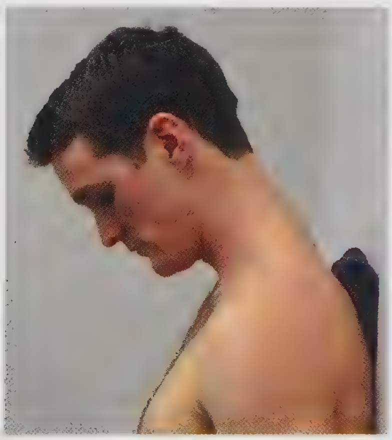


FIGURE 23-19 Long cervical extensor stretch: positioned at the wall to ensure that the upper thoracic spine remains in contact (can use a folded towel as feedback). The chin stays tucked and the head drops forward into full flexion.

FIGURE 23-20 Scalene stretch: first rib fixed, side flexion away, and slight rotation toward the affected side at the wall.

flexors for the habitual movement pattern of neck flexion also decreases overuse tightness of the sternocleidomastoid. If the muscle has become shortened by posttraumatic adhesions, it may be necessary to stretch the muscle. This can be achieved by side flexion away from, and rotation toward the side being treated, keeping the chin tucked, while extending the head behind the trunk. Lordosis must be controlled, because that position shortens the muscle. This effect can be achieved by bringing the CV flexed head on a straight neck back behind the line of the trunk (**Fig. 23-21**).

When attempting to lengthen the levator scapula muscle it is optimal to fix the scapula into both depression and upward rotation. Upward rotation can be achieved by arm elevation, but this shoulder position may be painful for some patients with neck pain. In that case, depression of the scapula can be maintained with the arm positioned in slight abduction to try to include some upward rotation (sitting, holding the underside of the chair). The muscle is then stretched by cervical side flexion and rotation to the opposite side and cervical flexion (**Fig. 23-22**).

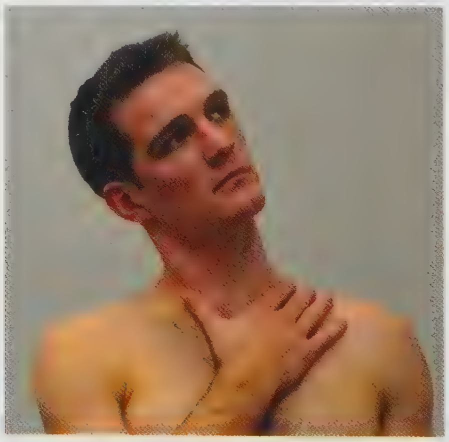


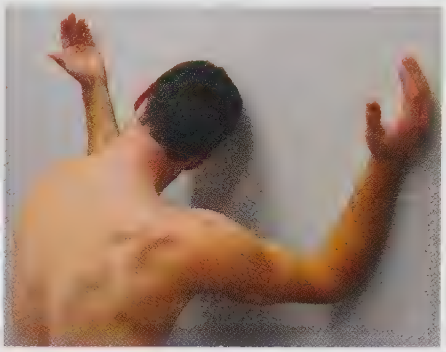
FIGURE 23-21 Sternocleidomastoid stretch: extension, side flexion away from and rotation toward the side being treated.

FIGURE 23-22 Levator scapula stretch: arm overhead (scapular upward rotation), scapular depression, side flexion away, rotation away from affected side, and flexion.

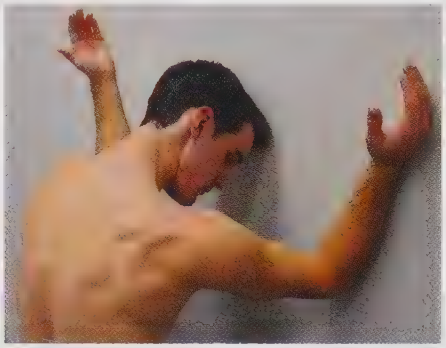
To stretch the upper fibers of the trapezius, the scapula must be fixed into depression, downward rotation, or both. Scapular depression and downward rotation can be achieved by reaching the arm down and behind the back. The stretch is then performed into neck flexion, with side flexion away from and rotation toward the affected side (**Fig. 23-23**).

The concern about the latter two stretches is the resultant forces on irritable zygapophyseal joints from the end-range combined movements. These two muscles and the scalene muscles, because of their angle of pull, may also produce an excessive lateral translation force on the vertebrae when stretched. An alternative exercise is to have the patient face the wall, with the ulnar border of the hands and forearm in contact overhead, and perform a wall slide. The arms are slid downward and slightly inward, creating scapular depression. The cervical spine can then be moved into flexion. From this position, contralateral rotation lengthens the levator scapula muscle, and ipsilateral rotation lengthens the upper fibers of the trapezius muscle (**Fig. 23-24**).

FIGURE 23-23 UFT stretch: scapular depression and downward rotation, neck flexion, side flexion away, and rotation toward the affected side.



A



B

FIGURE 23-24 Alternative wall slide exercise. **(A)** Contralateral rotation lengthens the right levator scapula muscle. **(B)** Ipsilateral rotation lengthens the upper fibers of the right trapezius muscle.

Adverse Neuromeningeal Tension Adverse tension in the neuromeningeal structures of the cervical spine can affect the mobility of the neck, thoracic spine, shoulder girdle, and upper extremity.[69] Signs of decreased extensibility of these structures are found on the upper limb neurodynamic tests, with a median, radial, or ulnar nerve bias. When prescribing an exercise designed to improve neuromeningeal extensibility, the effect on the cervical spine should be considered. Because of direct attachment of dural structures into the cervical vertebrae, tightness in the neuromeningeal system may cause lateral translation of the vertebrae with each attempt to stretch the structures, which can lead to hypermobility of the segment. The affected segment should be manually fixated by the opposite hand supporting under the neck so that the fingers wrap around to the affected side and prevent lateral translation (**Fig. 23-25**). The DNFs can also be used to stabilize the spine through an active nod, setting the spine in neutral.

The stretch can be performed by the patient in supine lying, with a belt wrapped over the shoulder and around the knee to prevent scapular elevation. Median, radial, and ulnar nerves are biased via various arm, elbow, forearm, and wrist positions as shown in **Figure 23-26**. It may be more effective initially to emphasize mobility of the system, by using "slider" exercises that add tension in one component of the movement, while removing tension in another component. For example, tipping the head toward the arm as the elbow is extended for a median nerve bias slider.

For median nerve bias, the arm, flexed at the elbow, is abducted to the tension point and externally rotated, with the

FIGURE 23-25 Dural stretch: with manual stabilization and fixation of lateral shear.

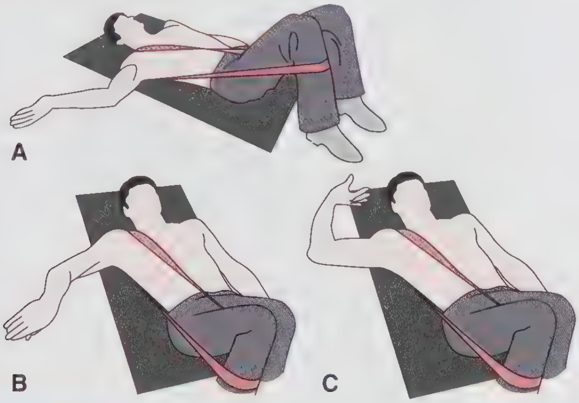


FIGURE 23-26 Dural stretch: in supine lying with a belt wrapped over the shoulder and around the knee to maintain scapular depression. **(A)** For median nerve bias, the arm, flexed at the elbow, is abducted to the tension point and externally rotated, with the forearm supinated and the wrist and fingers extended. The elbow is then slowly extended to produce the stretch. **(B)** For radial nerve bias, the arm, flexed at the elbow, is abducted and internally rotated, the forearm is pronated, with the wrist flexed. The stretch is produced by slowly extending the elbow. **(C)** For ulnar nerve bias, the arm, flexed to a right angle at the elbow, is abducted and externally rotated, the forearm is pronated, with the wrist extended. The stretch is produced through further flexion of the elbow.

forearm supinated and the wrist and fingers extended. The elbow is then slowly extended to produce the stretch (Fig. 23-26A).

Similar stretches can be performed by the patient in standing. The opposite hand is required to maintain depression of the scapula. With each of these exercises, a more intense stretch can be obtained by the addition of contralateral side flexion or rotation of the neck. For more detailed descriptions of these types of exercises, the reader is directed to other sources.[70]

Hypermobility

Etiology Hypermobility is excessive motion of the intervertebral segment. As hypothesized by Panjabi,[4] spinal stability is obtained through three subsystems:

- Passive musculoskeletal subsystem: inert osseoligamentous column, including the vertebra, disk, capsule, and ligament
- Active musculoskeletal subsystem: the muscle and tendon units
- Control subsystem: the neural and feedback mechanisms

The role of the spinal stability system is to provide sufficient stability through all three subsystems to match the demands made on the spine. Within certain limits, deficiencies in one subsystem can be compensated for by the other subsystems. Gross instability, as documented by functional radiographs, may require surgical fixation. Otherwise, hypermobilities are best addressed by conservative measures, including a progressive stabilization exercise program. Exercise programs can be used to enhance both the active and control subsystems.

Specific passive stability testing is performed to determine the degree and planes of laxity. Special attention is given to the amount of translation and the end-feel. This assessment determines the structural integrity of the passive subsystem of the spine. To determine the dynamic stability of the cervical spine, the passive tests can be repeated during an active preset DNF nod to neutral. If recruitment of the deep segmental stabilizers decreases the amount of translation on passive testing, there is a degree of dynamic stability present. The neck can also be observed or palpated during bilateral or unilateral elevation of the arm in the relaxed upright posture and then repeated with the cervical spine under the dynamic control of a pre-set nod (**Fig. 23-27**). If recruitment of the deep segmental stabilizers decreases the amount of translation, there is a degree of dynamic stability present. Because of the large neutral zone in the cervical spine, much of the stability in this region is imparted by the dynamic control of the active muscular system. In the case of loss of integrity of the inert stabilizing structures, training of neuromuscular control may result in a functionally stable spine.

Therapeutic Exercise Intervention For the hypermobile cervical spine, care must be taken in prescribing ROM or stretching exercises that may exaggerate the excessive translation. The neck must be passively fixed at the affected segment during the stretch, or another exercise should be chosen that does not incorporate the unwanted motion. For example, a patient may have a tight right levator scapula muscle but also be hypermobile into right lateral translation at the C3–C4 intervertebral

FIGURE 23-27 Dynamic stability testing: the neck can be observed or palpated during unilateral arm elevation in the relaxed upright posture, and then repeated with the cervical spine under the dynamic control of a pre-set nod.

FIGURE 23-28 Levator scapula stretch: fixing C4 to prevent right lateral translation.

segment. Attempts to stretch the levator scapula muscle by left side flexion encourage right lateral translation at C3–C4. The patient can control the right lateral translation with the left hand cupping behind the neck, offering a counteracting left translation at the C4 vertebra (**Fig. 23-28**). It may be more appropriate in this case to choose the wall slide levator scapula stretch exercise described in the "Hypomobility" section, using contralateral rotation rather than side flexion.

For the patient with lateral translation hypermobility, attempts to incorporate dural stretch exercises cause repetitive lateral translation at the affected joint. A stretch can be performed effectively by first manually stabilizing that segment for lateral translation (see Fig. 23-25).

Postural correction exercises are an integral component in unloading the hypermobile segment in the cervical spine. Any deviation from the optimal posture of the cervical spine increases the translational forces placed upon the spine. The resting posture of the shoulder girdle also plays a role in imparting translational forces to the cervical spine. For example, weakness or poor recruitment of the upper fibers of trapezius leads to a depressed and downwardly rotated scapula, which places the muscle in a lengthened position. Constant pull on the insertion into the cervical spine may eventually lead to hypermobility into lateral translation. In cases of preexisting lateral hypermobility, the continuous lateral force exacerbates symptoms arising from that segment. Exercise should focus on correcting the impairments found on assessment of the shoulder girdle. Taping to reposition the scapula into elevation and upward rotation can reduce this force, allow a more normal movement pattern of the cervical spine, and relieve the increased dural tension caused by the abnormal resting position (see Chapter 25).

Cervical hypermobility can also be addressed through training to facilitate neuromuscular control of the cervical spine with graduated exercise. A series of cervical strengthening exercises can be implemented as determined by specific muscle testing. These exercises, as described in the "Impaired Muscle Performance" section, enhance the active subsystem of the spinal stability system. Alternatively, a cervical stabilization program can be developed to focus on both the active and control subsystem. A stabilization program can be divided into three stages:

- Stage 1: Isolated contraction of the deep segmental flexors and extensors and cocontraction in the cervical neutral position
- Stage 2: Cervical stability during various upper extremity movement patterns
- Stage 2b: Higher load strengthening and endurance
- Stage 3: Cervical stability during functional neck movements

Display 23-1 provides examples of exercise that can be prescribed in each stage.

Throughout the stabilization program, motion at the hypermobile segment must be controlled, particularly for the excessive translation component. In many cases, the patient can be taught to palpate the translation motion of the vertebra and stop moving when it begins. The patient can also be taught to stabilize the affected level manually or through active muscle cocontraction by performing a pre-set nod as an exercise is performed. Progressing in the presence of translation of the affected level does not succeed in developing stability, and through increased stresses on the capsule and ligaments, it may result in painful exacerbation to the point that the program has to be discontinued.

Because of the importance of the role of muscles in dynamic stability of the spine, it can be deduced that, despite the presence of hypermobility, functional stability can be regained through neuromuscular retraining. The key is gradually challenging the cervical musculature over several months while preventing excessive motion at the involved segment. The degree of true strengthening that is required will depend on the demands placed on that particular cervical spine throughout daily, occupational and recreational activities.

Posture Impairment

Etiology

Although posture is affected by the whole of the axial skeleton, the cervical spine plays an important role in the control of posture. The rich supply of mechanoreceptors in the articular capsules and muscles of the cervical spine provides proprioceptive input and feed into the vestibular system.[71] Any attempt to alter cervical spine posture must include an examination and evaluation of the thoracic spine, shoulder girdle, and pelvis. Many of the involved muscles are multijoint muscles. Changes in the lengths of muscles such as the levator scapula, trapezius, pectoralis major and minor, or rhomboids have profound effects on the shoulder complex and the cervical spine. Changes in the strength of these scapular stabilizers also alter the resting posture of the neck. Alterations in the pelvic base in any plane have effects throughout the spinal column, including the cervical spine.

The optimal posture for the cervical spine is the position of cervical neutral or axial extension (**Fig. 23-29A** and **Patient-Related Instruction 23-2**). In cervical neutral, minimal muscle work is required to maintain the position, the spine is in an elongated state, and compressive and translatory forces on the spinal structures are reduced compared with other suboptimal postures. The most common postural impairment of the cervical spine is FHP.

A patient with FHP can present with several variations. In some individuals, the lower cervical spine flexion juts the whole cervical spine forward above that level, and extension mainly occurs at the CV region with little increase in the midcervical lordosis (Fig. 23-29B). In others, the lower cervical spine flexion is compensated for by an exaggerated cervical lordosis that may start abruptly, sometimes as low as the C6–C7 segment. In these cases, the midcervical lordosis tends to be accompanied by an excessive anterior translation that is an unphysiologic coupling of motion, because extension (i.e., lordosis) should couple with posterior translation (Fig. 23-29C). Each individual should be

DISPLAY 23-1

Cervical Spine Stabilization Program

STAGE I

The first goal of the stabilization program is to isolate the deep neck flexors and extensors. The next goal is to perform cocontraction patterns in the cervical neutral position. The following exercises can be used to achieve these goals. The exercises are described in more detail in the "Impaired Muscle Performance" section.

Isolation of the Deep Cervical Flexors

- Cervical core activation (DNF nod) in a variety of positions (Patient-Related Instruction 23-1; Figs. 23-2 and 23-3)
- Auto-resistance to the deep flexors

Isolation of the Deep Cervical Extensors

- Electrical muscle stimulation to the cervical extensors in supine
- Therapist-directed MET recruitment (Fig.23-8)
- Auto-resistance to specific multifidus or suboccipital muscles (Fig. 23-9)
- RTN in sitting (Fig. 23-10)

Rotation and Side Flexion Components

- Supine controlled rotation offset on a foam wedge (Self-Management 23-1)

Cocontraction of the Deep Cervical Flexors and Extensors

- Early cocontraction training can be accomplished in supine lying with the cervical lordosis supported over a towel roll. The extensors are recruited using the electrical muscle stimulator while the patient prevents the extension motion by simultaneously performing the head nod exercise such that the cervical spine remains in neutral.
- Cocontraction of the deep extensors and upper cervical flexors can also be practiced with the patient positioned prone over an exercise ball or in FPK. The RTN in FPK exercise is an example (Fig. 23-11).

STAGE IIa

After the patient is able to achieve cocontraction of the anterior and posterior muscles of the cervical spine in resting positions, the next goal is to be able to maintain cervical stabilization during arm motion. The exercises consist of initial cocontraction of the cervical musculature (a pre-set nod to obtain neutral), which is maintained while the patient performs repetitive motions of the upper extremity in various positions (i.e., supine, FPK, sitting, standing). The pattern of the arm motion, amplitude, and position of the exercise is based on what combination challenges the patient optimally while maintaining neutral position of the affected segmental level(s). The goal is to accomplish segmental cervical stability in a variety of positions with an assortment of arm movements and a range of amplitudes. See **Table 23-6** for Stage II exercise options.

- Because the most stable position is supine, it is used as the initial starting position.
- Various movements of the upper extremity (e.g., flexion, abduction, diagonals) are performed while palpating the affected segment for unwanted translation. Only those motions in which the segment remains neutral can be performed.
- Bilateral arm motions below 90 degrees often are the least challenging. Unilateral, overhead movements place higher demands on the stabilization system. (However, these effects depend on factors such as the plane or direction of the hypermobility, dural tension, and shoulder or thoracic mobility.)
- Progression includes adding hand weights, which increases the resistance, or lying on a half roll, which reduces the stability of the base (**Fig. A**).
- These same exercises can be progressed by having the patient perform them in a sitting or standing position, because these positions are more challenging to spinal stability. To make the transition to upright less challenging, the patient can be instructed to sit or stand with the back to the wall to provide feedback of where the head is in space (**Fig. B**). Upper extremity motion can be altered in direction, amplitude, and pattern.
- The therapy ball can be used as another surface to promote cervical spine stability with upper extremity movements. Ball sitting and the use of elastic band or pulley resistance are beneficial at this stage (**Fig. C**). In prone on the ball, the patient can be taught to maintain a controlled cervical spine position while performing simple rocking motions. Increased demands can be made on the cervical spine by adding unilateral or bilateral arm motions, with or without weights. This can be progressed to more complicated arm and leg lift patterns (**Fig. D**). Similar exercises performed in supine on the ball are of a much higher load to the cervical spine and should be added later in the retraining process, only once a higher level of motor control has been developed.
- The use of proprioceptive neuromuscular facilitation (PNF) patterns or sport- and work-specific movements introduce a more functional approach (**Fig. E**).
- Various wobble board systems can be used; the unstable base can further challenge the control of posture as the patient performs various upper or lower extremity movements.

Figure A: Maintaining axial extension on a half roll with weighted unilateral overhead motion.

DISPLAY 23-1 (continued)

Cervical Spine Stabilization Program

Figure B: Wall posture with pre-set nod and unilateral arm elevation.

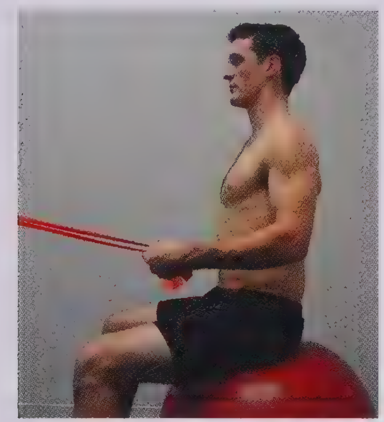


Figure C: Maintaining sitting axial extension on a ball during arm motion (scapular setting) with resistance.

Figure D: Maintaining axial extension prone over a ball during opposite arm and leg lift pattern.

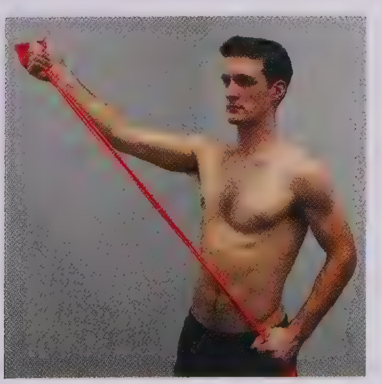


Figure E: Maintaining axial extension with proprioceptive neuromuscular facilitation (PNF) pattern against tubing resistance.

Stage IIb

At this stage, heavier loads can also be added to resist cervical musculature to truly achieve strength gains. Control of the unstable segment must be carefully monitored.

- Nod lift-off on high incline (Fig. 23-5)
- Supine neutral head lift (Fig. 23-4)
- Supine segmental curl-up head lift (Fig. 23-6)
- FPK extension lift
- Sidelying head lift (Fig. 23-14)
- Elastic band resistance leans (Fig. 23-7A), lunges (Fig. 23-7B), and rotation (Fig. 23-13 and 23-15). The lunges are particularly useful for gaining stability control because of the perturbations created during the movement of the body.
- Controlled, non–weight-bearing side flexion and rotation can be initiated in supine using a foam wedge, starting at the peak (Fig. 23-16), progressing to the offset position (Self-Management 23-1).
- Pure rotation and side flexion motions can be practiced with the head at the wall in front of a mirror to give feedback and prevent the tendency to collapse into the hypermobile plane of movement.
- Cervical segmental flexion and RTN from the flexed position are movement patterns that require segmental stabilization during a dynamic movement pattern (Fig. 23-10).
- Pure rotation in FPK challenges the extensor group of muscles, particularly activation of the suboccipital muscles, as well as proprioceptive control (Fig. 23-12).
- A faulty extension movement pattern using excessive anterior translation can be corrected and practiced in either a sitting or FPK position.
- Heavier loaded movement control exercises would include the following:
- Incline nod lift-off (Figs. 23-5).
- Segmental flexion curl-up head lift (Fig. 23-6).
- Sidelying head lift (Fig. 23-14).

Stage III

This stage challenges the patient to maintain segmental control during various neck motions. A pre-set nod activates the deep segmental flexor muscles as stabilizers, permitting the more superficial muscles to perform the movement pattern without excessive segmental translation patterns. Position is based on the ability to control segmental stability during neck motion with gravity-assisted versus gravity-resisted. The amplitude of motion is graded based on the range in which the patient can control segmental stability. See **Table 23-7** for some of the exercise options for this stage.

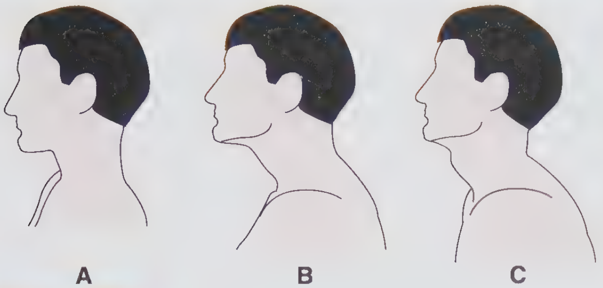


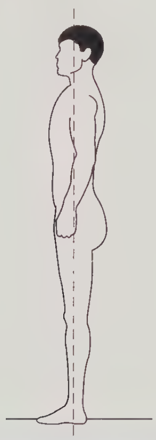
FIGURE 23-29 **(A)** Axial extension. **(B)** Forward head position: minimal midcervical lordosis. **(C)** Forward head position: excessive midcervical lordosis.

Patient-Related Instruction 23-2

Optimal Posture of the Neck

It is important to practice proper posture of the head and neck. Good posture decreases the stresses on muscles, joints, and ligaments of the cervical spine, which can reduce pain and prevent wear and tear on these structures. Your therapist will instruct you in additional exercises to enable you to achieve and maintain this posture.

The upper back should be straightened, the shoulder blades pulled back together to open up the front of the chest, and the chin brought back so that the head is centered over the trunk. A useful guideline is that the ear should be over the midline of the shoulder. Do not overcorrect, because a slight curve in the neck is normal. Proper posture must be practiced frequently throughout the day so that this position becomes habitual. This posture must also be adopted during exercise for the neck and upper extremity.



assessed to determine the exact components of his or her abnormal posture, the levels at which changes in the spinal curves are taking place, and thus, where the postural correction should focus. **Table 23-8** summarizes alignment findings at various levels of the cervical spine in the optimal position and FHP.

Reversal of the normal cervical lordosis is a less common postural impairment. In this situation, the patient presents with a very straight cervical spine or even a kyphosis. Treatment focuses on regaining extension in the cervical spine to encourage the normal cervical lordosis.

TABLE 23-6

Limb Load Challenge Options

LIMB LOAD CHALLENGES		
COMPONENT	**OPTIONS**	**POINTS**
Upper limb motions	*Motion:* Bilateral Unilateral Reciprocal	
	Plane: Flexion Abduction PNF	Bilateral flexion stresses anterior translation Unilateral flexion stresses lateral translation Abduction: stresses dural mobility and lateral translation
	Position: Below 90 degrees Overhead	
Positioning	*Supine:* Mat Foam: full roll ½ roll	Progressive challenges dependent on individual patient's dysfunction and requirements for their work/sport
	Sitting: Supported at wall Unsupported Ball	
	Kneeling: Knees 4PK	
Resistance	Free weights/ medicine ball/ pulleys/elastic	Start with low load to down-train excessive recruitment
	Isometric/ concentric/ eccentric	Focus on scapular stabilizers and extension patterns

Postural abnormalities may be observed in the frontal plane with the head and neck tilted to one side. This posture can be caused by factors such as muscle imbalance, articular hypomobilities, habitual work or leisure positions, and hearing or sight deficits necessitating altered head position. Treatment should be directed at the cause of the asymmetry.

Therapeutic Exercise Interventions

Treatment for FHP should address muscle imbalance, neuromeningeal extensibility, articular hypomobility, and proprioception. Muscles which require lengthening include the posterior cervical extensors, scalene, upper fibers of the trapezius (UFT), levator scapula, and pectoralis major and minor. Muscles that are weak and require strengthening include the deep, short cervical flexors, the scapular stabilizers (middle and lower fibers of the trapezius, rhomboids, and serratus anterior), and the upper thoracic erector spinae, In addition, abnormal cervical postures may be caused by an attempt to decrease stretch on shortened or mechanosensitive neuromeningeal structures. Ipsilateral side flexion of the cervical spine and elevation of the scapula decrease tension in these structures. Lastly, manual therapy techniques

TABLE 23-7

Segmental Motor Control Exercise Options

SEGMENTAL MOTOR CONTROL			
EXERCISE	**PURPOSE/AIM**	**MODIFICATIONS**	**POINTS**
Single plane movements	Practice corrected movement patterns	Eye level rotation Pure SF at wall Flexion pattern—top down Extension pattern—bottom up from flexion to neutral	Can use wall as feedback Laser pointer may also help with eye level rotation
Lower Load Control			
Wedge pillow	NWB rotation control	Peak → offset	
RTN segmental extension/flexion		Sit → FPK as progression	
Higher Load Control			
Controlled hyperextension: sit	Eccentric/concentric flexors in outer range	Can progress to a lean back position	Focus on motion occurring at CV joints through axis through ears Return with a nod pattern Control any midcervical collapse
FPK—CV extension	Practice pattern of CV flexion—extension		Control tendency to collapse anteriorly in the mid-cervical spine Keep neck back in line with trunk
FPK—CV neutral	Head lift keeping CV neutral	Could add a diagonal quadrant motion	
Pure rotation control: FPK	Rotation control—extensor focus	Prone on elbows	Maintain neutral nod position
Incline lift-off	Rotation control—flexor focus		

FPK, four-point kneeling; CV, craniovertebral; NWB, non-weight bearing; RTN, return to neutral.

TABLE 23-8

Summary of Optimal and Faulty Regional Cervical Spine Positions

OPTIMAL CERVICAL SPINE POSTURE (SEE FIG. 23-25A)	FORWARD HEAD POSITION—MINIMAL MIDCERVICAL LORDOSIS (SEE FIG. 23-25B)	FORWARD HEAD POSITION—EXCESSIVE MIDCERVICAL LORDOSIS (SEE FIG. 23-25C)
CV flexion	CV extension	CV extension
Midcervical spine neutral (slight cervical lordosis)	Midcervical lordosis	Excessive midcervical lordosis, can extend as low as C6–C7. Accompanied by abnormal anterior vertebral translation.
CT extension Upper thoracic neutral (slight kyphosis)	Low cervical and upper thoracic flexion Excessive thoracic kyphosis	Upper thoracic flexion Excessive thoracic kyphosis

CV, craniovertebral; CT, cervicothoracic.

may be indicated in conjunction with mobility exercises to regain the restricted motions of upper cervical flexion, CT junction extension, and upper thoracic extension.

Postural Correction To correct the FHP, the head must be brought back over the trunk. This can often be achieved by directing the patient to "lift the sternum upward," thus decreasing the upper to midthoracic kyphosis. It is important to not allow overcorrection, with patients adopting a flat or even lordotic mid to upper thoracic curve, as they overbrace with their superficial thoracic extensors.

Another primary exercise for achieving many of the goals of postural correction is the head nod exercise. It corrects the upper cervical extension, and because it also tightens ligamentum nuchae, it simultaneously reduces cervical lordosis. In patients with excessive lordosis of the midcervical spine, continuing the head nod into further cervical flexion stretches the posterior structures that have become shortened by the lordotic position.

FIGURE 23-30 Foam roll thoracic extension: lying lengthwise on an Epifoam roll to encourage thoracic extension, with the addition of a "T" position of the arms to further encourage that extension and stretch the tight anterior chest structures.

The head nod exercise can be modified to include posterior displacement (retraction) of the head and neck complex to encourage extension at the lower cervical spine and CT junction when indicated.

One study on the effect of repeated neck retractions in normal subjects found that there was a significant change in resting posture toward a more retracted position after two sets of repeated retractions.[72] Supine is a good position for the patient learning this exercise, because there is more proprioceptive feedback from the contact of the head. Lying lengthwise along an Epifoam roll also encourages the thoracic extension component of postural correction; adding arm movements into a "T" and "Y" position can accentuate that extension and open up the anterior chest (**Fig. 23-30**). Sitting and standing against wall support are natural progressions of the exercise (see Fig. 23-4). The patient must maintain a neutral lumbar spine position, and a towel may have to be used behind the head initially to support the forward head or later to maintain a neutral neck position. The reader is directed to Chapter 24 for additional thoracic spine exercise suggestions. Maintaining this cervical neutral posture while incorporating upper extremity motion is the next progression. Resisted upper extremity exercises can be added through the use of free weights, elastic tubing, or pulley systems. Exercises can be chosen to address strength impairments found on assessment or to simulate work or leisure movement patterns. Various wobble board systems can be used; the unstable base can further challenge the control of posture as the patient performs various upper or lower extremity movements. Because many daily activities require a bent-forward position, maintaining proper axial extension while in FPK or prone over the exercise ball can simulate this position, and upper extremity movements can be incorporated as described previously. The focus should remain on functional movement patterns related to activity limitations and participation restrictions.

Kinesthetic Awareness

Several studies[11,73–77] have shown that subjects with neck pain, particularly those with WAD who complain of dizziness, are less accurate in their ability to perceive a neutral resting posture, and return to a cervical neutral posture after motion in either the horizontal or vertical plane. Standing balance is also impaired in these subject groups.[78,79] Patients were able to improve their kinesthetic awareness following manual therapy, vestibular exercises, or by practicing RTN movements using a laser pointer and target.[80,81]

THERAPEUTIC EXERCISE INTERVENTIONS FOR COMMON DIAGNOSES

Some of the more common diagnoses of cervical spine disorders are discussed in the following sections. The impairments that occur with each diagnosis are identified, and examples of exercises for treatment are provided.

Disk Dysfunction

Etiology

Although disk herniation is less common in the cervical spine than in the lumbar spine, various dysfunctions of cervical disks do occur. The term *disk dysfunction* is used whenever changes in the disk alter its biomechanical properties and prevent normal function. Included in this grouping are degenerative disk disease, excessive disk clefting, and rim lesions (i.e., separation of the disk from the end plate).[82,83] In the acute stages, disk dysfunction can manifest as an irritable condition, with painful limitation of active ROM in all planes, particularly flexion; pain on cough or sneeze; painful cervical muscle contraction from guarding; and difficulty in maintaining upright postures because of the compressive load of the head on the neck. There may or may not be associated radicular symptoms or neurologic signs, depending on the degree of foraminal encroachment by the disk and the condition of other structures surrounding the foramen, such as the zygapophyseal joint capsule, ligaments, and bone. Radiculopathy is discussed in a subsequent section.

Treatment

Treatment initially is aimed at active rest of the cervical spine, which is achieved through education about proper resting positions that unload the compressive and translatory forces on the cervical spine. Therapeutic modalities may be useful to help alleviate the inflammatory response, decrease the associated muscle spasm, and manage pain. Manual therapy techniques can be used to mobilize the involved segment if segmental hypomobility is found during mobility testing. Muscle energy techniques can also be used to mobilize and alter muscle activity at that segment.

Manual traction techniques help to decompress the disk and increase intervertebral foramen size. If the condition is very irritable, excessive traction may increase symptoms because of the stretch on the nerve and dura. Breathing pattern reeducation is an appropriate exercise during the acute stages, because excessive use of the scalene muscles can add a compressive load to the cervical spine. Instruction in diaphragmatic breathing while monitoring scalene muscle activity through palpation encourages an optimal breathing pattern and unloads the cervical spine. Using postural correction exercises reduces translational forces. Supine exercises, such as gentle head nod (i.e., CV flexion), may be tolerated at this stage and will help improve posture as well as initiate proper recruitment of the cervical stabilizers. Any exercise that causes peripheralization of symptoms must be avoided, while any exercise that results in centralization of the patient's symptoms should be continued.

As the condition improves, impairments that contribute to activity limitations and participation restriction can be identified and addressed. After a period of protected function, the patient will usually exhibit signs of hypomobility. Degenerative changes at that vertebral segment may also decrease mobility. Care must be taken in selecting and teaching ROM exercises that minimize compressive or translatory forces. In addition, any exercises that further narrow the intervertebral foramen should be avoided if there is nerve root involvement.

Because muscle extensibility may be decreased as a result of muscle guarding during the acute phase, stretching exercises should be implemented. Neuromeningeal extensibility should also be assessed at later stages, particularly in cases of neurologic involvement. Exercises to increase the mobility of these structures should not be started while signs of decreased nerve conduction are present, because the movements can easily exacerbate the condition.

The disk is an important structure in the control of motion of the intervertebral segment, and hypermobility impairment may occur as a result of disk dysfunction. Stability testing at the affected segment may detect increased motion because of the loss of the disk's ability to control translational forces in the spine. This impairment must be addressed with a progression of stabilization exercises. The "Hypermobility" section describes these exercises. It is important to progress slowly, as higher load exercises will also load the healing disk.

To prevent further disk degeneration and reduce the incidence of recurrence of an acute episode, it is important to correct all postural impairments of the cervical spine, thoracic spine, and shoulder girdle. Postural asymmetry of the pelvic girdle also influences the cervical spine, and impairments should be addressed as previously discussed.

Cervical Sprain and Strain

Etiology

Any traumatic incident can produce a sprain or strain of the cervical spine. The most common incident is the WAD that occurs after a motor vehicle accident.

The complex injuries sustained by the cervical spine can affect many different tissues. The soft-tissue structures involved may include muscle, ligament, capsule, articular cartilage, and the disk (including rim lesions). Concurrent bony injuries can include fractures of the articular subchondral bone, transverse and spinous processes, lateral masses of the atlas, and the vertebral body.[82] Suspicion of fracture requires referral to the physician for management. Patients exhibiting signs of instability from traumatic injury should also be referred to the physician for further diagnostic tests and appropriate medical intervention. The severity of these injuries varies widely, and the irritability of the condition must be assessed individually. As discussed earlier in this chapter (see "Impaired Muscle Performance" section), patients with WAD have been shown to have decreased recruitment, strength and endurance of their deep cervical flexors, early and excessive recruitment of the more superficial flexors even at low loads, and decreased strength and atrophy of the deep cervical extensors. Motor patterning is altered during upper extremity tasks, and there are prolonged relaxation times for some of the superficial muscles. Subjects with WAD who also complain of dizziness demonstrate impairments of joint position sense, balance, and gaze stability as compared with controls.[73–79]

Treatment

During the acute inflammatory stage, treatment is aimed at reducing pain and inflammation and promoting optimal healing. Education about proper resting positions, limitations of activity, and the use of ice can assist in obtaining these goals. If segmental hypermobility is suspected, bracing should be considered to reduce stresses on the healing structures. Interventions during this phase include breathing exercises and pain-free ROM exercises. The supine position is often best tolerated at this stage, because it unloads the weight of the head. Rhythmic neck rotation movements performed in a supine position in conjunction with relaxed breathing can increase mobility and assist vascular flow. The wedge pillow can be used to assist the mobility exercise. Rosenfeld et al.[61–63] showed that regular rotation ROM exercises in the upright position performed 10 times hourly, resulted in significantly less pain, better mobility, and less time loss from work.

Therapeutic modalities such as ice, interferential current, pulsed ultrasound, or transcutaneous electrical nerve stimulation may also be indicated at this stage to reduce inflammation, decrease muscle spasm, and assist in pain control.

In the subacute stage, it is important to continue to protect the injured structures and to introduce stresses that encourage optimal healing. Grade I and II manual therapy mobilization techniques are effective in pain relief, and grade III and IV mobilizations can help restore motion of the involved segments (see Chapter 7). Impairment of mobility may continue to be the primary dysfunction. Mobility exercises may be progressed into larger arc movements, more specific to the multiplanar articular restrictions found on manual mobility testing. Specific muscle length tests may also indicate that certain muscles are short. However, the effect on the whole spine (e.g., dural stretch, disk compression) must be taken into consideration when choosing mobility exercises. Depending on the degree of ligamentous or disk injury, there may be a mobility impairment of hypermobility. As studies have shown that decreased dynamic stability occurs early in this patient population, stabilization exercises should be included as soon as possible. The Stage I exercises put very little stress on the cervical spine and can be implemented early in the rehabilitation process. Development of a stabilization program must take into consideration the direction, severity, and irritability of the hypermobility (see the "Hypermobility" section). It is also prudent to begin postural reeducation, progressing through the exercises as tolerated. Overhead arm motions are often too stressful on the cervical spine at this stage because of increased translation and compression forces.

During the remodeling phase, as the condition becomes more chronic, other impairments can be addressed. The muscles strained at the time of injury and the segmental muscles related to levels of articular dysfunction often show impairment of force production. A specific strengthening program can be designed to improve muscle function. Higher load Stage II and III stabilization exercises (see Display 23-1) should be taught and progressed as tolerated. It has been shown that the lower load nod type exercises do not regain strength to the same extent as higher load head lift type exercises,[52,84] so these should be included when the healing structures of the neck are able to tolerate the larger forces. In some chronic cases, overactivity of the superficial muscles is the predominant feature, and so continuing to use low load exercises to focus on the downtraining of these superficial muscles may be more appropriate than a focus on strengthening with no consideration given to the motor pattern. Postural impairments continue to be a concern, and treatment interventions should include dynamic exercises that encourage movement patterns that incorporate optimal posture.

Neural Entrapment

Etiology

The cervical nerve roots can become entrapped as they exit at the intervertebral foramen. The foramen is bounded by the zygapophyseal joint, the UV joint, the disk, and the pedicle. Any pathologic condition increasing the size of these surrounding structures can lead to narrowing or stenosis of the foramen, potentially entrapping the nerve root. Foramen size is also reduced by the movements of extension, ipsilateral side flexion, and rotation. Any muscle imbalance producing this resting position of the cervical spine would further aggravate the problem. The FHP can place the upper and midcervical spine into a posture of increased cervical lordosis, decreasing the intervertebral foramen size. Any scapular resting position that encourages this cervical position (e.g., elevated scapula) or stretches the nerve root (e.g., depressed or protracted scapula) would also aggravate the condition. Changes in neural conduction depend on the degree of pressure or traction on the nerve root.

The term *double crush syndrome* or *multiple crush syndrome* has been used to describe the syndrome in which the nerve is affected at multiple sites along its course from the cervical spine to the hand. Common sites of entrapment are the cervical intervertebral foramen, the thoracic outlet, the elbow, and the carpus. Pressure at any one of these sites in isolation may be insufficient to produce symptoms, but there can be a summative effect as subsequent sites add their "crush" to the nerve.

A common example of crush syndrome is carpal tunnel syndrome. There may be decreased space in the carpal tunnel locally, but it may not be as marked as the symptoms suggest. There may be additional proximal symptoms that are unexplained by pressure at the carpal tunnel alone. In the cervical spine, there may be some mild degenerative changes involving the zygapophyseal joint and uncinate process that decrease the intervertebral foraminal dimensions. A superimposed FHP places the upper and midcervical spine into a resting position of extension, further compromising intervertebral foramen size. A short scalene muscle on the same side, because of a faulty respiratory pattern or the habitual crooking of a phone between head and shoulder, causes a side-flexed posture of the cervical spine and further decreases the intervertebral foramen space. At the thoracic outlet, a shortened scalene muscle can also elevate the first rib, decreasing the size of the thoracic outlet and creating another potential site of neural entrapment. A depressed scapular resting position places a traction force on the brachial plexus, which can also decrease neural conduction, and increases tension in the neuromeningeal system in the upper quadrant, which can aggravate the condition.

Treatment

Thorough assessment at each of the sites of entrapment can identify the impairments contributing to the condition. Treatment interventions address the impairments found at the cervical spine, thoracic spine, shoulder girdle, and wrist. If wrist dysfunction is treated in isolation, the symptoms tend to recur or change, often working their way proximally. Exercise treatment interventions for the impairment of posture are particularly useful, as is addressing the findings of neuromeningeal hypomobility.

Cervicogenic Headache

Etiology

CHA can be caused by two mechanisms. First, the posterior aspect of the skull, as far forward as the vertex, is supplied by the greater occipital nerve (a branch of the C2 and C3 posterior rami). Any structure supplied by the second or third cervical nerve can refer pain into that distribution. Second, the spinal nucleus of the trigeminal nerve descends into the spinal cord to at least the level of C3. Branches of the trigeminal nerve supply the mandibular, maxillary, and frontal areas of the face. Afferents from the first three or four cervical nerves converge with afferents of the trigeminal nerve. Any structure supplied by these neurologic segments can refer pain into the head and face, causing headache of cervical origin.[71]

There has been conflicting results in studies that have looked for the presence of FHP in subjects with CHA as compared to other headache types.[8,66,67,85] Hypomobility is a feature of CHA. In particular, symptomatic segmental stiffness in the upper cervical spine has been found in this population.[19,67,85,86] As with other subjects with neck pain, those with CHA demonstrate weakness and lack of endurance of the deep cervical flexors and extensors along with excessive activity of the superficial groups.[19,67,86] Zito et al.[67] found a higher incidence of muscle tightness in these subjects as compared to other headache types, but this tightness was not confined to a specific muscle or muscle group. Jaeger[87] found a significant number of myofascial trigger points on the symptomatic side compared with the asymptomatic side in patients presenting with CHA.

Treatment

Treatment interventions should target impairments of posture, mobility, and muscle performance. Mobility exercises may be performed as generalized ROM exercises or designed as specific articular mobilization exercises to address the segmental mobility restrictions found on manual mobility testing, most often of the upper cervical intervertebral levels (see the "Hypomobility" section). Specific muscle stretches can address the myofascial tightness and trigger points that may be contributing to the headache. Progressive exercises to increase muscle performance and endurance of the deep cervical flexor and extensor muscles should be included in the exercise program. Jull et al.[88] showed that a combination of manual therapy and specific therapeutic exercise gave significant improvement in intensity, frequency, and duration of headaches in a population with chronic CHA as compared to controls. This improvement was maintained at 12 months.

LAB ACTIVITIES

Constructing New Knowledge

- Consider a 45-year-old male patient with long-standing mild neck pain. Examination findings reveal weakness of both the DNF and the superficial flexors. Describe a progression of exercises to first address the deeper muscle weakness and then the more generalized flexor weakness. Be sure to include dosage.
- Consider a 22-year-old-female patient who has resolved from a recent episode of acute wry neck (torticollis). This is her third episode in the past year. Your examination reveals hypermobility on testing at the C4–C5 segment. Outline the progression of exercises you would prescribe to develop dynamic stabilization of her cervical spine.
- A 35-year-old female patient sustained a WAD II injury in a motor vehicle accident 2 weeks ago. She is reluctant to move her neck, and you note excessive bracing of the superficial musculature on many of your tests. Describe three exercises that you could prescribe on this first visit to assist in improving her mobility and relaxation of her superficial muscles. Be sure to provide information about the education component to assist this patient in confidently performing the appropriate dosage for this group of exercises.
- Your patient is a 65-year-old male with poor static resting posture. He has a FHP along with an increased thoracic kyphosis. A number of his neck muscles have shortened because of this constant position, and his SCM muscle is overdominant. List those muscles which are likely to have shortened in this situation. Create an exercise program to address both the muscle length and balance impairments and to gain control over the FHP.
- Consider a patient with a restriction of left side flexion, with the tightness felt on the right side of the neck. List three different types of structures which could be contributing to this restriction of motion. Describe one mobility exercise you could teach to address each one. Give a progression wherever possible.
- Describe the situations in which you would use a higher load neck flexor strengthening exercise as compared to a low load DNF recruitment exercise.
- Your patient presents with an asymmetric loss of strength of rotation/side flexion to the right. Which exercises could you use to specifically target this asymmetric pattern?
- Your patient is a painter with neck pain, aggravated by overhead work, particularly when painting ceilings. You notice that his neck collapses forward into anterior translation in the mid-cervical spine on active neck extension. You have already helped him to retrain and strengthen the DNFs, but you notice that his extension pattern has not really changed. Describe a progression of exercises you could use to retrain an optimal extension pattern, leading to control of the anterior translation tendency while painting ceilings.
- Your patient presents with a diagnosis of thoracic outlet syndrome. On examination, you identify overactivity of her anterior scalene muscles. Describe three exercises you could prescribe to assist in downtraining the excessive activity of this muscle.

KEY POINTS

- The cervical spine examination and evaluation consists of a patient report (subjective history) and the physical (objective) examination. The patient report should include information about the patient's job, sitting position, and type of exercise performed. The physical examination includes visual observation; active and passive movement tests, including myofascial and neuromeningeal extensibility tests; manual muscle testing; neurologic tests; various special tests; and clearing tests of the thorax, shoulder girdle, and TMJ.
- Common impairments of body structures and functions affecting the cervical spine include muscle performance impairment, posture impairment, and mobility impairment (i.e., hypomobility and hypermobility).
- A therapeutic exercise program is developed to address each impairment that is directly related to activity limitations and participation restrictions
- The following are common diagnoses of the cervical spine:
  - Disk dysfunction: Impairments that are often associated with this diagnosis include mobility (i.e., hypomobility and hypermobility) and posture.
  - Sprain or strain: Impairments associated with this diagnosis include mobility, posture, and muscle performance.
  - Neural entrapment: Impairments associated with this diagnosis include mobility and posture.
  - CHA: Associated impairments include mobility, posture, and muscle performance production, particularly endurance.
- For any patient presenting with a particular diagnosis, the associated impairments are identified. They must then be prioritized according to their relative importance as those requiring immediate attention and those most likely to be tolerated by the patient.

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CHAPTER 24

The Thoracic Spine

ELIZABETH A. V. BLOOM • CARRIE M. HALL

The thoracic spine is unique in its structure and function from the remainder of the spine because of its articulations with the sternum and ribs and its critical role in ventilation. The thoracic spine's location between the cervical and lumbar spine creates a vulnerability to impairments in these related regions. Conversely, impairments in the thoracic region affect function of the surrounding spinal regions. As a critical link in the kinematic chain, functions of other regions of the body (e.g., shoulder girdle, hip, foot, ankle) affect function of the thoracic spine and vice versa.

Unlike the lumbar and the cervical spine, there is a paucity of literature regarding the management of thoracic spine impairments, particularly regarding interventions for impaired muscle performance. Much of the approach to exercise for the region must be extrapolated from the lumbar and cervical regions, with allowance made for differences because of the thoracic cage. This chapter presents principles and examples of therapeutic exercise prescription for common pathologies and impairments affecting the thoracic region which ultimately contribute to a person's activity limitations and participation restrictions.

As you progress through this chapter, it may be helpful to keep patient scenarios in mind. For each scenario in **Display 24-1**, ask yourself how you would address the patient's impairments, activity limitations, and participation restrictions through an appropriate exercise program. What exercises would you choose? How would you dose the exercises (number of repetitions, sets, speed of movement, amount of rest, progression from initial session to discharge, and so on).

DISPLAY 24-1

Patient Cases

Pain

Orson Buggy is a 60-year-old horse-drawn carriage driver who complains of mid-back pain that limits his work tolerance. He describes an ache that increases the longer he sits, which he must do to drive tourists. He also reports a sharper pain of short duration that occurs when the carriage hits a bump or hole, relatively often in the area he must drive. You observe that he sits in a flexed posture. His pain is aggravated by flexion with overpressure, and vertical compression of his trunk while in his resting sitting position. His pain is less with extension. Compression of his trunk when sitting upright is painfree.

Osteoporosis/Insufficiency Fracture

Viola Fuss is a 64-year-old meditation and stress relief counselor with moderate osteoporosis who complains of mid-back pain. Radiographs reveal a stable compression fracture of the T6 vertebral body; both her orthopedist and radiologist feel it is stable and she is cleared for exercise. Her primary activity limitation is decreased walking endurance because of fatigue and shortness of breath.

Hyperkyphosis/Parkinson Disease

Denton Fender is a 56-year-old auto body mechanic who was diagnosed with Parkinson disease 3 years ago, and is still in the early stages. Individuals with this disorder typically acquire a flexed posture as they age and the disease progresses. In addition, their voice volume is often low, reflecting a decrease in chest and diaphragm excursion because of the resulting hyperkyphosis.

Dustin Dubree is a 72-year-old construction company owner with Parkinson disease who's "on" periods last about 3 hours. He remains active running his company, including overseeing work at job sites. His major complaint at this time is having to take three or more attempts at rising from a chair, and taking up to a minute some times to straighten into an upright posture upon standing. You note on physical exam that he has limited hip flexion and lumbar extension.

Thoracic Outlet

Laura Biden is a 22-year-old policewoman with diffuse neck, shoulder, arm, and hand pain and numbness in the fifth digit. These problems make it difficult to write traffic tickets. You note that she sits and stands with an exaggerated kyphosis and forward, drooping shoulders. Passively or actively holding her shoulders back and straightening her back improves her UE symptoms after several minutes. She notes she is unable to maintain this position for long, however.

EXAMINATION AND EVALUATION

A comprehensive examination, including the history, systems review, and tests and measures, enables the physical therapist to determine the diagnosis (based whenever possible on impairments, activity limitations, and participation restrictions), prognosis, and interventions.[1–3] The physical therapist must follow an organized, sequential approach in order to avoid omitting crucial information that may prevent an accurate interpretation of the findings. In addition, a detailed history must be taken to determine the nature and extent of the dysfunction. Beyond the general data generated from a patient/client history as defined in Chapter 2, the following information is important to obtain from a patient with impairment, activity limitations, or participation restrictions involving the thoracic spine.

History

While primary thoracic spine pain is common in the general population,[4] (**Evidence and Research 24-1**) the thoracic region is also the site of many visceral and pathologic causes and sources of pain (**Evidence and Research 24-2**). Most of the visceral organs are innervated by the thoracic spinal nerves and may refer pain to the thoracic spine and rib cage (e.g., back or chest pain due to acute myocardial infarction or dissecting aortic aneurysm,[5] pain located at the costovertebral angle of the lower thoracic segments that actually originates in the kidneys, chest pain or back pain because of infection or other inflammatory disorders, back pain due to vertebral fractures, referred pain due to neoplasms). Therefore, questions must be asked which will help determine whether or not physical therapy is the appropriate management option for the patient, especially as physical therapists may see patients in a direct access setting. The findings from a thorough history can indicate possible nonmechanical sources of symptoms (see Appendix 1). If the therapist suspects that the pain is derived from nonmechanical or visceral sources, the patient should be referred to the appropriate medical practitioner.

EVIDENCE and RESEARCH 24-1

A systematic review of 33 studies concluded that the prevalence of thoracic back pain was very broad because of many factors, including the duration of thoracic back pain.[4] Prevalence data ranged from 4% to 72% (at any one time), 0.5% to 51.4% (7 days), 1.4% to 34.8% (1 month), 3.5% to 34.8% (1 year), and 15.6% to 19.5% (lifetime). Reports of thoracic back pain were higher in children and adolescents. In children and adolescents, pain was associated with female gender, postural changes associated with backpack use, backpack weight, other musculoskeletal symptoms, participation in specific sports, chair height at school, and difficulty with homework. In adults, pain was associated with concurrent other musculoskeletal symptoms and difficulty in performing activities of daily living (ADLs).

EVIDENCE and RESEARCH 24-2

Ozaki et al.[6] reported on 22 cases of spinal osteoid osteoma or osteoblastoma of which six were in the thoracic spine. Deyo and Diehl[7] reported on 1975 patients in an outpatient primary care setting with spinal pain of which 316 (16%) had thoracic spine pain. Two (0.63%) of these patients had cancer as the cause of the thoracic pain. This was similar to the 0.66% of cancer-related pain for patients with low back pain.

Systems Review

A systems review provides a screen of the pertinent systems. If problems are observed during this review, more detailed tests and measures should be performed as the next phase of the examination process. Information about disorders of other systems (e.g., cardiopulmonary, genitourinary, gastrointestinal) that may mimic thoracic musculoskeletal disorders should be obtained during the medical history portion of the examination, and used to guide the subsequent systems review. For example, a systems review of the cardiopulmonary system includes screens of the lungs (e.g., respiratory rate, breath sounds), heart (e.g., heart rate, heart sounds), and blood pressure.

A systems review of the skeletal system is also called a scan examination. The scan examination is a quick procedure that includes tests and measures listed in **Display 24-2**. Because the thoracic spine spans the upper and lower quadrants, screens of both regions are advisable, particularly as they relate to the transitional zones (i.e., C7–T1 and T12–L1). Chapter 23 provides a more detailed explanation of the upper quadrant scan

DISPLAY 24-2

Outline of a Scan Examination

Observation

- Range of motion
- During trunk flexion observe for rib hump (scoliosis)
- Motor assessment
- Sensory assessment
- Vascular status
- Reflexes
- Palpation
- Clearing tests

Upper Quadrant (see Chapters 23 and 25)

- Foraminal encroachment
- Compression or distraction
- Upper limb tension test (ulnar bias may indicate upper thoracic pathology)
- Thoracic outlet syndrome (TOS) tests

Lower Quadrant (see Chapters 17 and 19)

- Prone knee bend (may indicate low thoracic pathology)
- Straight-leg raising
- Slump test
- Hip flexion, abduction, external rotation (FABER)
- Scour test

examination, and Chapter 17 explains the lower quadrant scan examination.

Individuals with kyphotic postures, especially elder women with a history of osteoporosis, should be screened for vertebral body fractures. In the case of a healthy spine, vertebral body fractures can result from blunt force or injury. Individuals with excessive spinal stiffness should be examined radiographically for ankylosing spondylitis. To be considered significant, radiographic findings must be correlated with the clinical examination findings.

Additional medical screening is highly indicated in individuals whose symptoms do not appear to be mechanical in nature, who have a history of cancer, risk factors for vascular disease, a history of exposure to tuberculosis, or bilateral lower extremity neurologic complaints with or without reports of incontinence (see Appendix 1). It is important to understand the origin of the problem, because the decision to refer on an emergent basis rather than on a routine follow-up visit with the physician will depend upon the system involved, the nature and severity of the complaint, and the clinical findings.

Tests and Measures

The next step in the examination process is the selection of one or more tests and measures to ascertain the impairments, activity limitations, and participation restrictions of the patient. This determination leads to the development of the final diagnosis and the prognosis, which should guide the physical therapist's choice of management options. The selection of tests and measures, like the choice of questions asked, should be driven by the provisional diagnosis list. The choice of performing any tests and measures therefore depends on the results of the history and systems review. Each test or measure should contribute to the process of either confirming or refuting a potential cause of the problem. Proceeding in this manner eliminates unnecessary procedures and streamlines the examination.

Tests for regions other than the thoracic spine, for example, the lumbopelvic, hip, or cervical areas, may be chosen should the provisional diagnosis list require them. **Display 24-3** lists impairments that may require examination in patients with thoracic complaints. The reader is referred elsewhere for a detailed explanation of each test and measure.[8]

DISPLAY 24-3
Component Impairments Related to Thoracic Kyphosis During Gait

Stance Limb

- Initial contact: Hip extensor strength is necessary to prevent backward lean by means of lumbar lordosis. Lumbar lordosis can lead to thoracic kyphosis.
- Terminal stance: Hip flexor length and hip joint extension mobility are necessary to prevent lumbar lordosis and secondary thoracic kyphosis.

Swing Limb

- Hip extensor length, hip joint flexion mobility, and hip flexor strength are necessary to perform proper hip flexion during swing and prevent backward lean by means of lumbar lordosis to advance the limb. Lumbar lordosis can lead to thoracic kyphosis.

Trunk

- Balance between length and performance of oblique abdominal or spinal extensor muscles is necessary to prevent thoracic kyphosis.
- Counterrotation between the pelvis and trunk is necessary to promote optimal trunk function during gait to prevent compensatory thoracic flexion.

THERAPEUTIC EXERCISE INTERVENTIONS FOR COMMON IMPAIRMENTS OF BODY STRUCTURES AND FUNCTIONS

The basic steps in designing the plan of care for a patient or client are to (1) identify the impairments that relate to the observed posture or movement pattern, activity limitation and participation restriction, and (2) address each causative impairment as necessary. Therapeutic exercise interventions for the thoracic region include activities and techniques that address impairments that directly and indirectly affect thoracic spine function. Comprehensive treatment of thoracic activity limitations and impairments requires treatment of related areas, including the cervical spine, the shoulder girdle, and the lumbopelvic region.

The ultimate goal of all therapeutic exercise interventions should be to regain maximum pain-free function. This requires addressing impairments contributing to the faulty movement that are related to activity limitation and participation restriction. Analysis of complex movements (e.g., gait, forward bending, reaching, rising from sitting, ascending or descending stairs) requires division of the movement into component parts to analyze the contribution from each segment or region involved in the movement. The examination and evaluation should reveal specific regional physiologic impairments such as hypomobility in the hips, restricted mobility of the spine, or impaired muscle performance of the shoulder girdle. Combining the information obtained from movement analysis and specific examination of selected regions can determine which impairments need to be addressed to improve the strategy of movement for the given task. For example, a goal of maintaining a neutral spine while walking for an individual with pain related to thoracic kyphosis may require improving any one or all of the impairments listed in **Display 24-4**.

In an appropriate treatment progression, component impairments are first addressed, followed by integrated movements with relatively simple activities or techniques, progressing to more challenging activities or techniques, and then progressing to complex, integrated functional movement patterns. **Figure 24-1** demonstrates an integrated movement in sidelying, which is gravity-lessened for the hip flexors and gravity-assisted for the oblique abdominal muscles and spinal extensors. This movement pattern can be progressed to the upright position of the swing phase of step-up (**Fig. 24-2**) and eventually into the swing phase of gait (after the stance phase of gait components has adequately improved through another set of exercises).

Because the thoracic spine lies between the shoulder girdle and lumbo-pelvic-hip complex, correction of movement impairments of these regions may be necessary to improve the movement pattern of the thoracic spine. Movement impairments

DISPLAY 24-4

Required Tests and Measures for Thoracic Spine Examination

Aerobic Capacity: Assessment of vital signs may be necessary, particularly when working with patients with a cardiopulmonary disorder or patients at risk of falls.

Ergonomics and Body Mechanics: The ergonomics of the patient's workstation(s) can provide vital information regarding the pathomechanics of the condition. Observation of the ADLs and the patient's occupational and recreational movement patterns can reveal impairments in movement in the thoracic and related regions. For example, when reaching across the body, one might observe excessive thoracic flexion and lateral flexion as compensatory movements for insufficient hip and thoracic rotation.

Gait, Locomotion, and Balance: Assessment of these skills can determine risk for falls.

Joint Mobility and Integrity: Arthrokinematic testing of the zygapophyseal, costotransverse, sternocostal, and sternochondral joints. Motion findings in these tests should correlate with osteokinematic findings. Specific testing of osteokinematic function of the ribs can be assessed during inhalation and exhalation.[9]

Motor Function: Altering impaired movement patterns and observing for an associated change in symptoms will assist in determining the pathomechanics of the symptoms. For example, in the case of compensatory thoracic flexion and lateral flexion because of reduced hip and thoracic rotation, having the patient rotate the hip and thoracic spine to the limit of mobility while thoracic flexion and lateral flexion are restricted should alter the movement. This can be achieved manually by the therapist or actively if the patient is able to make the change from verbal instruction alone. If the symptoms are reduced with the new movement pattern, the flexion or lateral flexion movement patterns are assumed to be contributing to the symptoms.

Muscle Performance: Include muscle performance tests to determine the presence of nerve root dysfunction in the cervicothoracic and thoracolumbar regions. Manual muscle testing can identify imbalances in muscle performance between synergists and agonist–antagonist muscle pairs in the trunk and shoulder girdles (see Chapters 17 and 25).

Pain Tests and Disability Measures: The Functional Rating Index[10] (measures the magnitude of clinical change in spinal conditions), Oswestry,[11] and Roland–Morris Disability Questionnaires[12] (disability scales developed for the cervical and lumbar spines which, although not specific to the thoracic spine, can be used to gain insight into the condition's effect on the patient's life; see Chapters 17 and 23).

Posture: Particularly as it relates to the head and neck and lumbar-pelvic-hip complex in standing, sitting, and recumbent positions, signs of asymmetry and scoliosis.

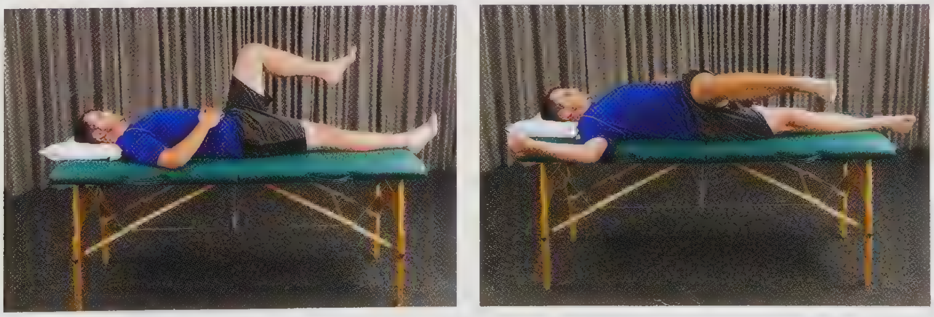
Range of Motion and Muscle Length: Assess the quality and quantity of motion in general as well as intersegmental mobility during active and passive osteokinematic thoracic and upper extremity movements; observe for localized areas of hypermobility with associated areas of hypomobility. Assessment of unilateral upper extremity elevation can assist in the assessment of mobility of the upper thoracic region. For example, upper thoracic extension and rotation to the ipsilateral side should accompany upper extremity arm elevation.[2]

If articular function in a specific joint is found to be normal, and yet overall mobility is limited, lack of myofascial extensibility can be suspected as a primary cause. For example, a stiff or short right external and left internal oblique can limit right thoracic rotation. If this were the case, accessory joint play assessment would reveal normal joint mobility.

Sensory Integrity: Function of the intercostal nerves; special tests, such as those for TOS and neural tension.

Ventilation, Respiration, and Circulation: Observation of breathing patterns can be very useful in fully understanding underlying contributing factors to numerous diagnoses such as kyphosis-related diagnoses and TOS. Assess the quality (e.g., proper pump and bucket handle motions of the rib cage, looking for movement in all three directions) and quantity (rate, inspirometry) of respiration.[2]

Other: Radiographs (diagnosis and curve angle in scoliosis, Scheuermann disease, and kyphosis related to osteoporosis, signs of ankylosing spondylitis); MRI (soft tissue pathology such as herniated nucleus pulposis); additional medical screening for visceral sources of thoracic pain (see Appendix 1).



A B

FIGURE 24-1 This exercise promotes simultaneous hip flexion and trunk counterrotation to prepare for the complex movement of the swing phase of gait on the left. **(A)** The start position is supine with hip and knee flexion. **(B)** The end position is sidelying with hip and knee flexion and left trunk rotation.

FIGURE 24-2 During the swing phase of the step-up, trunk counterrotation can be emphasized to facilitate the complex movement during the swing phase of gait.

at the foot and ankle also can contribute to impairments in the thoracic spine. The link between the foot and the thoracic spine is reviewed in a subsequent section on scoliosis. Chapter 21 details the exercise prescriptions for impairments in the foot and ankle.

Impaired Muscle Performance

Patients with impairments, activity limitations, or participation restrictions related to impaired muscle performance require resistive exercise with dosage parameters targeted toward a goal of increased force or torque production, power, or endurance (see Chapter 5). The cause of the altered muscle performance must be determined to ascertain the appropriate intervention to treat the impairment. The intervention plan developed is specific to the source or cause. There are several possible sources of reduced force or torque production:

- Neurologic impairment or pathology (e.g., peripheral nerve injury, nerve root injury, CNS disorder, impaired neural dynamics)
- Muscle injury or strain
- Disuse resulting in atrophy and general deconditioning
- Length-associated changes resulting in altered length–tension properties

Neurologic Impairment or Pathology Intervention

When muscle performance is impaired because of neurologic injury or pathology, the neural input must be restored in order for muscle performance to improve. If the nerve injury or pathology is permanent and paresis or paralysis is the outcome, the clinician must consider the effect of the resulting muscle weakness and subsequent adaptive shortening or contracture in the opposing muscles. In the case of paresis, the clinician must consider the effect of stretch on the weak muscle because of antagonist action superimposed on the initial weakness caused by the nerve damage. If reinnervation is latent, these same considerations must be heeded during the recovery process. Weak muscles must be protected from overstretch with proper support and stimulated with appropriate-dosage resistive exercise in the short range. The strong muscles must be stretched to maintain proper extensibility and prevent contracture and deformity.

One example of impaired muscle performance related to neurologic injury or pathology is reduced muscle force production in the diaphragm resulting in faulty breathing mechanics. Diaphragmatic breathing exercises cannot be effective until the source of the weakness is appropriately addressed. Because the diaphragm is innervated by the phrenic nerve (C3–C5), treatment of any cervical dysfunction at these levels may be necessary to improve diaphragmatic function. Subsequently, appropriate diaphragmatic breathing must be taught along with stretch of the lateral trunk and intercostal muscles (**Patient-Related Instruction 24-1**; **Fig. 24-3**). The lateral trunk and intercostal muscles may become stiff because of the unilateral rib approximation that may result from inadequate rib expansion, causing weakness in the diaphragm.

In the case of paraplegia with thoracic spine involvement, impaired respiration may result. Full excursion of chest expansion should be encouraged via deep breathing exercises utilizing the diaphragm. Resistance can be applied to the chest walls, diaphragm, and sternum via manual contacts using principles of proprioceptive neuromuscular facilitation (see Chapter 15) or using equipment. For example, inspiration can be facilitated using elastic bands wrapped around the chest. Resistance can be given to the diaphragm by placing weight on the abdomen while in supine (**Fig. 24-4**). The patient should be instructed to take full, deep breaths.

Evaluation of back pain should also include evaluation of neural tissue mobility by conducting upper and lower limb tension tests. Though the evidence is limited, neural tissue dynamics has been reported in clinical orthopedic physical therapy literature and is supported by basic science research and clinical case reports.[13–15] Since the sympathetic chain is positioned anteriorly along the rib heads and costovertebral joints,[16] further tension and stretching of the sympathetic chain can occur with thoracic flexion (e.g., excessive kyphosis, poor posture, or during a slump test) and contralateral side bending. The area from T4–T9 is significant because of the smaller diameter of the vertebral canal; T6 is reported to be a tension point in the nervous system. Butler postulates that during cervical and thoracic flexion, the spinal cord, relative to the spinal canal, moves cranially toward the cervical spine and caudally toward the lumbar spine. Segmental hypomobility of the middle thoracic spine could contribute to signs and symptoms associated with adverse neural tissue dynamics. Therefore, restoring thoracic mobility may help to facilitate treatment goals[14,17–20] related to upper or lower extremity neural tension.[21]

Muscle Strain or Injury

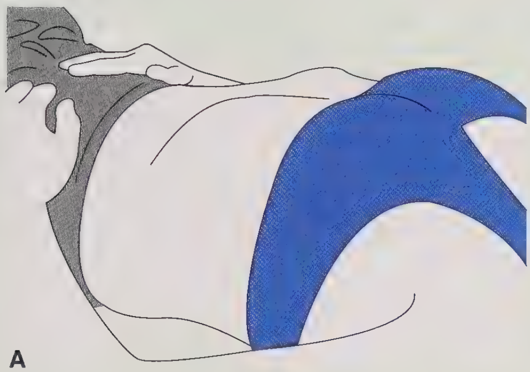
Causes Trauma, such as a blow to the chest or a sudden rotational injury sustained in a motor vehicle accident, can lead to muscle injury. An insidious-onset strain can also occur in muscles surrounding the thoracic region. Possible mechanisms of gradual insidious-onset muscle strain include overuse or overstretch.

One example of overuse in the thoracic region is provided by the scalene muscle group, particularly the anterior scalene. The actions of the anterior scalene include cervical flexion, ipsilateral cervical lateral flexion, contralateral cervical rotation, and elevation of the first rib (i.e., acting as an accessory muscle of respiration). Overuse of the anterior scalene can result from underuse or weakness of the deep cervical flexors (i.e., longus colli and capitis and rectus capitis anterior), other contralateral cervical rotators

Patient-Related Instruction 24-1

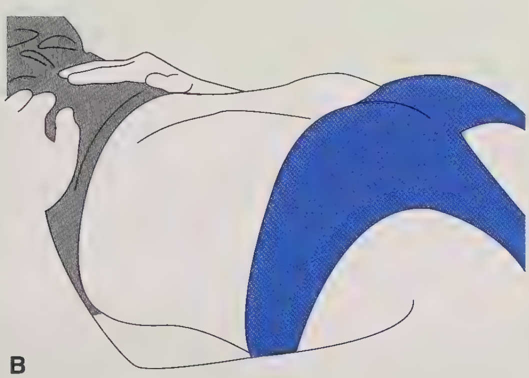
Diaphragmatic Breathing

- Initially, assume a comfortable position on the floor with your hands on your stomach.
- Relax your belly as much as possible.
- During the first third of inhalation, the belly should expand slightly (on its own) in an outward direction as the diaphragm pushes down on the contents of the abdomen.



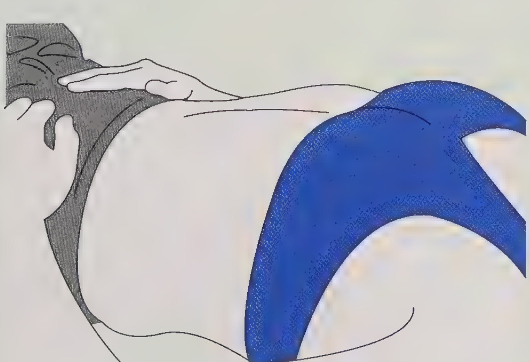
A

- Next, the air should move into the middle portion of the lungs, causing the area of the lower and middle ribs to expand. Complete inhalation means filling the lungs forward, sideways, and backward.



B

- The dimension of breathing often neglected is sideways intercostal breathing.
- Exhalation is largely a passive occurrence. The chest muscles and diaphragm relax, the ribs drop back close together, and the lungs recoil as air is quickly expelled.



C

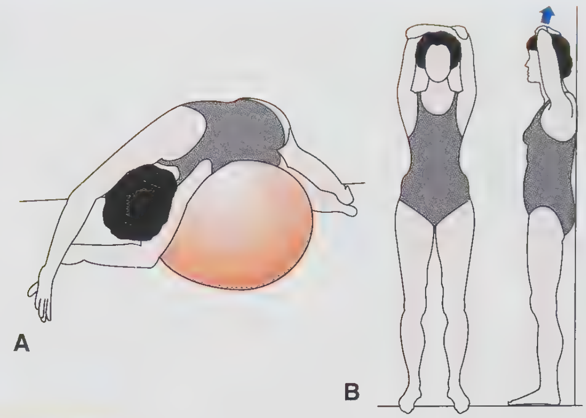


FIGURE 24-3 **(A)** Lateral trunk flexion stretch is assisted by gravity over a gymnastic ball. **(B)** Lateral trunk flexion while standing against a wall with arms overhead. The wall guides movement in the frontal plane. The arms-overhead position facilitates stretch to the intercostals. Diaphragmatic breathing into the stiff region can augment the stretch.

FIGURE 24-4 Resisted diaphragmatic breathing. **(A)** A weight can be placed on the patient's abdomen while in supine to provide resistance to diaphragm excursion. **(B)** Alternatively, by positioning the patient supine with the head inclined downward, the diaphragm must work against the weight of the abdominal contents during inhalation.

(i.e., deep cervical rotators, semispinalis cervicis, sternocleidomastoid, or upper trapezius), or primary muscles of inspiration (i.e., diaphragm, levator costarum, and intercostals). Chronic overuse can lead to stiffness or adaptive shortening of the anterior scalene, which can contribute to elevation of the first rib. Elevation of the first rib can disrupt cervicothoracic joint mechanics and contribute to TOS (see the section "Thoracic Outlet Syndrome").

Another example is middle and lower trapezius strain, which refers to the painful upper back condition resulting from gradual and continuous tension on the middle and lower trapezius muscles.[22] The strain in these muscles is caused by overstretch from a habitual position of forward shoulders (see Chapter 25), kyphosis, or a combination of these two faults. Treatment of the thoracic region must include treatment of the impairments related to the postural fault and/or the kyphosis to reduce the habitual stretch on the tissues (see the sections "Posture and Movement Impairment" and "Kyphosis").

Intervention Treatment of overuse of a particular muscle group must improve muscle performance of underused synergists and address the posture and movement patterns contributing to excessive use. In the anterior scalene example described above, instructing the patient in proper diaphragmatic breathing (see Patient-Related Instruction 24-1) rather than using accessory muscle strategies may be an important intervention to reduce the stress placed on the anterior scalene. The deep neck flexors are often weak, particularly after a neck injury (such as whiplash), and need to be strengthened in isolation of the overused muscle(s). Chapter 23 provides exercises in the "Impaired Muscle Performance" section to address weak cervical flexors. Stretch of the anterior scalene should be performed with caution. Stabilization of the first rib is essential so that gentle active range of motion (ROM) of the cervical spine in ipsilateral rotation can stretch the scalene without rib elevation or cervical anterior shearing (**Fig. 24-5**). The patient should be instructed to avoid chronic postures of cervical flexion or neck ipsilateral side bending and contralateral rotation to avoid overuse of the muscle in the short range (e.g., using a mobile device or talking on the phone for prolonged periods without use of a hands-free accessory (**Fig. 24-6**).

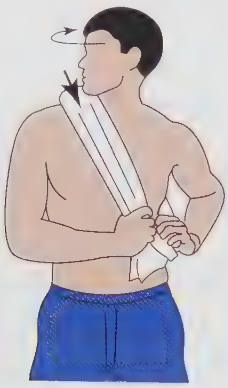


FIGURE 24-5 It is important to stabilize the first rib while stretching the anterior scalene. After the rib is stabilized, *gentle* active ROM into ipsilateral rotation stretches to the same side anterior scalene without undue cervical shear or first rib elevation.

Disuse Resulting in Atrophy and General Deconditioning

Disuse and deconditioning can be caused by illness, immobilization, sedentary lifestyle, or subtle shifts in muscle balance from repetitive faulty movement patterns. Progressive resistive exercises for the upper body can address general disuse and deconditioning. Initially, the weight of the limb alone can provide enough stimulus for strength gains in the severely deconditioned individual. Progression in small increments is recommended because the upper body muscles are small compared with those of the lower body, and excessive resistance added prematurely may promote muscle imbalance by strengthening the dominant synergists or antagonists (see Chapter 25). Abdominal and back extensor strengthening (see **Fig. 24-7**) may be indicated to improve the alignment, movement, and stabilizing function of the thoracic region (**Evidence and Research 24-3**). Chapter 17 describes proper exercise prescription for the abdominal muscles.

A B

FIGURE 24-6 Resting a telephone on an elevated shoulder with the neck in lateral flexion and opposite rotation can cause shortening and overuse of the anterior scalene muscle **(A)**. Prolonged neck flexion can lead to anterior scalene shortening **(B)**.

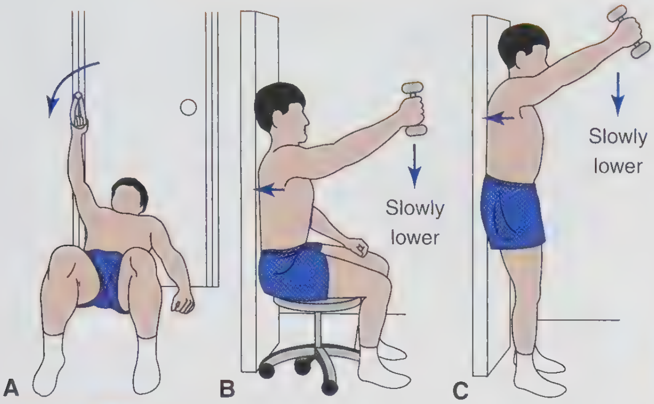


FIGURE 24-7 Activity promoting strength of the thoracic spine extensors in the short range in various start positions. In each position, the patient is instructed to maintain neutral cervical, thoracic, and lumbar spine positions using core activation strategies (see Chapters 18 and 24 for details on core activation strategies for the lumbar and cervical regions, respectively). Supine **(A)**, resisted upper extremity extension from a flexed position using elastic tubing. The thoracic extensors stabilize against the flexion moment. Sitting **(B)** and standing **(C)** upper extremity eccentric lowering from a flexed position stimulates thoracic extensor activity to stabilize against a flexion moment.

EVIDENCE and RESEARCH 24-3

Colado et al.[23] reported that maintaining a neutral posture alignment during exercises that stress the lower back can stimulate core-muscle activation as much or more than exercises involving stability devices.

Muscle function in response to injury has not been as well studied in the thoracic spine as it has in the lumbar spine. However, one can extrapolate lumbar findings to the thoracic spine in an attempt to make educated decisions regarding thoracic spine management (**Evidence and Research 24-4**).

EVIDENCE and RESEARCH 24-4

Many authors have highlighted the importance of the lumbar multifidus muscle in providing dynamic control,[24–27] and there is cumulative evidence that the cross-sectional area of the paraspinal muscles is smaller in patients with chronic[28–31] and postoperative low back pain.[32,33] Furthermore, it has been shown that recovery of multifidi muscle function in the lumbar spine is not automatic following resolution of the pain.[34] This atrophy may permit spinal hypermobility and instability and therefore be an important factor to consider in treatment of persons with spine-related pain.[35]

A study of cadavers found differences in position and mass between lumbar and thoracic multifidi, which may have implications for their function. Compared to the lumbar spine, the thoracic spine multifidi are deeper, thinner, and the fibers are more tendinous and oblique.[36] There is general consensus in the literature supporting the need for active reconditioning exercise in the treatment of spine pain.[37] Add to these findings the natural tendency toward kyphosis and forward shoulder posturing (because of the effects of gravity, aging, and habitual usage patterns), and it seems clear that thoracic extension strength and scapular stabilization should be an emphasis in any plan of care for the region. To improve the role of thoracic extensors and periscapular muscles in supporting posture, any exercise plan should be dosed so as to improve muscular endurance. Unfortunately, there is little agreement on which exercise regimens are most effective. The use of static stabilization training has been advocated[38] as an ideal means of improving the recruitment of back muscles capable of enhancing spinal stability, particularly the multifidus, obliques, and erector spinae (**Evidence and Research 24-5**).

EVIDENCE and RESEARCH 24-5

A study of 30 subjects with chronic low back pain found that pain and Oswestry disability index improved with lumbar stabilization combined thoracic extension exercises.[39] De Ridder et al.[40] observed thoracic and lumbar paraspinals had higher activation with trunk extension movements compared to leg movements and with movements that combined dynamic trunk extension (2 seconds for trunk extension) with a static hold for 5 seconds compared to dynamic trunk extension alone (2 seconds for trunk extension).

Though studies on scapular stabilization exercises are primarily focused on populations with shoulder pain or pathology, these studies also report improvements in posture, specifically in the position of the shoulder and head.[41–43] Postural dysfunction consisting of forward head and rounded shoulders is commonly noted in patients with thoracic pain.

This text describes a series of specific exercises to promote spine stability in Chapter 17 (see Patient-Related Instruction 17-1 and Self-Managements 17-1 and 17-2) and scapular stabilization in Chapter 25. The exercises presented in Chapter 17 can be extrapolated to the thoracic spine by adding the focus on thoracic spine alignment and thoracic multifidus activation. Progression of these exercises to use of thoracic paraspinals and periscapular muscles during ADLs and occupational and recreational activities are necessary for the best functional outcome.

Length-Associated Changes Resulting in Altered Length–Tension Properties

Causes Subtle imbalances in muscle length can lead to length-associated strength changes and positional weakness of one synergist compared with its counterpart or its antagonist muscle group. For example, in the thoracic spine, the erector spinae and upper rectus abdominis are susceptible to length-associated strength changes from chronic kyphotic posture. The thoracic erector spinae are vulnerable to overstretch while the anterior muscles such as pectoralis major, pectoralis minor, and upper rectus abdominis are susceptible to adaptive shortening. Overstretching and shortening can lead to conditions within the thoracic region such as joint impairments and respiratory dysfunction. Muscle imbalance can contribute to conditions in the adjacent cervical and lumbopelvic areas, and soft tissue dysfunction from the kyphosis-lordosis or swayback posture (see the section "Kyphosis").

Intervention Treatment of muscle length imbalance requires a twofold approach of strengthening the weak and overstretched muscle group (e.g., the thoracic erector spinae) in the shortened range (see **Figs.** 24-7 and **24-8**), while concurrently stretching adaptively shortened muscle groups (e.g., the upper rectus abdominis

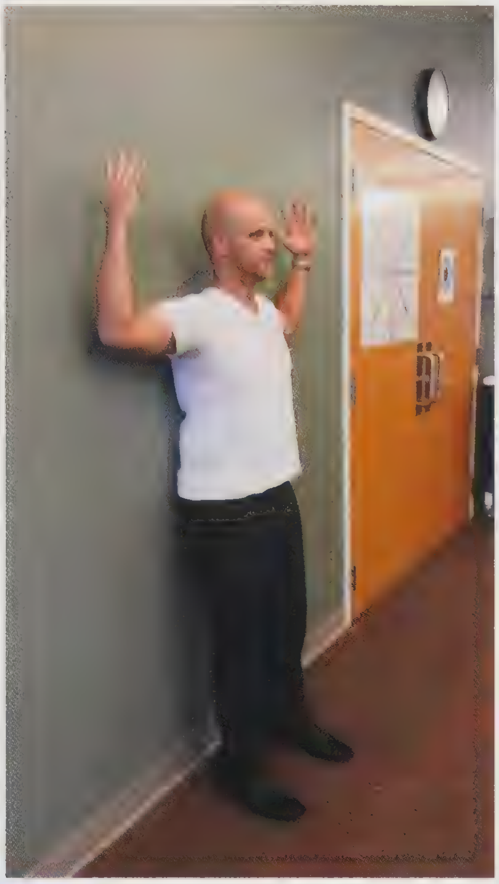


FIGURE 24-8 This exercise stretches superior fibers of the external oblique muscle at the rib angle and the shoulder adductors, and it provides resistance to the spine extensors and scapular upward rotators in the short range. Standing with the back to the wall in a neutral spine position, the patient raises her arms raised in horizontal abduction. The elbows are forward of the wall to maintain the arms in scapular plane. Deep diaphragmatic breathing is performed in this position. The arms can slide up the wall as the length of the pectoralis major allows. The lower abdominals contract to maintain the lumbar spine and pelvis in neutral alignment.

and pectoralis muscles). Supportive taping (see **Fig. 24-9**) can be used as an adjunctive measure to facilitate positive length-associated changes. Patient-related instruction aimed at correcting posture and movement patterns that perpetuate these length-associated changes is required to prevent recurrence of conditions caused by this muscle performance impairment. Instruction in appropriate ergonomic changes for computer or mobile device use is also necessary as use of technology is commonplace.

Impaired ROM, Muscle Length, and Joint Mobility/Integrity

Optimal function of the thoracic region requires full and symmetrical cardinal plane motion as well as combined motions. In addition, full thoracic spine and rib motion during breathing should be a goal. The examination should delineate joint versus soft tissue impairments, and the plan of care be designed appropriately. Lack of motion (hypomobility) can be the result of either joint or soft tissue impairments, and manual intervention will differ in each case (joint mobilization vs. soft tissue mobilization, for example). The exercise intervention, on the other hand, will typically address both causes simultaneously. Furthermore, improving thoracic mobility may restore length–tension relationships and allow more efficient strengthening of postural stabilizers. The general plan for excessive motion (hypermobility) is to stabilize with muscle function while addressing biomechanical factors, such as adjacent hypomobile areas, that transmit increased forces to, and produce excess motion in, the problem area. Finally, optimal function requires trunk stability during extremity movements. Therefore, appropriate thoracic exercise management will progress from active extremity movement to resisted extremity exercise, while demanding concurrent trunk stability.

Hypermobility

Causes A well-designed intervention plan for hypermobility of the thoracic spine must consider the mechanism or cause of the hypermobility. Spinal mobility must be examined both globally (e.g., the thoracic spine as a whole) and locally (e.g., segmentally). Optimal global spinal movement incorporates motion contributions from each spinal level. Lack of motion in one segment will transfer the mechanical stress to adjacent movement segments. The segments experiencing greater stress over time will become hypermobile. Tissue responses to the increased load may render the region symptomatic. In this case, intervention must address the local impairments. If the underlying cause is impairment in habitual posture or repetitive movement, the clinician must consider the integrated relationship between the foot and ankle, pelvic girdle, trunk, and upper extremity in developing a plan of care. If there is a history of macrotrauma but the expected healing time has been surpassed, the clinician must consider issues contributing to delayed or interrupted healing.

Interventions Regardless of the mechanism or cause of the hypermobility, central to the success of a program to improve stability of the thoracic spine is the concept that the trunk muscles must hold the vertebral column stable for independent upper and

A B

FIGURE 24-9 **(A)** Longitudinal tape spanning the kyphosis, applied in four-point kneeling to capture neutral spine alignment, can prevent excessive thoracic flexion. **(B)** Taping to inhibit scapular abduction and protraction, promoting neutral spine positioning of the scapulae.

lower extremity movement to occur. This role must be executed regardless of the speed of movement and any additional load the individual may be carrying. Spinal stability must be maintained without sacrificing adequate chest mobility necessary for respiration. Loads must be transferred from the ground upward in an efficient manner, and this can be done without cumulative microtrauma only if the forces are attenuated through an efficient kinematic chain from the foot and ankle upward through to the thoracic spine.

Improved Motor Control

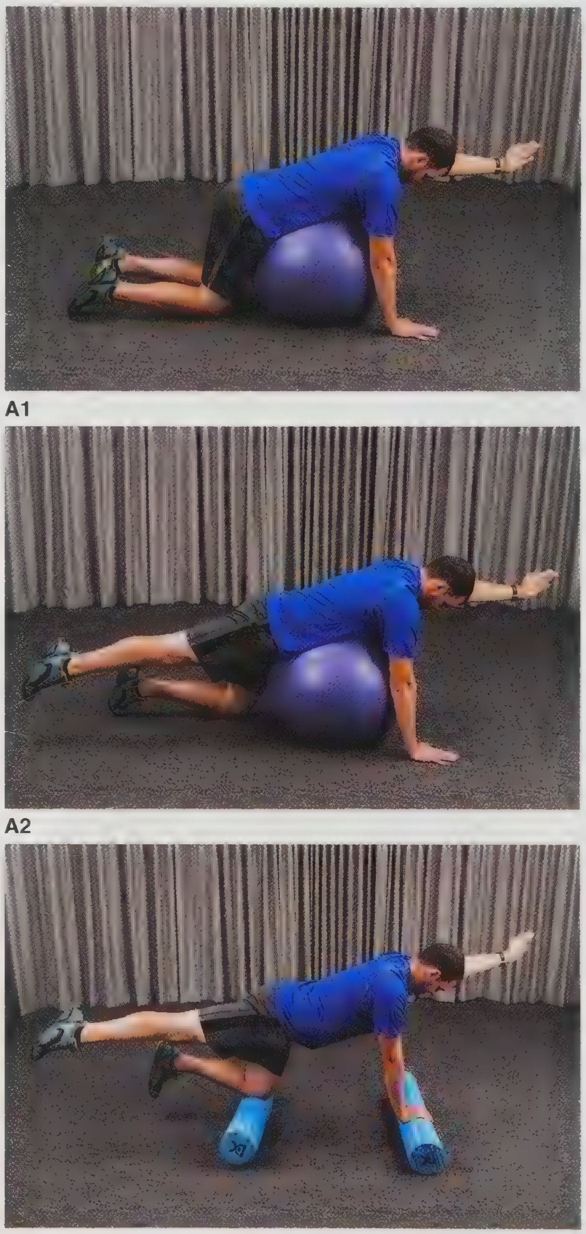
Intervention for hypermobility begins at the stability stage of motor control. Applying an axial load to the thorax and gauging the response can allow the estimation of ideal or optimal alignment in sitting or standing. In the optimal position, axial loading forces are distributed equally throughout the vertebral body and intervertebral disk. In symptomatic patients, the ideal alignment or "neutral spine" position will often allow asymptomatic axial loading. Additionally, in patients and clients alike, the therapist can feel the increased stability of the spine as the load is applied, as the spine does not give way into either flexion or extension. Specific motion segments that demonstrate hypermobility can be identified and exercises promoting stability can be prescribed. Exercises should target the single segment muscles, such as the multifidi, since multi-segment muscles like the semispinalis or iliocostalis promote multi-segmental motion. Since the primary action of the multifidus is rotation, resisted isometric rotation isolated to the hypermobile segment is a rational starting point. This can be initiated in sidelying with manual resistance. Home exercises can be performed using a straight-backed chair for stability and elastic band or tubing for resistance.

To progress the patient into the next stage, controlled mobility, movement is superimposed on a stable spine. The patient is instructed to hold the spine in ideal alignment during movements of the upper and lower extremity. The activity or technique chosen depends largely on the level of intensity the patient can sustain while maintaining ideal alignment with proper recruitment patterns. The prescribed direction of force imposed on the spine depends on the direction of the hypermobility. For example, a patient may present with difficulty in stabilizing against flexion forces such that, when the arm is lowered from a flexed position, the thoracic spine flexes instead of remaining in neutral alignment. A flexion force such as resisted (in some cases, using only the weight of the arm) or rapid upper extremity extension (from an overhead start position) can be used to challenge the spinal extensors. The exercises can begin in sitting with the back against the wall or in supine (see Fig. 24-7), and then progressed to standing. The former positions require stabilization of fewer regions than standing (i.e., sitting eliminates the need to stabilize the foot, ankle, knee, and hips), and the wall or floor provides proprioceptive feedback to enhance stabilization. Similar principles can be used in creating exercises to stabilize against rotational or lateral flexion forces.

As control of the hypermobile segment(s) improves, several variables can be adjusted to progress the difficulty of the controlled mobility exercises and make them more specific to the activity limitations and participation restrictions of the patient. For example, the speed of extremity movement can be altered based on the functional demands of the patient's work or lifestyle. Slow, controlled movements promote stability and endurance while faster movements such as catching a medicine ball promote fast recruitment.

Motor control and motor learning theory, based on findings in normal individuals,[44] suggests that altering the practice conditions and the amount, type, and scheduling of feedback is essential to optimal acquisition of motor skills. Accordingly, exercises and activities should be sequenced in a random fashion, rather than repeating the same activity. Feedback should be provided on an intermittent, rather than continuous, basis. Attention to these details will enhance skill acquisition.

Gymnastic balls, foam rolls, and balance boards can modify stabilization activities to provide a greater challenge by destabilizing the base of support (**Fig. 24-10**). The theory behind the



A1

A2

B

FIGURE 24-10 **(A1** and **A2)** These exercises use the labile surface of the gymnastic ball to stimulate balance and equilibrium reactions. The patient is instructed to maintain axial extension and neutral thoracic and lumbar spine alignment. Teach the patient cervical and lumbopelvic core activation prior to adding any arm or leg movements (see Chapters 18 and 24 for details on lumbar and cervical core activation strategies, respectively). **(B)** The foam rolls further destabilize the base of support.

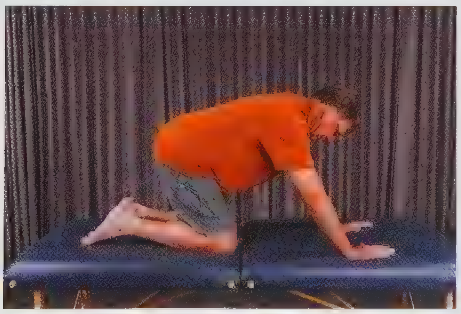
use of these pieces of equipment is that the labile base of support stimulates balance and equilibrium reactions. Continuous postural adjustments are required, facilitating smooth coordination of posture and movement. Care must be taken to ensure that the patient employs proper trunk stabilization strategies when using equipment that destabilizes the base of support.

Adjacent Areas of Hypomobility

Difficulty stabilizing against flexion forces is a common problem for the thoracic spine. The therapist must consider that excessive thoracic flexion may occur because of lack of mobility in related regions. For example, in sitting, a decrease in hip flexion mobility may be compensated for by thoracic flexion with forward-reaching or forward-bending movements. Four-point kneeling with a sit-back movement (**Fig. 24-11**) can promote hip flexion mobility and thoracic spine stability. This movement pattern must eventually be transferred to controlled mobility and skill level activities in sitting and standing positions, such as reaching forward with hip flexion while maintaining neutral spine position (**Fig. 24-12**).

Another common cause of excessive thoracic spine motion is lack of thoracic and hip rotation combined with excessive shoulder girdle protraction. For example, in cross-body reaching tasks, the elbow extends and the shoulder flexes and horizontally adducts until the full length of the arm has been reached. If further reach is required, the thoracic spine should rotate, followed by lumbar spine and hip joint flexion and rotation. If standing, a step toward the object can increase the reach span. The arm can effectively reach across the body if the scapula provides a stable base for arm movement and the thorax provides a stable base for the shoulder girdle. This movement requires appropriate recruitment and length–tension properties of the scapulothoracic, glenohumeral, spinal extensor, and oblique abdominal muscles. There must be ample mobility in the glenohumeral joint for upper extremity horizontal adduction and in the thoracic spine and hip joints for rotation. A prevalent faulty movement pattern is to reach instead with scapular abduction and thoracic flexion (**Fig. 24-13**). Impairments in the shoulder girdle, thorax, and hips may need to be addressed separately to improve the movement pattern of cross-body reaching and thereby reduce the tendency toward excessive thoracic flexion. One useful activity to retrain independent motion among the upper extremity, thoracic spine, and hip joints is shown in **Self-Management 24-1**. The prerequisites for correct performance of this exercise are proper movement patterns at the scapulothoracic, glenohumeral, and hip joints (see Chapters 19 and 25).

A



B

FIGURE 24-11 In four-point kneeling, the patient is instructed to maintain neutral spine position while rocking back toward the heels (**A** and **B**). At the point of hip flexion stiffness, the tendency is to flex in the lumbar and/or thoracic spine. The patient is instructed to stop at the onset of spine flexion.

A

B

FIGURE 24-12 **(A)** The standing subject reaches forward with excessive thoracic flexion. **(B)** The movement pattern is altered such that flexion takes place at the hips, knees, and shoulder, and the thoracic spine remains in neutral.

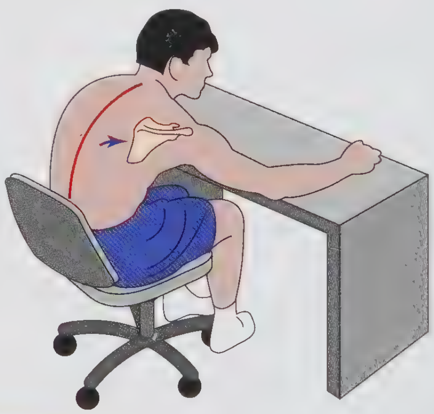


FIGURE 24-13 A prevalent movement pattern is to reach with scapular abduction and thoracic flexion.

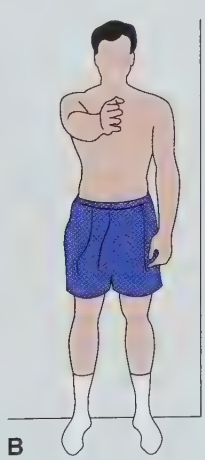
SELF-MANAGEMENT 24-1
Cross-Body Reaching

Purpose: To promote independent motion of the shoulder joint from the shoulder blade, torso, and hip. You should not progress to the next level without mastering the previous level. Use the movement pattern acquired in Level 4 (noted below) when reaching across the body for an object farther away than the span of the arm. Avoid reaching by moving your shoulder blade or flexing in your thoracic spine excessively.

Starting Position: Stand, facing away from the wall, with feet about two in away from the wall and the pelvis and spine in neutral. If your hip flexors are short or stiff, you may need to flex your hips and knees to achieve a neutral spine and pelvis position.

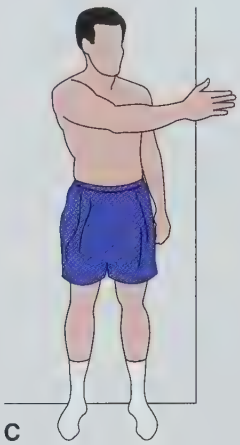
A

Movement Technique: **Level I:** Move your arm across your body to the midline without letting your shoulder blade move from its starting position. This may require a submaximal contraction of your interscapular muscles.



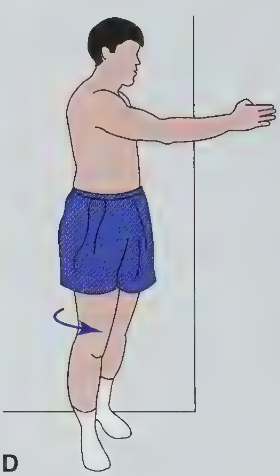
B

Level 2: After you can reach your arm to the midline of your body, rotate your torso as far as you can without moving at the hips, knees, ankles, or feet. Do not move your shoulder blade from its starting position. Do not let your thoracic spine flex; *rotate* it.



C

Level 3: After you have mastered independent rotation of your torso, add hip rotation to the movement. Do not move your feet from the starting position (i.e., do not take a step forward, but allow your ankles and feet to rotate naturally with hip rotation). Do not move your shoulder blades from the original position or allow your thoracic spine to flex forward.

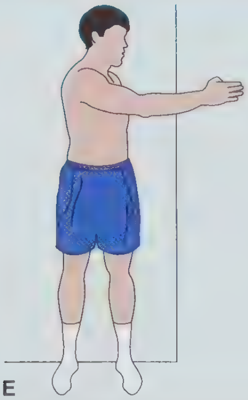


D

Level 4: After you have performed rotation sequentially at the torso and hips, take a step diagonally forward across midline of your body. Do not let your shoulder blade move from its starting position, but achieve a greater reach by stepping across your body.

(*continued*)

SELF-MANAGEMENT 24-1
Cross-Body Reaching *(continued)*


E

Dosage:

Repeat: ______________________________ times

Sets: ______________________________

Frequency: ______________________________

Variations: ______________________________ After a wall is no longer required for feedback, a pulley or elastic can be used to resist the movement pattern.

______________________________ Increase the speed of the movement.

______________________________ Add a weight in your hand.

External Support

Treatment of hypermobility in the thoracic spine may also include supportive devices such as a posture brace (to prevent thoracic flexion; **Fig. 24-14**) and taping. Taping can be used to facilitate and remind against excessive flexion and rotation (Fig. 24-9) and to retrain appropriate scapular positioning (inhibit protraction). As proprioception, strength, endurance, and control improve, the patient can be weaned off the supportive devices.

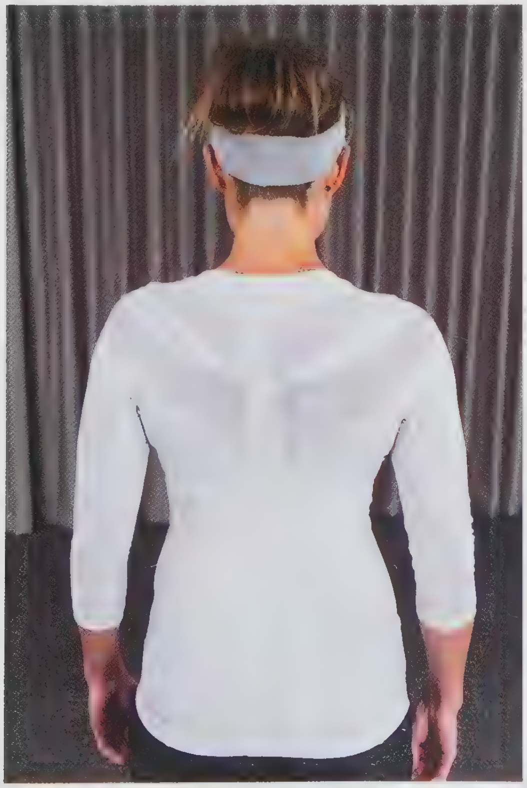


FIGURE 24-14 A posture brace or garment can be used to control excessive thoracic flexion.

Hypomobility

Impaired mobility of the thoracic spine and ribs may manifest as dysfunctions in other regions (**Evidence and Research 24-6**).

EVIDENCE and RESEARCH 24-6

Patients with cervical pain can have decreased pain and increased ROM after manipulation of the thoracic spine.[20,21] The last degrees of end-range shoulder flexion require thoracic extension and rotation; improving thoracic mobility has been shown to decrease shoulder pain.[19] Lumbar spine pain may result from excessive lumbar mobility that is related to relative thoracic hypomobility.[21]

In addition, poor thoracic spine and costovertebral mobility can remain asymptomatic while anteriorly pain can develop at the costosternal joints, resulting in costochondritis. Poor thoracic spine and rib mobility will result in decreased chest expansion and therefore decreased lung capacity. This can result from disease processes such as ankylosing spondylitis,[45] from structural deformities such as scoliosis, or from habitual postures such as seen in the patient with Parkinson's who spends most of his time sitting in flexion. Because of gravity, the tendency is to sit in a flexed posture; therefore, restrictions in extension mobility and a relatively fixed kyphosis are typical findings on examination (see **Building Block 24-1**).

BUILDING BLOCK 24-1

Consider the patient with Parkinson disease in Case No. 3, Display 24-1. You are finding it difficult to hear the patient because of low vocal volume. Describe one postural change and two exercises that would likely improve the patient's vocalization.

Causes Hypomobility can result from pain or altered tone, restrictions in neural or dural mobility, trauma-inducing osteokinematic restriction, degenerative joint changes, disease processes, or generalized stiffness in the joints or myofascial tissues from self-induced or externally induced immobility. Self-induced immobilization can result from pain or repetitive altered movement patterns. Repetitive altered movement patterns can produce sites and directions of relative mobility and concurrent sites and directions of hypomobility. For example, the movement strategy of scapular abduction and thoracic flexion to reach across the body can lead to hypomobility in thoracic rotation. One must consider the effect that postoperatively induced immobility, such as open heart surgery or mastectomy, has on the mobility of the thoracic cage[46] (**Evidence and Research 24-7**).

EVIDENCE and RESEARCH 24-7

Hanuszkiewicz et al.[46] proposed that breast cancer treatment may be a cause of postural dysfunction. They reported significant reductions in thoracic kyphosis and lumbar curvature in post-breast cancer treatment with fitness walking, using poles for postural support as compared to general fitness activities.

Hypomobility can be caused by limitations in myofascial length or mobility. In the case of myofascial restriction in the absence of articular hypomobility, correlating articular glides are normal, but osteokinematic motion is limited in rotation. For example, restriction in right rotation can indicate short or stiff right external and left internal oblique muscles. Hypomobility of the thoracic spine can also be found in relation to breathing, with reduced movement in pump or bucket handle breathing mechanics.

Intervention Patients with long-standing joint mobility restrictions are likely to develop myofascial restrictions, requiring concurrent intervention to both. Treatment of joint restrictions usually requires joint mobilization techniques, and treatment of myofascial tissue requires passive stretching, active ROM exercises, or both. Therefore, to maintain mobility gained with joint mobilization techniques, it is important to teach the patient a self-management exercise program that includes a passive stretch, active ROM exercise, or both. Functional movement patterns should be learned that reinforce the mobility gained through mobilization and specific exercise.

A clinical example may best illustrate this point. A patient presents with left rotation and left lateral flexion restrictions in the thoracic spine at the T7 segmental level. The examination determines that this restriction is articular. The appropriate joint mobilization technique is performed to restore the arthrokinematic glide.[2,3] To maintain the mobility gained, the patient is instructed to perform specific midthoracic lateral flexion, blocking motion at the relatively hypermobile segments below T7, to facilitate motion at the stiff segmental level (**Fig. 24-15**). Repeated thoracic left rotation can also be instructed (**Fig. 24-16**). The patient should be instructed to use left rotation of the thoracic spine frequently throughout the day to further facilitate maintenance of articular mobility. All exercises should be done with high repetitions (up to 20 times) and frequently throughout the day (up to 10 times), and in the pain-free range to prevent aggravation of symptoms.

Proper diaphragmatic breathing is essential to the treatment of numerous impairments in the thoracic spine and related regions (see Chapters 17 and 22). The Patient-Related Instruction 24-1 describes proper diaphragmatic breathing, with an emphasis on pump and bucket handle breathing. After

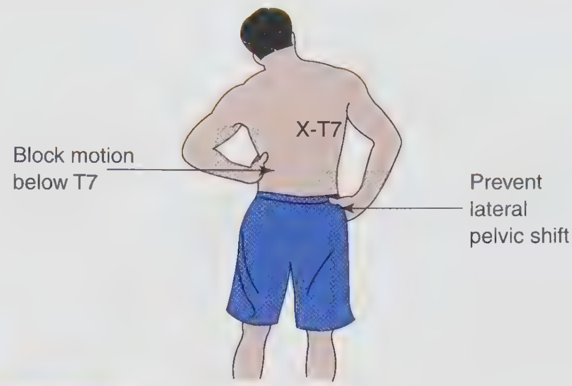


FIGURE 24-15 Left thoracic spine lateral flexion can be encouraged at T7 by blocking excessive lateral flexion below T7.

FIGURE 24-16 Holding onto a light dowel rod can encourage thoracic rotation by keeping the dowel rod level while rotating the torso. The patient is instructed to rotate the sternum. Lower segments can be stabilized by keeping the lower back flat against the back of the chair.

mastering diaphragmatic breathing in a supine position, the patient should progress to sitting and standing while applying the same breathing techniques. The ability to maintain diaphragmatic breathing in different postures is important in isolation, but should also be emphasized during exercise and functional activity (**Evidence and Research 24-8**).

EVIDENCE and RESEARCH 24-8

In older adults, aerobic conditioning may provide significant improvements in spinal mobility, physical function, and overall health.[47] The effects of a 3-month supervised program of spinal flexibility and aerobic exercises was compared to one with aerobic exercise alone on axial rotation, maximal oxygen uptake ($\dot{V}O_2$ max); functional reach, timed bed mobility; and the Physical Function Scale (PhysFunction) of the Medical Outcomes Study SF-36. Both groups improved in all measures although there was no difference between the groups, suggesting that for this population either type of exercise would be beneficial.

Muscle/Myofascial Length

Specific myofascial tissue length impairments may promote poor thoracic mobility and can be assessed via muscle length testing of each muscle. Commonly impaired muscles include

FIGURE 24-17 Rotation stretch for short or stiff right external and left internal oblique muscles.

the pectoralis major and minor, rectus abdominis, and oblique abdominals (limit extension); the paraspinals and the more lateral iliocostalis (limit flexion); and the intercostals, which can limit motion in all directions. Specific soft tissue mobilization and longitudinal stretching techniques are often necessary to restore full mobility but must always be followed by exercises aimed at maintaining the new mobility. Additionally, the patient must work to maintain the newly achieved length in daily postures and activities, which may involve changing major postural habits.

Restrictions in oblique abdominal muscle length can limit thoracic rotation. In the case of myofascial restriction in the absence of articular hypomobility, correlating articular glides are normal, but osteokinematic motion is limited in rotation. Restriction in right rotation can indicate short or stiff right external and left internal oblique muscles. A passive stretch (**Fig. 24-17**) can be used in conjunction with diaphragmatic breathing (see Patient-Related Instruction 24-1) into the right thoracic rib cage. Lying on a foam roller can increase the stretching force. Postural habits and repetitive movement patterns must be analyzed for potential causes of myofascial restrictions. Comprehensive treatment may include changing the ergonomics of the workstation to reduce factors contributing to myofascial restrictions (e.g., rearranging the workstation to reduce sustained and repeated left rotation and promote occasional right rotation). The patient's movement patterns and activities may need to be altered to limit repeated left rotation and promote more activities requiring symmetric rotation. For example, the patient should reduce the time spent playing tennis (an asymmetric activity) and begin walking, jogging, biking, or swimming (symmetric activities) (see **Building Block 24-2**).

BUILDING BLOCK 24-2

Consider the buggy-driving patient in Case No. 1, Display 24-1. This patient, like many large equipment operators, spends much of his day rotating to one side because of the nature of the traffic flow. He is having pain when rotating to the left, the direction he must turn to most frequently at work. Provide some recommendations for his work and leisure activities as well as exercise intervention choices.

Patients who have undergone surgery such as a coronary artery bypass graft (CABG) or mastectomy[47] will develop thoracic spine and rib hypomobility if not exercised properly. Early exercises should focus on maintaining deep inspiration ROM as tolerated by the patient. Diaphragmatic breathing will also assist in lymphatic drainage post-mastectomy. Gentle stretching of the chest musculature should be undertaken, within the confines of postoperative precautions. In general, precautions would follow the typical stages of healing; excessive stretching and resisted exercises that stress the involved musculature and their associated joints should be avoided until such time as allowed by postoperative protocols and the appropriate phases of healing. For example, pectoralis major strengthening after a CABG should not take place until the sternum has healed. As the surgical incisions heal, shoulder ROM exercises should be introduced, gradually progressing to full arcs of motion and adding resistance (Fig. 24-8).

Pain

Pain in the thoracic region has many possible causes or mechanisms. The onset of pain may be the result of joint dysfunction (i.e., thoracic vertebrae or rib articulations), soft tissue injury or strain, or of non-visceral (e.g., osteoporosis, ankylosing spondylitis, Scheuermann disease) or visceral diseases (see Appendix 1).

Treatment must focus on the cause or mechanism of the pain. This chapter provides a theoretical framework and clinical examples of exercises used to alleviate impairments that could be contributing to the causes and mechanisms of musculoskeletal pain.

Impaired Posture and Motor Function

Optimal postural alignment is discussed in detail in Chapter 9. As noted previously, it is important to distinguish between postural faults that are due to permanent changes in the structure of the spine and those that are amenable to change. The impairments of body structures common to the thoracic spine were discussed earlier. This section will address the nonstructural impairments of posture, which are amenable to change.

Head posture is contingent upon thoracic posture which in turn is dependent on the lumbar spine, pelvis, and lower extremities. In addition, as noted earlier, full motion of the upper extremity requires thoracic mobility. Therefore, all aspects of the kinetic chain must be examined and evaluated.

Kyphosis

Causes Postural kyphosis is caused by habitual trunk flexion, for which there are several reasons. An individual with poor postural habits, such as a student who spends most of her time sitting in class in a flexed posture, is likely to develop a kyphosis. Weak trunk extensors can exacerbate already poor posture. A dominant daily activity that encourages thoracic flexion, for example use of a laptop or other mobile devices such as cell phones and tablets, will likely encourage a kyphotic spine. Finally, there are diseases that tend to manifest with thoracic kyphosis as a secondary complication. Parkinson disease is an example of one such disorder, in which there is a lack of movement into extension, and is discussed later in this chapter.

Intervention Any plan of care for kyphosis must consider the structural impairment and pathology in addition to the related impairments in body function. **Display 24-5** lists potential impairments of body functions associated with kyphosis, and **Table 24-1** lists general exercise recommendations to address these impairments.

DISPLAY 24-5

Impairments of Body Functions Associated with Kyphosis

Alignment

Forward head
Cervical lordosis
Abducted and protracted scapulae

Kyphosis-lordosis: Lumbar lordosis, anterior pelvic tilt, hip joint flexion, knee joint hyperextension, ankle plantar flexion
Swayback: Lumbar flexion, posterior pelvic tilt, hip joint hyperextension, knee joint hyperextension, neutral ankle

Kyphosis-Lordosis	Swayback
Short and Strong*	**Short and Strong***
Neck extensors	Hamstrings
Hip flexors	Upper fibers of internal oblique
Lumbar spinal extensors	
Shoulder adductors	Shoulder adductors
Pectoralis minor	Pectoralis minor
Intercostals	Intercostals
Elongated and Weak	**Elongated and Weak**
Neck flexors	Neck flexors
Upper back spinal extensors	Upper back spinal extensors
External oblique	External oblique
Hamstrings	One-joint hip flexors
Middle and lower trapezius	Middle and lower trapezius

**Findings associated with short muscles must be tested by muscle length and manual muscle tests, because not all muscles held in short positions develop shortness.*

Although diseases such as osteoporosis and Scheuermann disease cause structural changes in the vertebrae that create the kyphosis, postural habits and movement patterns can exaggerate the posture impairment. Although exercise cannot correct the structural changes that have occurred in the vertebrae, it can positively influence physiologic factors that exaggerate the kyphosis. Only through a comprehensive program of exercise and patient-related instruction can these contributing factors be properly addressed.

In patients without a structural kyphosis in whom lack of extension ROM is the primary impairment, manual joint and soft tissue mobilization is a key part of successful management. In addition, trigger-point dry needling is another method to achieve soft tissue mobility; early studies show promising results for the utilization of dry needling in treatment of thoracic spine pain.[48–50] Joint mobilization techniques are described and discussed in Chapter 7. Often a kyphotic posture is associated with shortened soft tissues on the anterior aspect of the thorax. Soft tissue mobilization and manual stretching of the pectoralis major and minor is often required, followed by a home stretching program (Fig. 24-8).

Patient-related instruction is indicated to improve posture alignment and avoid positions that contribute to the kyphosis. Support to the lower back may be indicated to help relax the musculature holding the spine in lordosis in the lordosis-kyphosis posture, and a shoulder support such as a figure 8 strap may be indicated to stretch anterior structures while positioning posterior musculature in a proper position (see Fig. 24-14). As illustrated by Table 24-1, exercise prescription for the treatment of kyphosis oftentimes goes well beyond strengthening the thoracic erector spinae. The thoracic spine must function as part of a kinematic chain, and treatment of impairments in each region influencing the kyphosis is indicated. Specific, isolated exercises must progress to functional movements meaningful to that patient. For example, a patient with Scheuermann disease with a desk job needs to maintain a neutral spine when working. As such, the patient would benefit from learning to lean forward and backward from the hip joints ("hip hinge") while maintaining a neutral spine. Thinking about the distance between the symphysis pubis and the base of the sternum and keeping this distance constant during forward and backward

TABLE 24-1

Therapeutic Exercise Management for Kyphosis

STRETCH	STRENGTHEN
Kyphosis	
Cervical spine extensors (see Figs. 23-14 and 23-15)	Cervical spine flexors (see Display 23-1)
Intercostals (see Figs. 24-3 and 24-8)	Thoracic spine extensors (see Fig. 24-7)
Lumbar spine extensors (see Fig. 24-11)	
Pectoralis minor, shoulder adductors (see Fig. 24-8)	Middle and lower trapezius (see Self-Management 25-2)
Lordosis	
Lumbar spine extensors (see Fig. 24-11)	External oblique (see Self-Management 17-1)
Hip flexors (see Self-Management 19-9)	Hip extensors (see Self-Management 20-1)
Swayback	
Intercostals (see Figs. 24-3 and 24-8)	External oblique (see Self-Management 17-1)
Hamstrings (see Fig. 19-20A and Self-Management 19-7)	Hip flexors (see Self-Management 19-5)

movements at the hip joints can be useful in changing movement patterns that promote thoracic flexion.

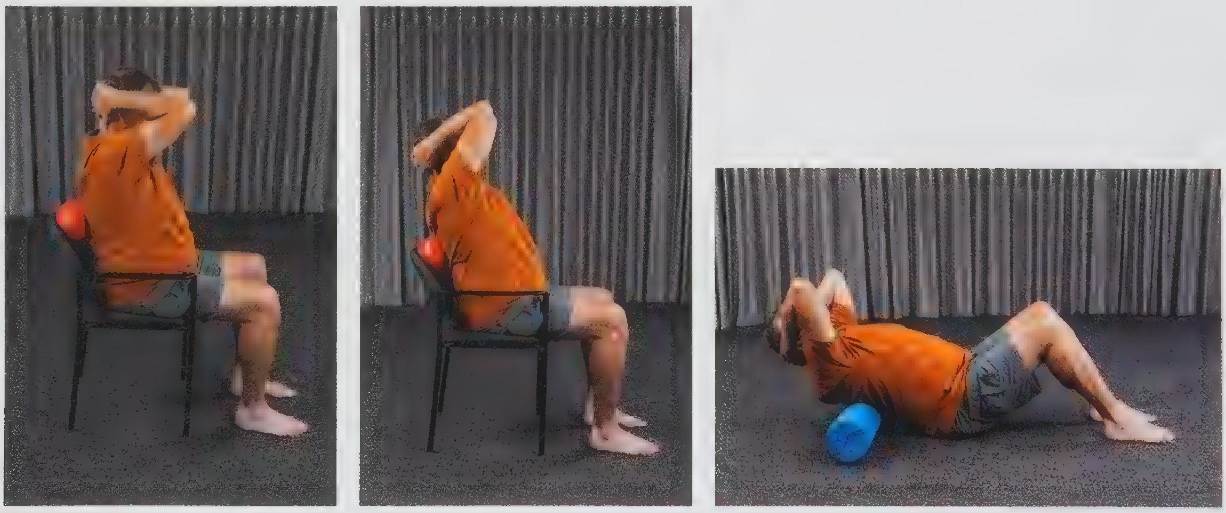
Home exercises that promote extension throughout the thoracic spine may be beneficial. However, if the patient presents with specific hypomobile segments adjacent to hypermobile segments, the patient must be instructed how to segmentally mobilize hypomobile segments while protecting areas of hypermobility. As such, a global approach may exacerbate hypermobile segments, because the hypomobile segments resist movement and transfer the motion to the segments that move easily. It is therefore important to utilize self-management exercises that target the stiff segments while protecting the mobile ones. **Figure 24-18A** to **C** illustrates a progression of effective self-mobilization techniques.

Throughout all these mobility exercises, deep breathing should be emphasized, to incorporate chest mobility. As with the use of tennis balls, the key subsystem in this exercise's potential for success is maintaining the mobilization for a sufficient amount of time (1 minute per segment to start), being consistent (every day without fail), and staying with the program (2 to 4 months). Considering that gravity is forcing the thoracic spine into flexion every second of every day that the patient is upright, encouraging extension 10 minutes per day seems a paltry amount of time in comparison. Asking for more time than this, however, risks losing the patient's compliance. The patient may fare better with dividing the exercise program into parts of the day as a practical strategy for preventing and managing symptoms.

Taping the thoracic spine for proprioceptive feedback and as a reminder to avoid flexion postures is a powerful, inexpensive biofeedback tool. The patient is asked to assume a quadruped position with the thoracic spine in neutral. The tape is applied along the paraspinal region on each side and spans several segments above and below the hypermobile segment or "hinge point" (Fig. 24-9A). Each time the patient flexes from this area the tape will provide proprioceptive feedback in the form of a pull on the skin, reminding the patient to stay in more extension. This type of feedback is very successful when used during symptomatic activities, alerting the patient to how often they are flexing the spine. Similarly, taping to limit scapular protraction and abduction may be helpful (Fig 24-9B). Cue the patient to sit tall (neutral spine) and pull their shoulder blades down and back (adducted and retracted). The tape is applied over the scapula and toward the lower contralateral ribs, in the direction of adduction. This method is a helpful reminder for appropriate scapular position in a neutral spine. Leaving the tape on for several hours at a time helps to counteract the constant force of gravity compressing the spine into flexion. The use of tape is gradually decreased as the patient develops improved awareness and the endurance necessary to actively maintain optimal posture. The benefit of taping over a postural brace is that patients will be more comfortable without anterior chest compression or shoulder discomfort from a brace. This allows the therapist to treat wider variations in body types with minimal cost.

Finally, exercises to address kyphosis need to be prescribed that address muscle performance impairments in the thoracic extensors and in the shoulder girdle complex. This is described in the section on "Muscle Performance Impairment."

Intervention in Patients with Scheuermann Disease In patients with Scheuermann disease, intervention is usually limited to patients with a painful deformity, documented progression, and at least 2 years of growth remaining. Younger children with a mild deformity can be initially treated with a program of exercise to strengthen spinal extensor muscles (see



A B C

FIGURE 24-18 A self-management exercise can be used to mobilize stiff segments in the thoracic spine. A single ball can be placed mid-back in sitting **(A)**. The patient is seated with a small ball positioned at the mid-back and against a chair. Have the patient support the neck and head by clasping the hands together at the back of the head. Instruct the patient to reach the elbows toward the ceiling while extending the thoracic spine over the ball. Active trunk extensors are used to improve thoracic mobility **(B)**. A more advanced progression involves the use of a foam roll on the floor. Lying on the foam roll with it positioned horizontally encourages extension of the thoracic spine but also serves to mobilize the ribs. If positioned in the hook-lying position, rolling the knees to one side encourages trunk rotation. With the roll positioned at 45 degrees, mobilization into extension and rotation is possible **(C)**.

Fig. 24-7) and stretch the hamstrings (see Self-management 19-7), pectoralis major (see Fig. 24-8), superior fibers of the rectus abdominis muscles and anterior longitudinal ligament (see Self-Management 17-7, level II, in Chapter 17) (**Evidence and Research 24-9**).

EVIDENCE and RESEARCH 24-9

Though there is a paucity of research into the effect of spinal exercise on spinal parameters in Scheuermann disease, one study did demonstrate the beneficial effect of regular exercise.[51] During a 12-month study of 103 patients with Scheuermann disease, Somhegyi et al.[51] observed that patients who exercised regularly demonstrated no increase in kyphosis and increased finger to floor distance compared to patients who did not participate in regular exercise. The inactive patients showed a small but significant increase in kyphosis and no change in finger to floor distance.

In adolescents, Scheuermann disease is effectively managed with bracing until skeletal maturity is attained (see the section "Scoliosis"). Contraindications to brace treatment include curves >70 degrees, severe apical wedging, and a rigid curve. Surgery (spinal fusion) is considered as an option for patients with severe deformity and disabling pain; surgical intervention is necessary in cases of neurologic compromise. At any stage in life, management of the resulting kyphosis can be effective in preventing increased postural kyphosis overlaid over the anatomic kyphosis (see the section "Kyphosis").

Scoliosis

Causes Nonstructural scoliosis may result from highly repetitive, asymmetric activities related to hand dominance. A common pattern of muscle imbalance and alignment changes for right-handed individuals is pictured in **Figure 24-19**. The therapist should be aware of the postural habits of a child in various positions such as sitting, standing, and lying, because

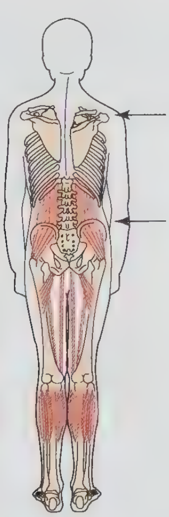


FIGURE 24-19 In a typical dominant right-hand pattern, the right iliac crest is high and the shoulder low. The darkly shaded muscles can develop adaptive shortening, while the lightly shaded muscles can develop adaptive lengthening. (From Kendall FP, McCreary EK, Provance PG. Muscles: Testing and Function. 4th Ed. Baltimore, MD: Williams & Wilkins, 1993:89.)

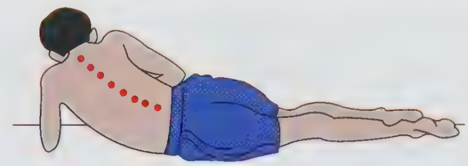


FIGURE 24-20 Children sometimes assume a sidelying position on the floor or bed to do their homework. A right-handed person lies on the left side so that the right hand is free to write or turn the pages in a book. Such a posture places the spine in a left convex curve.

FIGURE 24-21 Sitting on one foot (the left in this illustration) causes the pelvis to tilt downward on the left and upward on the right. This places the spine in a left convex curve.

childhood habits persist into adulthood. A right-handed child may sit at his desk to write in right lateral flexion. If this posture is also assumed in sidelying to perform homework (**Fig. 24-20**), sitting (**Fig. 24-21**), and to carry a backpack slung over the right shoulder, he is prone to develop muscle imbalance problems that can lead to acquired scoliotic deviations of the spine that persist into adulthood.

The pronation of one foot, standing on one leg, or standing with the same knee always bent (these habits often occur together) can contribute to the development of acquired scoliosis. The imbalances in hip musculature, faulty foot alignment, or knee position that result in lateral pelvic tilt are more closely related to primary lumbar or thoracolumbar curves than to primary thoracic curves.

Intervention To develop a comprehensive approach to treatment, a comprehensive musculoskeletal evaluation must be performed. The evaluation should include the tests and measures described in **Display 24-6**. Exercises should be carefully selected on the basis of the examination findings. The general principles of exercise prescription for patients with scoliosis are listed in **Display 24-7**. Exercises to be avoided by individuals with scoliosis include those listed in **Display 24-8**. An alternative exercise is shown in **Self-Management 24-2**. Exercises for muscle imbalances associated with acquired scoliosis have been described previously.

Patients with mild scoliotic curves often do not require treatment, as long as the curve does not progress. Periodic observation is required to make sure the degree of curvature is not increasing. After skeletal maturity has been reached, a curvature (as measured by the Cobb method) of <25 degrees[52] to 30 degrees[53] typically does not progress. In the patient with

DISPLAY 24-6

Tests and Measures Included in a Scoliosis Evaluation

Posture Alignment

- Plumbline views (anterior, posterior, and lateral)

Muscle Length Tests

- Hip flexor (differentiating psoas from tensor fascia lata, rectus femoris, and sartorius)
- Hamstrings
- Standing forward bend for length of posterior muscles
- Tensor fascia lata–iliotibial band
- Teres major and latissimus dorsi

Muscle Strength Tests

- Back extensors
- Abdominal muscles (differentiating trunk curl from pelvic stabilization roles)
- Lateral trunk
- Oblique abdominals
- Hip flexors
- Hip extensors
- Hip abductors (differentiating posterior gluteus medius)
- Middle and lower trapezius

Movement

- Forward bending to determine a structural curve and the location of the curve

DISPLAY 24-7

Principles of Exercise Prescription for Scoliosis

- Symmetric exercises should not be attempted.
- If one group or one muscle within a group is too strong for its antagonist or synergist, that muscle or group should be stretched, and the weaker, longer antagonist or synergist should be strengthened and supported to provide balance to the region.
- The lateral and anterior abdominal muscles, pelvic girdle, and leg muscles usually have asymmetric strength, causing the body to deviate about all three planes of motion with the transverse and frontal planes affected the most. Because the posterior spinal muscles are relatively less affected, the program should emphasize promoting strength of the relatively weak muscle or groups of muscles in the anterior thoracolumbar region and the pelvic-hip complex.

DISPLAY 24-8

Exercises to Avoid in Treating Scoliosis

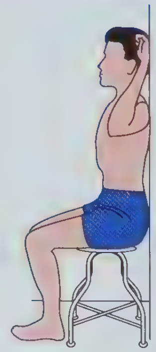
- Exercises that promote flexibility of the spine should be avoided without counterbalancing exercises or support promoting opposing shortening and strength to maintain corrections.
- A subject who is also developing kyphoscoliosis should avoid back extension exercises performed in prone because it promotes further lumbar extension (Self-Management 24-2).
- Trunk curl exercises or sit-ups should be avoided even if the rectus abdominis and internal oblique muscles are weak, because thoracic flexion promotes kyphosis (see Chapter 17 for alternative methods of abdominal strengthening).

SELF-MANAGEMENT 24-2

Postural Exercise with Back to Wall

Purpose: To reduce the tendency for excessive mid-back forward flexion and forward shoulder posture. After this exercise is mastered in sitting, it can be progressed to standing.

Starting Position: Sit on a stool with the lower back nearly flat against the wall. You should be able to fit your hand behind your lower back if your spine is in optimal position. If you have an exaggerated upper and mid-back curve, you may have a larger space between the wall and your back. Try to reduce this space as much as possible by contracting your lower abdominal muscles. *Caution:* Do not let your upper and middle back forward flex more in an attempt to reduce the curve of your lower back. (Note: this exercise can be modified to be performed in supine.)



A

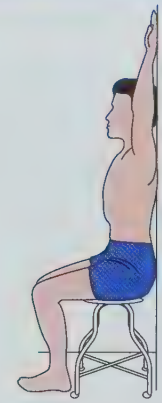
Press your head back with your chin tucked down. If you have an exaggerated curve of your

SELF-MANAGEMENT 24-2
Postural Exercise with Back to Wall (*continued*)

upper or middle back, you may not be able to get your head to the wall. Place one or two towel rolls behind your head with your head as close to the wall as possible and with your eyes and nose positioned horizontally. *Caution:* Do not let your chin rise upward in an attempt to get your head closer to the wall.

Place your thumbs on the wall with your elbows pointing slightly forward. If you have an exaggerated curve of your upper or middle back, you may not be able to get your thumbs to the wall (**Fig. A**).

Movement Technique: Keep your thumbs in contact with the wall; keep your head and low back in the starting position, and slide your arms to a diagonal position overhead. When your head or low back deviates from the start position or your shoulders shrug excessively, stop the movement (**Fig. B**).



B

Dosage:

Repeat: ______________________ times

Sets: ______________________

Frequency: ______________________

an immature spine, if the curve is between 25 and 40 degrees, there is a high risk of further progression. These patients need to be treated using a brace, which in 70% to 80% of the cases will prevent further progression[52] (**Evidence and Research 24-10**).

EVIDENCE and RESEARCH 24-10

In one study, a brace worn 16 or more hours each day was shown to be effective in preventing 90% or more of the curves from progressing, particularly mild curves of 25 to 35 degrees.[54]

Most authorities recommend wearing the brace for 23 hours each day, because using it part time can create compliance problems. When wearing the brace is an established part of a daily routine, it becomes a standard function. However, the brace cannot correct a curve; it can only prevent it from worsening. In adults, the curve may progress slowly over years, and bracing may not be a practical solution.

Early detection and intervention is the key to the treatment of scoliosis. A few carefully selected exercises that help to maintain muscle balance and a kinesthetic sense of good alignment are recommended over a vigorous, complex program. This means providing good patient-related education about how to avoid habitual positions and activities that can increase the curvature. It also means providing incentives that help keep the child, adolescent, or adult interested and motivated in an ongoing program.

The use of exercise in the management of scoliosis is controversial. Muscle imbalance that exists as a result of postural or other nonstructural scoliosis theoretically can be treated through the use of exercise to prevent further exaggeration of the scoliosis beyond that which the disease has caused[55] (**Evidence and Research 24-11**).

EVIDENCE and RESEARCH 24-11

A review of two studies involving 154 patients total evaluating effectiveness of scoliosis-specific exercises in reducing curve progression and postponing or avoiding invasive treatments such as surgery in adolescents with adolescent idiopathic scoliosis found no evidence for or against scoliosis-specific exercises compared to electrical stimulation, traction, and posture training for avoiding curve progression. Scoliosis-specific exercises as the only treatment had similar results as general physical therapy.[56] However, a review of randomized controlled trials and prospective non-randomized controlled trials was also inconclusive in determining the effectiveness of surgical treatment compared to nonsurgical treatments for teens with idiopathic scoliosis.[57]

The message that exercise is of little or no value prevails in the literature, leaving individuals with scoliosis a range of treatment options including doing nothing, bracing, or surgery. Regarding physical therapy intervention, Kendall et al.[22] warn that overemphasis on flexibility is the exercise approach that leads to the view that exercise is of little value or even counterproductive in the treatment of scoliosis. The authors state that adequate musculoskeletal evaluation has been lacking, and as a result, there has been little scientific basis on which to justify the selection of therapeutic exercises. Kendall's premise for using therapeutic exercise is that scoliosis is a problem of symmetry and that restoring symmetry requires the use of asymmetric exercises along with appropriate support. Stretching of stiff or short muscles is desirable only if it is performed with simultaneous exercise and appropriate support to shorten and strengthen what is too long and relatively weak.

The correction of asymmetrical postural habits may be helpful in preventing the development of scoliosis during childhood. Exercises should be carefully selected on the basis of thorough examination findings, and adequate instruction is needed to ensure that the exercises will be performed correctly and with precision. The object is to use asymmetric exercises to promote symmetry. To illustrate this point, consider the following case.

The patient is a gymnast with a right thoracic, left lumbar curve (**Fig. 24-22**). Along with other findings, right iliopsoas and right external oblique weaknesses are diagnosed. An example of an asymmetric exercise is resisted exercise to the right iliopsoas (**Fig. 24-23**). Because the iliopsoas muscle attaches to the lumbar vertebrae, transverse processes, and the intervertebral disks, this muscle can pull directly on the spine. **Figure 24-24A** demonstrates the adverse effect of resisting the left iliopsoas, and Figure 24-24B illustrates the positive effect of resisting the right iliopsoas. A left upper extremity diagonal reaching movement pattern can facilitate right thoracic lateral flexion. Simultaneous right hip flexion and left upper extremity diagonal reaching should promote lateral deviation, correcting both curves (**Fig. 24-25**). If performed as a home program, this movement should be monitored (by an observer or using a mirror) to ensure that the appropriate spine correction occurs.

Kendall et al.[22] describe an exercise in supine to address the weakness of the right external oblique. In the supine position, the subject places the right hand on the right lateral chest wall and the left hand on the left side of the pelvis. Keeping the hands

FIGURE 24-22 This person has a right thoracic and left lumbar curve.

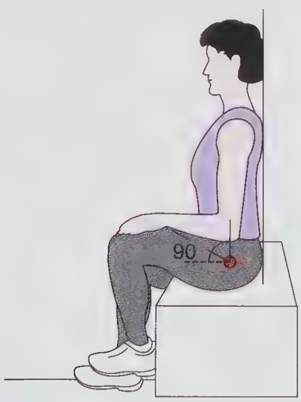


FIGURE 24-23 Resisted end-range hip flexion can isolate the iliopsoas from the other hip flexors that do not attach directly to the spine. The patient is instructed to passively lift the thigh to end range and hold the position against gravity while maintaining a neutral spine position. The patient is instructed to activate the lumbopelvic core prior to letting go of the leg (see Chapter 18 for core activation strategies). Resistance is applied only after the patient is able to hold the limb against gravity without resistance.

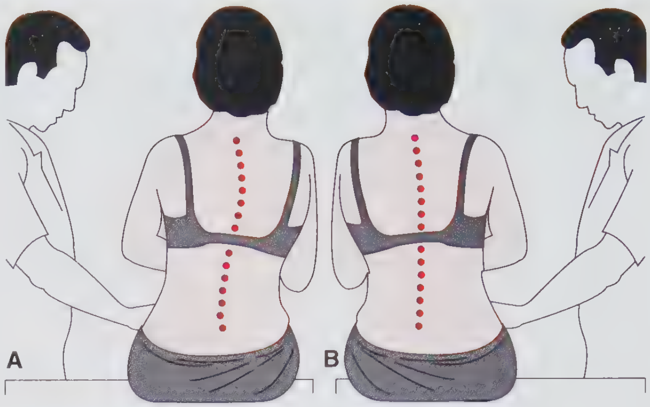


FIGURE 24-24 **(A)** The dotted line shows the adverse effect of resisting the left iliopsoas in a left lumbar curve. **(B)** The dotted line shows the positive effect of resisting the right iliopsoas in a left lumbar curve.

FIGURE 24-25 The dotted line shows the effect of reducing the right thoracic and left lumbar curve by simultaneously reaching diagonally upward with the left arm and resisting right hip flexion.

in position, the object of the exercise is to bring the two hands closer by contraction of the abdominal muscles without flexing the trunk. It is as if the upper part of the body shifts toward the left, and the pelvis shifts toward the right. By not allowing trunk flexion and contracting the posterior lateral fibers of the external oblique, there will be a tendency toward some counterclockwise rotation of the thorax in the direction of correcting the thoracic rotation that accompanies a right thoracic curve.

There is some evidence in small groups that exercise using trunk rotation may inhibit the progression of adolescent scoliosis.[58] However, there was no control group in this trial and there were only 20 subjects. One study has looked at the effect of axial unloading in changing the spinal curvature and found some improvement but without lasting results.[59] Again, the group was small (six subjects) and there was no control group for comparison. A review of the literature found that physical exercise prevents or reduces disabilities, and facilitates the neutralization of postural deficits to produce a stationary or regressive curve.[60]

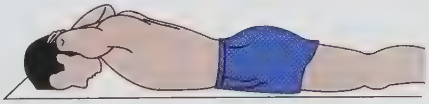
Often adolescents with scoliosis will have impairments in their overall fitness level. This impaired fitness has to do as much with poor self-image and reluctance to participate in activities while wearing the brace as it has to do with impairments in respiratory function. These children must be encouraged to remain as physically active as possible, and the parent must take an active role in this process. If the curve is severe enough, aerobic capacity may become impaired and appropriate endurance exercises should be prescribed. Thirty minutes of bike ergometry four times a week over 2 months produced a significant improvement in aerobic capacity in young girls with scoliosis compared to a control group of girls with scoliosis who did not exercise.[3] Cardiovascular exercise selection for patients with scoliosis is very important. The activity must not strengthen already short, tight muscles; rather it should encourage lengthening of short muscles and strengthening of weak muscles. For example, with the example of the gymnast previously discussed, swimming might be a good option for her. She should be encouraged to swim freestyle and breathe to the left, encouraging left rotation of the thoracic spine.

Consider a case of asymmetry and muscle imbalance found in acquired and structural scoliosis associated with unilateral pronation. For example, the combination of left pronation, shortness of the left tensor fascia lata, left gluteus medius and right hip adductors, and weakness of the right gluteus medius, left hip adductors, and left lateral abdominals can be seen in a person with a right thoracic curve and left lumbar curve. In such cases, along with specific exercises to improve the length of the left tensor fascia lata and strength of the right gluteus medius, left hip adductors, and lateral abdominal muscles (see Chapters 17 and 19), the use of an orthotic to support the left foot may be indicated, but only after all expected strength gains are made (see Chapter 21). Correction of lateral pelvic tilt associated with a lumbar curve can be helped by proper lift on the side of the low iliac crest. However, no lift can help if the patient continues to stand in an asymmetric posture, such as with weight predominantly on the leg with the higher iliac crest and with the knee flexed on the side of the lift.

Thoracic Lordosis

Causes Thoracic lordosis is a loss of the normal posterior curve of the thoracic spine, and it can be associated with abnormal postural correction strategies. For example, in an attempt to correct forward shoulders, the individual may extend the thoracic spine, rather than adduct the shoulder girdle on the stable thorax. If this is done habitually, the thoracic spine becomes a site of relative flexibility.

Intervention Attempts to improve impairments of the shoulder girdle with lower trapezius resistive exercises (**Fig. 24-26A**) cause thoracic extension instead of scapular adduction. Use of a support under the sternum (Fig. 24-26B) can somewhat block the undesired thoracic extension to allow resistive exercises to transmit forces to the scapula instead of the thoracic spine.



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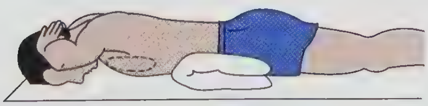
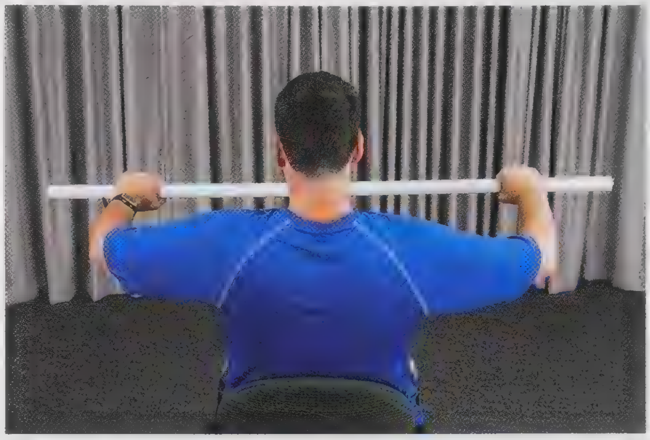


B

FIGURE 24-26 **(A)** In a person with thoracic lordosis, attempts at performing resisted lower and middle trapezius exercises promote thoracic extension instead of scapular adduction. **(B)** Use of a firmly rolled towel placed under the sternum can stabilize the thoracic spine in flexion, allowing the force of the middle and lower trapezius to adduct the scapula instead of extending the thoracic spine.

Applying tape anteriorly as a proprioceptive feedback mechanism to prevent excessive thoracic extension will facilitate movement in the lumbar spine and pelvis. Patient-related instruction is necessary to alter the strategy of posture correction performed by the patient. Self-mobilization into thoracic flexion can be performed, using the back of a firm chair to stabilize caudal segments while the cranial vertebrae are actively flexed (**Fig. 24-27**).



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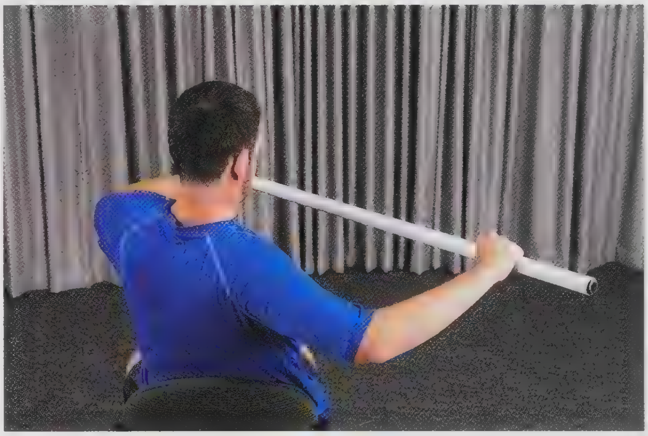

B

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FIGURE 24-27 Blocking motion of the caudal segments by stabilizing against the back of a chair, while mobilizing the segments above. **(A)** Starting position. **(B)** End position, rotation. Be sure to instruct the patient to rotate the spine versus adduct the scapula. **(C)** End position, extension. Be sure to instruct the patient to stabilize the thoracolumbar and lumbar regions to prevent extension.

THERAPEUTIC EXERCISE INTERVENTION FOR COMMON DIAGNOSES

This section contains selected medical diagnoses that have a bearing on the muscular, skeletal, and nervous systems as they relate to the thoracic region. Although numerous musculoskeletal diagnoses are associated with the thoracic region, only a few are discussed to provide examples of therapeutic exercise prescriptions for the related activity limitations, participation restrictions, and related impairments.

Prevention and Intervention in Patients with Osteoporosis

When treating patients with vertebral compression fractures secondary to osteoporosis, the therapist must know the status of the fracture (stable vs. unstable). Most compression fractures, such as those seen with osteoporosis, are stable and typically managed conservatively. Physiologic forces or movement will not displace these fractures. Patients are treated acutely with a short period (no more than a few days) of bed rest. Prolonged inactivity should be avoided, especially in elderly patients. Pain control can be in the form of oral or parenteral analgesics, muscle relaxants, external back-braces, and physical therapy modalities.[61,62] Intervention should focus on strength and flexibility exercises, as well as information on falls risk and assistive devices, balance, and gait training[63] (see **Building Block 24-3**).

BUILDING BLOCK 24-3

Why is extended bed rest and prolonged inactivity to be avoided?

A 77-year-old male spent the last 2 weeks in bed recovering from pneumonia. His cough is nearly gone and his breathing is no longer impaired. He is otherwise healthy. What impairments and activity limitations might be found in this patient? Design an exercise program that will effectively treat his impairments and improve his function, using two in-clinic visits and a home program.[64,65]

Patients who do not respond to conservative treatment or who continue to have severe pain may be candidates for surgical intervention. However, most patients are managed conservatively and make a full recovery or at least significant improvements in 6 to 12 weeks; resumption of a regular exercise program can occur once the fracture has fully healed. A well-balanced diet, regular exercise that includes weight-bearing activity and some form of resistance training, calcium and vitamin D supplements,[66,67] smoking cessation, and medications to treat osteoporosis may help prevent additional compression fractures. Age should never preclude treatment (**Evidence and Research 24-12**).

EVIDENCE and RESEARCH 24-12

There is current evidence that diagnosing and treating osteoporosis does indeed reduce the incidence of compression fractures of the spine.[67-70] Regular activity and muscle strengthening exercises have been shown to decrease vertebral fractures and back pain.[71] Inactivity leads to bone loss, but weight-bearing exercise can reduce bone loss and increase bone mass.

The optimal type and amount of physical activity that can prevent osteoporosis has not been established, but moderate weight-bearing exercise such as walking is recommended. Resisted upper extremity exercise is also recommended to induce weight-bearing stress on the spine and wrist. Exercise to reduce the stress of kyphosis is discussed in a later section of this chapter (see the section "Kyphosis") (see **Building Block 24-4**).

BUILDING BLOCK 24-4

Consider the patient in Case No. 2, Display 24-1. She is currently able to walk half a mile before the onset of pain that requires her to discontinue exercise. She uses yoga as an additional exercise. Design a therapeutic exercise program to help her get back to walking 3 to 4 miles per day. What additional activities might be part of an ongoing prevention program for her?

Measures to prevent falls must be initiated by patients and their caregivers, as a fall in this population can lead to morbidity or death from the secondary effects of immobilization and reduced activity. Specific exercise techniques addressing impairments related to balance are addressed in Chapters 8 and 19. **Table 24-2** lists items that should be assessed when determining what preventive measures should be followed.[72]

Exercise Management of Parkinson Disease

Parkinson disease is a progressive neurologic disorder that results in the loss of L-dopa in the substantia nigra. Clinical findings of the disease include rigidity, facial masking, resting tremor, dyskinesia, bradykinesia, difficulty initiating movement, and a flexed posture.

Intervention

Appropriate treatment for patients with Parkinson disease includes a combination of drug therapy, usually a form of L-dopa replacement, and exercise. A consideration in designing exercise programs in Parkinson disease is the typical waxing and waning of the drug effectiveness, often termed the "on" and "off" periods. The patient may swing from a fully functional and mobile

TABLE 24-2

Items to Assess in Determining Risk for Falls in the Elderly

AVOIDANCE OF RESTRAINTS	MUSCLE STRENGTH
Balance assessment	Neurologic function; cortical, extrapyramidal, and cerebellar functions; lower extremity peripheral nerves; proprioception; reflexes
Cardiac function, cardiac rhythm, heart rate, orthostatic pulse, and blood pressure	Vision
Gait	

individual while "on" to one who is immobilized and "frozen," all in a matter of minutes. As the disease progresses, the "on" periods may become very short despite appropriate medication doses (see **Building Block 24-5**). The patient in this situation may not wish to spend this valuable "on" time exercising, opting instead for performing highly valued or necessary tasks. In these cases, the exercise program must be economical in effect given the time needed to perform it. That is, only the few, most effective and broadly useful exercises should be chosen. The patient must be made aware of the importance of the exercises in order to consider them worth the time investment. This can be accomplished in a powerful way if the patient can experience the benefit of performing the exercise. For example, a simple exercise practicing a forward weight shift in sitting using an exercise ball or a stick (**Fig. 24-28**) often will result in dramatic improvement in sit to stand ability (from unable to independent). Experiencing this improvement will make it more likely that the patient will attach importance to it and will therefore increase compliance.

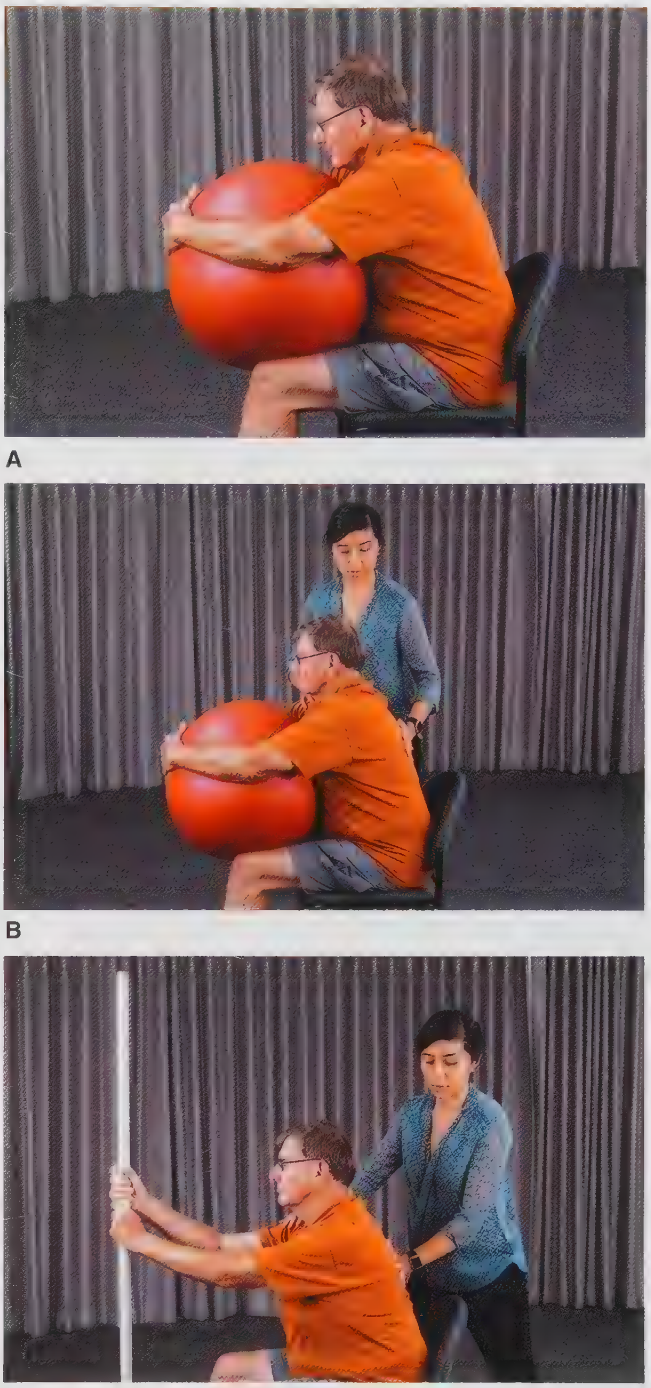
BUILDING BLOCK 24-5

Consider the patient in Case No. 4, Display 24-1. He is a 72-year-old construction company owner with Parkinson disease who has two to three "on" periods per day, each lasting about 2 hours. You note on physical exam that he has limited hip flexion and lumbar extension. Describe how this might limit his ability to arise from a chair, and design an exercise program that he can do at work that will address his impairments while simultaneously working on his function. Include dosage parameters, considering the amount of time he may spend sitting in a truck each day.

There are situations where the "on" periods are so short that it makes it unreasonable to ask the patient to spend it doing exercises. In these cases, the help of a family member or caregiver is crucial, in the form of a program of primarily ROM exercises. Utilizing inexpensive equipment such as exercise balls and wands or canes, combined with instruction in positioning techniques that promote spinal extension, can allow even a frail spouse to assist with exercises (see Fig. 24-28 and **Evidence and Research 24-13**).

EVIDENCE and RESEARCH 24-13

There is growing evidence that exercise can play an important role in the management of Parkinson disease. For example, the effectiveness of an exercise intervention for people in early and midstage Parkinson disease (stages 2 and 3 of Hoehn and Yahr) in improving spinal flexibility and physical performance in a sample of community-dwelling older people was described by Schenkman et al.[73] They compared people with Parkinson disease who received 10 weeks (30 sessions) of exercise instruction with a group of patients who received no exercise instruction and found improved functional axial rotation, functional reach, and timed supine to stand (see **Building Block 24-6**).



A

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FIGURE 24-28 Encouraging thoracic extension coupled with shoulder elevation, using a forward weight shift. **(A)** With the exercise ball resting in the patient's lap and his arms resting on top of the ball, the patient shifts his weight forward, causing shoulder elevation and thoracic extension. **(B)** Assistance with the movement can be provided by a family member or friend. **(C)** A stick, dowel, or broomstick can be substituted for the ball. These exercises can be especially effective in encouraging spinal extension with simultaneous hip flexion as a pre-transfer activity in patients with Parkinson disease. Be sure to instruct the patient to stabilize against lumbar flexion during this motion by activating lumbar erector spinae. The hips must have enough mobility to move into flexion without associated lumbar flexion.

BUILDING BLOCK 24-6

Consider the patient in Case No. 3, Display 24-1. The patient is a 56-year-old auto body mechanic who was diagnosed with Parkinson disease 3 years ago, and is still in the early stages. Develop a preventative home exercise program that would address impairments of decreased extensor strength, endurance, and extension mobility.

Thoracic Outlet Syndrome

TOS was first described by Peet et al.[74] as a syndrome caused by compression or stretching of the brachial plexus and/or the subclavian artery and vein as they transverse the thoracic outlet. All the symptoms attributed to TOS imply compression or stretching of the brachial plexus, subclavian artery and vein, or both areas (see **Building Block 24-7**).

BUILDING BLOCK 24-7

Consider the patient in Case No. 5, Display 24-1. The patient is a 22-year-old policewoman with diffuse neck, shoulder, arm, and hand pain and numbness in the fifth digit. These problems make it difficult to write traffic tickets. She is referred to PT with a diagnosis of neurogenic TOS. List the findings you would expect on her history and physical examination.

Traditionally, the etiology of TOS has been thought to be due to mechanical, nontraumatic brachial plexus compression caused by bony, ligamentous, or muscular obstacles anywhere between the cervical spine and lower border of the axilla. Common sites of compression include the anterior scalene, between the clavicle and first rib, and under the pectoralis minor. Several types of impairments of body structures, such as a cervical rib, a J-curve structural variation of the first rib, and a long transverse process of C7, may predispose the neurovascular bundle to compression. Fibrous bands between the cervical vertebrae and first rib may also be a source of compression. Less commonly, a tumor in the thoracic outlet (such as a Pancoast tumor) may compress the neurovascular bundle.

There are three types of TOS—neurogenic, venous, and arterial. Neurogenic TOS is the most commonly observed condition (95%) while the vascular variety is observed only 5% (venous 3% to 5% and arterial 1% to 2%) of the time. Swift and Nichols[75] reported that some patients with TOS had *droopy shoulder syndrome* suggesting that their symptoms resulted from stretching of the brachial plexus. Nakatsuchi et al.[76] proposed that the symptoms of TOS might be related to increased tension of the brachial plexus and surrounding vasculature because of muscular imbalance and the resultant downward traction.

Diagnosis

A careful evaluation is necessary to diagnose the subsets of TOS and to differentiate it from a spinal tumor, a Pancoast tumor, multiple sclerosis, cervical disk pathology, carpal tunnel syndrome, angina, tendinitis, and other brachial plexus injuries (**Evidence and Research 24-14**). Patients with TOS present with the following signs and symptoms:

EVIDENCE and RESEARCH 24-14

Sanders et al.[81] documented the following frequency of symptoms and symptom locations reported in patients: paraesthesia in the upper limb (98%), neck pain (88%), trapezius pain (92%), shoulder and/or arm pain (88%), supraclavicular pain (76%), suboccipital headache (76%), chest pain (72%), paraesthesia in all five fingers (58%), paraesthesia in the fourth and fingers only (26%), and paraesthesia in the first-third fingers (14%).

- Persistent diffuse pain and/or paraesthesia involving the neck, shoulder, arm, forearm, or wrist and hand
- Sensory and motor loss most commonly involves the C8–T1 segmental level, fine coordination may be affected, and patients may complain of symptoms when holding a newspaper, combing hair, or buttoning clothes
- A positive Tinel sign over the brachial plexus
- Elicitation of reproducible pain and/or paraesthesia by at least one provocation maneuver[77–80] or induction and/or aggravation of symptoms upon pulling downward on the arm and their improvement or elimination upon supporting the arms upward
- Exclusion of diseases of the cervical spine and a peripheral neuropathy.

Treatment

Treatment can be specified toward relieving compression, stretching, or both. Ultimately, the patient must be instructed in self-management techniques that treat the site and cause(s) of TOS and prevent recurrences.[82]

Often, patients with neurogenic TOS present with pain, paraesthesia, numbness, and/ or weakness related to poor posture. The presenting poor posture may include forward head, rounded shoulders, increased thoracic kyphosis, downward rotation and/or depression of the scapulae, and posterior pelvic tilt. Consider the patient in Building Block 24-7 who presents with drooping shoulders and poor posture. The distance between the first thoracic spinous process and coracoid process indicates the stretch placed on the neurovascular bundle. Presumably, the greater the distance, the greater the magnitude of stretch.[83] Therefore, treatment aimed at improving muscle performance and reducing the elongation of the upper trapezius and middle trapezius would be highly beneficial. Supportive taping of the scapula can relievè the stretch on the brachial plexus. General shoulder strengthening exercises to prevent traction on the brachial plexus and posture education is recommended. Conservative treatment is often successful with neurogenic TOS. Thoracic outlet decompression surgery may not be effective in patients whose major symptoms are due to stretching of the brachial plexus[84,85] (see **Building Block 24-8**).

BUILDING BLOCK 24-8

Let us return to Laura Biden, the 22-year-old policewoman with diffuse neck, shoulder, arm, and hand pain and numbness in the fifth digit. Recall that these problems make it difficult for her to write traffic tickets. You note that she sits and stands with an exaggerated kyphosis and forward, drooping shoulders. Passively or actively holding her shoulders back and straightening her back improves her UE symptoms after several minutes. She notes she is unable to maintain this position for long, however. Given the impairments you expected to find in Laura, design an exercise program that addresses these impairments, and progress the dosage parameters from initial visit to discharge from physical therapy.

General Treatment Concepts for Treatment of TOS

- Correct posture and movement impairments relevant to neurovascular compression and/or stretching, such as correcting a depressed and anterior tilted scapula.
- Taping the scapula into elevation (see Fig. 25-21) often reduces compression and alleviates symptoms until the related impairments are remedied.
- Alter sleep habits such as sleeping on the stomach with the neck extended and rotated, or arms overhead.
- Improve diaphragmatic breathing patterns. Accessory breathing patterns using scalenes and pectoralis minor may elevate the first rib and pull the scapula, and therefore the clavicle, closer to the first rib, causing compression of the fibers of the anterior scalene, within the costoclavicular space, or under the pectoralis minor.
- Correct impairments of body functions linked to posture and movement impairments, such as improving the length of the scalenes and pectoralis minor to increase the space of the thoracic outlet and mobility of the first rib; force-generating capacity or length–tension properties of underused synergists or antagonists such as the upper trapezius to alleviate a depressed scapula or lower trapezius to offset a short pectoralis minor.
- Alter movement patterns during instrumental ADLs. Examples include changing workstation ergonomics, body mechanics, or sport-specific movements.
- Appropriately refer for treatment of any patients with cognitive-emotional subsystems or exacerbating health habits that may be causing tension in the relevant musculature. For example, anxiety may cause cervical or brachial tension, or smoking may cause poor breathing habits.

LAB ACTIVITIES

1. Your patient has trouble stabilizing against rotational forces in the upper thoracic region. Develop and teach your partner three sequentially more difficult exercises to improve stabilization skills against rotational forces.
2. Refer to the Patient-Related Instruction 24-1. Assess your partner's breathing in the supine position. Does your partner have integrated pump and bucket handle rib motions? Are they symmetric? Teach your partner proper breathing mechanics.
3. Play the role of a person with Scheuermann disease with a desk job at a visual display terminal. Teach your partner proper ergonomics at the workstation. Teach your partner to reach across the desk and into a file cabinet. Avoid exaggerating the kyphosis.
4. Design an exercise program for a patient with right thoracic and left lumbar scoliosis. Teach each activity to your partner. Can you see or feel the effect of asymmetric exercise on the spine?
5. Referring to Critical Thinking Question 4, what alternative exercise would you prescribe to your patient with osteoporosis if she had weak abdominal muscles? Teach your partner this activity. Which abdominal muscle would you expect to dominate in the exercise you instruct for someone with kyphosis?
6. Referring to Critical Thinking Question 5, what alternative exercise would you prescribe to your patient with osteoporosis if she had weak thoracic erector spinae? Teach your partner this activity. Be sure to role-play someone with moderate to marked kyphosis.

KEY POINTS

- A comprehensive examination of all patients, including the history, systems review, and tests and measures, must be performed to enable the therapist to determine the diagnosis (based on impairments, activity limitations, and participation restrictions), prognosis, and interventions.
- When considering therapeutic exercise interventions for common impairments of body functions of the thoracic region, the therapist must consider the role of the thoracic spine in the kinematic chain and how other segmental levels can affect the physiologic function of the thoracic spine.
- Although few exercises solely address the thoracic region, those that address respiration, mobility, and performance of the trunk, shoulder girdle, and cervical muscles are important for optimal thoracic function.
- Thoracic spine function can be enhanced by treating the cervical and lumbar spine, shoulder girdle, pelvic-hip complex, and foot and ankle complex.
- Therapeutic exercise intervention is thought to affect the course of nonstructural scoliosis if the disorder is treated through asymmetric exercises, patient-related instruction, and movement retraining.
- There are many causes of kyphosis. If the cause is a disease such as Scheuermann's or osteoporosis, exercise intervention cannot reverse the pathology, but it may be able to retard or prevent further exaggeration of the kyphosis.
- Exercises may play an important role in the management of Parkinson disease. Exercises should be chosen carefully to maximize their effect without stealing precious "on" time from the patient.
- Diagnosis and treatment of TOS requires extensive knowledge of the anatomy and kinesiology of the cervical, thoracic, and shoulder girdle regions.

CRITICAL THINKING QUESTIONS

1. Describe how function of the foot and ankle, hip, and shoulder girdle could affect function of the thoracic spine. Provide one example for each region.
2. You have been referred an 18-year-old boy with Scheuermann disease.
   a. What two posture types would this patient probably exhibit?
   b. List the possible shortened and lengthened muscles around the trunk and pelvis for each posture type.
3. You have been referred a 16-year-old female with right thoracic and left lumbar scoliosis.
   a. What are the possible shortened and lengthened muscles in the anterior and posterior trunk and pelvic girdle?
   b. What foot and ankle alignment faults could contribute to this scoliosis?
4. Why would trunk curl exercises be contraindicated for someone with Scheuermann disease or osteoporosis?
5. Why would prone hyperextension exercises be contraindicated for someone with Scheuermann disease or osteoporosis?
6. What five exercises would you choose to teach to a patient with Parkinson disease who complains of an increasingly flexed posture, if he has only 3 hours each day when he is "on?"
7. List common postural impairments found in someone with TOS.
8. Given the list you created in No. 7, what muscles would you want to stretch versus strengthen?

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CHAPTER

25

The Shoulder Girdle

CARRIE M. HALL

The shoulder girdle functions with the arm, elbow, forearm, wrist, and hand in a kinetic chain with the trunk and lower extremity. Therefore, dysfunction of the shoulder girdle can affect the function of related regions, and conversely dysfunction of related regions can affect shoulder girdle function. For example, faulty movement patterns and associated impairments of the shoulder girdle can affect the function of the cervical spine and vice versa because of shared musculature (i.e., levator scapula and upper trapezius). In addition, faulty movement patterns and associated impairments of the spine and pelvis can affect function of the shoulder girdle. For example, anterior pelvic tilt, combined with thoracic kyphosis, can result in an anterior tilt to the scapula, leading to subacromial impingement with overhead movements.

This chapter will first present information related to anatomy, kinesiology, and evaluation of the shoulder girdle. This information will set the stage for the sections on therapeutic exercise intervention for common shoulder girdle impairments. As with all other chapters in this book, the goal is to provide the necessary information to become a critical thinker and perceptive problem solver such that you will be prepared with the knowledge necessary to develop an efficient and effective exercise prescription for any case involving the shoulder girdle.

REVIEW OF ANATOMY AND KINESIOLOGY

The shoulder girdle is one of the most complex regions of the body as it pertains to anatomy and kinesiology. The coordinated movements of the three distinct articulations and the involved muscles and periarticular structures allow the arm and hand to be positioned in space for a variety of functions. The result is a range of motion (ROM) that exceeds that of any other joint complex in the body.

The shoulder girdle is composed of the sternoclavicular (SC), acromioclavicular (AC), and glenohumeral (GH) joints. Scapulothoracic (ST) motion occurs through combined SC and AC joint motions over the surface of the rib cage.[1] Therefore, rib structure and function also impact the function of the shoulder girdle. The importance of understanding the complexity of the anatomy and kinesiology of the shoulder girdle as it pertains to therapeutic exercise prescription cannot be underestimated. For that reason, a thorough review can be found on thePoint.lww.com/BrodyHall4e.

EXAMINATION AND EVALUATION

More than 50 physical diagnostic tests have been described for the shoulder girdle.[1–5] Diagnosis of dysfunction in the shoulder girdle is challenging because of the complex anatomy and kinesiology and interrelationships of the AC, SC, and GH joints and the cervicothoracic spine. Furthermore, functions of the elbow, forearm, wrist, and hand are related to the function of the shoulder girdle as part of the upper quarter kinetic chain. Dysfunction in one segment of the chain affects the function of other segments.

A clinical example of the close relationship between upper quarter joints is demonstrated in an individual presenting with reduced forearm pronation ROM. The compensation for this restriction during activities of daily living (ADLs) may be medial rotation and abduction of the GH joint to orient the palm of the hand downward (see **Fig. 25-1**). If this pattern is performed repetitively, particularly in elevated arm positions biased toward the frontal plane, impingement of the subacromial structures of the shoulder may develop.

The descriptive examination and evaluation information discussed in this section is not intended to be comprehensive or reflect any specific philosophical approach. It is presented in alphabetical order and should simply serve as a review of pertinent tests performed in shoulder girdle examinations.

Patient/Client History

In addition to the general data collected from a patient/client history as defined in Chapter 2, several patient-reported outcomes (PROs) have been shown to demonstrate acceptable levels of reliability and validity and can be used as a baseline assessment of how the function of the shoulder is affecting function and quality of life. Of 16 PROs used for the shoulder, disabilities of the arm, shoulder, and hand,[6] Shoulder Pain and Disability Index (SPADI),[7] and Simple Shoulder Test,[8] each have good evidence in support of four of the following five properties—internal consistency, reliability, content validity, hypothesis testing, and responsiveness.[8] The reader is referred elsewhere for a review of each PRO.[9–11]

FIGURE 25-1 Use of arm abduction and medial rotation to orient palm downward versus pure forearm pronation. The former pattern can lead to wrist extensor overuse (aka "tennis elbow") due to using wrist extensors to both extend the wrist and flex the elbow in lieu of using the biceps and brachialis to flex the elbow.

Clearing Examinations

Routine cervicothoracic spine screening should be included during the examination of any patient with shoulder girdle complaints. Dysfunction of the cervicothoracic region may contribute to shoulder dysfunction.[12–14] Additionally, the elbow-wrist-hand complex should be excluded as a source of pain, although it rarely refers pain proximally to the shoulder (**Evidence and Research 25-1**).

EVIDENCE and RESEARCH 25-1

Connection Between Shoulder Girdle Function and Mechanical Neck Pain

Studies using electromyography (EMG) have shown alterations in cervical muscle behavior in patients with mechanical neck pain (MNP) compared with healthy control subjects.[15,16] One muscle group that is intricately related to the mechanical function of the cervical spine is the axioscapular muscle group.[17,18] On a clinical basis, some patients with MNP exhibit alterations in scapular orientation and motion similar to that observed in patients with painful shoulder disorders who report no cervical pain.[19–22] In shoulder conditions such as impingement, scapular dysfunction has been shown to be associated with changes in the behavior of the axioscapular muscles.[21] This, at present, is speculative and underpins the need for studies combining measures of axioscapular muscle behavior with measures of scapular kinematics in MNP as has been performed in patients with shoulder girdle impingement disorders.[21] Nevertheless, the observed changes in trapezius muscle behavior suggest that impairment of the trapezius muscle appears to be a feature of some MNP disorders.[23–27] Certainly, these findings support the literature that suggests evaluation of the shoulder girdle, and therapeutic exercise to improve shoulder girdle function when indicated should be an integral component of the management of MNP.[28–30]

TABLE 25-1

Referred Pain Sites to the Shoulder Girdle

- Abdominal problems, such as gallstones or pancreatitis.
- Pelvic problems, such as a ruptured ovarian cyst.
- Heart or blood vessel problems in which pain is more often felt in the left arm and shoulder, such as heart attack or inflammation around the heart (pericarditis).
- A lung problem, such as pneumonia or Pancoast tumor, where pain may be felt throughout the shoulder, shoulder blade area, upper chest, upper arm, neck, and axilla. Pain is usually felt in the shoulder on the same side as the lung problem.
- Other conditions, such as herpes zoster (shingles), Paget's disease, or thoracic outlet syndrome.
- Other problems, such as gas from laparoscopic abdominal surgery or air entering the vagina under pressure from some gynecologic procedures.

Unexplained shoulder pain that does not change with shoulder or arm movement or that occurs with symptoms elsewhere in the body (such as in the abdomen or chest) may be referred shoulder pain. Causes of referred shoulder pain are listed in **Table 25-1**. A thorough health history can assist in identifying signs of visceral sources of symptoms.

Motor Function (Motor Control and Motor Learning)

Visual observation and palpation of the multiplanar motions of the scapula on the thorax have been developed into scapular dyskinesis tests.[31,32] A comprehensive scapular dyskinesis classification test combining both visual and palpation methods has satisfactory interrater reliability.[32] This type of qualitative testing is important, because active ROM may be within normal limits (WNLs) but have abnormal associated kinematics contributing to shoulder dysfunction (**Evidence and Research 25-2**).

EVIDENCE and RESEARCH 25-2

Evidence of Altered Kinematics Contributing to Shoulder Dysfunction

The mobile scapula is dependent on the synchronous action of all axioscapular muscles, as well as rotator cuff (RC) muscles, to control its multidirectional rotations and translations, particularly during upper limb activities that load the scapula.[33–35] Changes in the orientation of the scapula during upper limb activities could affect the efficiency of the scapular upward rotators (upper and lower trapezius, serratus anterior) due to changes in muscle length–tension relationships as well as lever arms.[17,18] Alterations in scapular kinematics effect the entire shoulder girdle. For example, heightened lower trapezius activity during upper limb tasks is a finding of Ludewig and Cook[21] in patients with impingement of the shoulder. The cause of altered trapezius behavior may be directly due to pain; in addition, it may be reflective of the presence of altered axioscapular muscle function irrespective of pain. Potentially, changes in trapezius muscle behavior may be a contributor to scapular dysfunction or, alternatively, may be compensatory for inadequacies of other axioscapular muscles in an attempt to correctly orientate the scapula during loaded upper limb tasks.[21,30]

Muscle Performance

Impaired muscle performance can result from numerous causes/sources (refer to Chapter 5). Various tests can determine the presence and potential cause or source of impaired muscle performance.

Specific manual muscle testing (MMT) provides information regarding the amount of force or torque that a musculotendinous unit can generate. **Display 25-1** provides a list of muscles that should be included in MMT of the shoulder girdle. MMT is traditionally done, but testing of muscle performance can be performed with a dynamometer, and both types of testing can be performed in conjunction with surface EMG when appropriate. In addition, muscular endurance can be assessed by counting the number of repetitions a patient can perform with a small load. For example, because of the RC's role in stabilizing the humeral head in the glenoid during movement, it functions as a low-load, high-volume muscle. As such, the endurance of the muscle can be assessed via a number of repetitions the patient can successfully perform with a 1 to 2# weight. The number can be expressed as a percentage of the number of repetitions performed on the uninvolved side. This method also helps with dosing of the exercise for home. Texts on manual testing for specific protocols should be consulted.[36,37]

Positional strength testing is a specialized form of MMT that tests the muscle at a specific length; this provides information regarding the length–tension properties of the muscle (see Chapter 5). Positional strength testing is particularly useful in determining whether a muscle is weak because of altered length–tension properties. If a muscle is lengthened, it tests weak in the short range but strong in a slightly more lengthened range. If a muscle is weak because of other causes, it tests weak throughout the range. Sahrmann[38] has provided more information on positional strength testing of muscles in the shoulder girdle.

Selective tissue tension tests combine active and passive ROM with resisted tests of muscles about the shoulder girdle.[39] The sum total of the results of each test assists the practitioner in determining which tissue is the probable source of the shoulder condition.[40,41] Many clinicians use Cyriax's selective tissue tension model for the diagnosis of soft-tissue lesions of the shoulder.[42] The Cyriax model has been shown to be a reliable scheme for assessing patients with shoulder pain.[43] If selective tissue tension test results are positive for a contractile lesion, the resisted test can further diagnose the severity of the lesion. **Table 25-2** highlights the diagnostic findings of resisted tests.

DISPLAY 25-1

Shoulder Girdle Muscles to Include in MMT*

- Anterior, middle, and posterior deltoid
- Glenohumeral lateral rotators
- Glenohumeral medial rotators (with isolation of subscapularis)
- Upper, middle, and lower trapezius
- Serratus anterior
- Rhomboids and levator scapula
- Pectoralis major
- Latissimus dorsi

**The reader is referred to the appropriate reference for specific MMT techniques.*

TABLE 25-2

Diagnosis Based on Resistive Tests

FINDING OF RESISTIVE TEST	LESION
Strong and painless	Normal
Strong and painful	Minor muscle lesion
	Minor tendon lesion
Weak and painful	Gross macrotraumatic lesion such as fracture
	Partial rupture of muscle or tendon
Weak and painless	Muscle or tendon rupture
	Neurologic dysfunction

Pain

Evaluation of pain is done throughout the examination process. Palpation of suspected tissues is used to evaluate tissue tension, temperature, swelling, and provocation of pain.[44] Cyriax[39] and Maitland[45] advocate use of the sequence of pain and resistance during passive movement testing to establish the irritability level of a tissue. This information can guide the aggressiveness with which stretching and mobilization techniques are performed.

Because a subjective report of the pain associated with specific activities can help in the assessment, the clinician should question the patient about which activities are associated with pain. Pain often is latent (i.e., experienced after the activity), which makes it difficult to relate a cause or source. The range of pain, from the least pain to the worst pain experienced, should be examined through some accepted method of pain assessment (e.g., visual analog scale).[46]

The clinician must attempt to determine a mechanical cause of the pain during the course of the examination. This is often quite challenging but necessary to ensure full recovery and prevention of recurrences. For example, although the supraspinatus tendon can be diagnosed as the source of pain through selective tissue tension testing and palpation, the cause of the pain may be excessive scapular anterior tilt.[47] Excessive anterior tilt or insufficient posterior tilt, during arm elevation, can lead to pain because of mechanical impingement of the supraspinatus under the acromion process. Local treatment of the supraspinatus may decrease the pain in the short term. However, treatment of the faulty postures and movement impairment in addition to related intrinsic and extrinsic physiological impairments is essential to manage the condition in the long term. In this case, the clinician should implement stretching of the pectoralis minor and short head of the biceps (both attaching to the coracoid process and exert an anterior force on the scapula) with neuromuscular reeducation of the posterior scapular muscles, particularly the serratus anterior, prior to strengthening the supraspinatus. However, recent advances in pain science have demonstrated that, in general, symptom intensity and the magnitude of disability experienced by the patient seem to be influenced by a variety of factors unrelated to the physical diagnosis, including socioeconomic, emotional, and occupational status.[48–51] Interestingly, these factors have been shown to have a greater impact on symptoms and disability than the severity of the patient's diagnosis[51] (**Evidence and Research 25-3**).

EVIDENCE and RESEARCH 25-3

Biopsychosocial Factors as They Relate to Shoulder Pain and Anatomic Diagnoses

The traditional biomedical model of illness assumes a direct relationship between nociception and pain, and the biopsychosocial model acknowledges the influence of biological, psychological, cultural, and social factors on a patient's experience with his or her own pain.[52] The results of a study by Menendez et al.[53] provide support that biological (body mass index), psychological (pain catastrophizing and ineffective coping strategies), and social (work status) factors were independently associated with symptom intensity and magnitude of disability. However, the primary diagnosis did not independently predict the SPADI, even though one would expect variation in pain and disability between different shoulder conditions. A similar effect has been seen previously in the shoulder, as one study found that tear size, retraction, or humeral head migration did not predict functional scores in patients with RC abnormalities.[54] Interventions to decrease catastrophic thinking and to optimize self-efficacy during treatment hold potential to ameliorate symptom intensity and the magnitude of disability, and merit additional study.

Peripheral Nerve Integrity

Results of thoracic outlet,[55] neural tissue provocation testing,[56] peripheral nerve integrity tests, and resisted tests diagnose a pattern of pain and/or muscle weakness due to peripheral nerve involvement. Tests of shoulder girdle musculature, combined with elbow, forearm, wrist, and hand musculature, can indicate whether a nerve deficit is at the level of the cervical spine (i.e., nerve root), a peripheral nerve lesion, or, possibly forms of myopathy (i.e., facioscapulohumeral muscular dystrophy.[57]

Neural tissue sensitivity tests including upper limb neurodynamic testing and palpation of the courses of the median, ulnar, and radial nerves. The neurodynamic test is considered positive if arm symptoms (at least in part) were reproduced along with positive structural differentiation tests.[58,59]

Posture

Atypical positions of the scapula on the thorax, GH joint, and cervicothoracic spine have been noted in patients with shoulder girdle dysfunction.[12–14,60,61] Although there is inconsistent clinical reliability and validity with tests to objectively measure scapula and humerus resting position,[62] there is research supporting the relationship between the incidence of pain in the shoulder girdle and aberrant scapula and humerus posture[12,13] (**Evidence and Research 25-4**). Therefore, the clinician should observe and document the following:

- Total body alignment—particularly related to symmetry in lower extremity (LE) limb lengths
- Head position, cervical, thoracic, and lumbar spine alignment
- Pelvic position about all three planes
- Analysis of alignment of the scapula, clavicle, and humerus about all three planes

EVIDENCE and RESEARCH 25-4

Evidence for Postural Consideration When Treating a Shoulder Condition

Spinal alignment, especially thoracic curvature, is proposed to be critical for determining the scapular position, which influences overall shoulder function. With excessive thoracic kyphosis, the orientation of the scapula on the thorax is altered. A more anterior tilt and internally rotated scapula position and increased forward head is evident.[63–65] Shoulder flexion, abduction, and external rotation require substantial movements of the scapula into posterior tilting, upward rotation, and scapular external rotation.[66] These are impaired with a scapula resting in anterior tilt and internal rotation. In addition, in the elderly, it was found that subjects with severe thoracic kyphosis at rest had a narrower subacromial space than those with less thoracic kyphosis[67] Interestingly, the statistically significant effects of thoracic kyphosis on shoulder ROMs were found not only between the erect and maximum slouched postures but also between the erect and comfortable slouched postures.[68] These findings highlight that even a subtle increase in thoracic kyphosis of approximately 7.10 degrees such as that occurring in the comfortable slouched posture might require further attention. It was shown that a reduction of 5.80 degrees of thoracic kyphosis could produce greater pain-free shoulder ROMs both in flexion (mean 16.20 degrees) and abduction in the scapular plane (mean 14.70 degrees).[69]

ROM, Muscle Length, Joint Mobility, and Joint Integrity

Elements to include in testing ROM, muscle length, joint mobility, and joint integrity of the shoulder girdle are listed in **Display 25-2**.

DISPLAY 25-2

Elements to Include in Testing ROM, Muscle Length, Joint Mobility, and Joint Integrity of the Shoulder Girdle

- Active and passive osteokinetic ROM of the GH joint and both the cervical and thoracic spine.
- Passive arthrokinematic mobility tests of the SC, AC, GH, cervicothoracic spine, and scapula mobility on the thorax.
- Capsuloligamentous integrity[70–74]
- Glenoid labrum integrity tests[75–78]
- Rotator cuff integrity[77,78]
- Subacromial impingement tests[79,80]
- Muscle length testing for scapulohumeral, axioscapular, and axiohumeral muscle groups. Examples of muscles that fall into each category are summarized in **Display 25-3**. Sahrmann[61] and Kendall et al.[36] have described the appropriate muscle length testing procedures.
- Functional movements should be examined, including reaching behind the back, touching the back of the head and neck, and reaching across to the opposite shoulder.

DISPLAY 25-3

Shoulder Girdle Muscles Prone to Adaptive Length Changes

Adaptive Shortening	Adaptive Lengthening
Rhomboid major and minor	Middle trapezius
Levator scapula	Lower trapezius
Upper trapezius*	Upper trapezius*
Subscapularis**	Subscapularis**
Teres major	Serratus anterior
Latissimus dorsi	
Pectoralis major and minor	
Short head of biceps	
GH lateral rotators	

**Upper trapezius can be short with an elevated scapula and long with a depressed scapula*

***Subscapularis can be short with humeral medial rotation and long with anterior humeral head displacement*

Work (Job/School/Play), Community, and Leisure Integration or Reintegration (Including Instrumental ADLs)

Functional testing, whether in the form of performance testing or subjective grading (PRO), should be included in the examination. See previous section on patient/client history for details regarding specific PROs.

THERAPEUTIC EXERCISE INTERVENTIONS FOR COMMON IMPAIRMENTS OF BODY STRUCTURES AND FUNCTIONS

After thorough examination and evaluation of the shoulder girdle, the clinician should have a good understanding of the activity limitations and participation restrictions affecting the patient as well as the related body function and structure impairments. A diagnosis and prognosis are formulated, and an intervention is planned. After it is determined which body function impairments should be treated to restore activity and participation level, a plan of care must be developed to treat the appropriate impairments and limitations/restrictions. Therapeutic exercise intervention is vital in the restoration of shoulder girdle function in order to restore the precise coordinated muscular force couples acting on the three integrated joints in the shoulder girdle complex. The following sections provide information about therapeutic exercise interventions for common impairments of body structures and functions. Pain is presented as the first impairment because of the importance of understanding the underlying impairments contributing to and/or causing pain.

Pain

Differential diagnosis of the source of pain experienced in the upper quarter is difficult in part because of the interdependence in the anatomy of the shoulder, elbow, wrist, hand, and cervicothoracic spine. Pain stemming from tissues in the shoulder girdle may be experienced locally or referred distally down the arm as far as the wrist and hand.[81] Confounding the diagnosis of the source of shoulder pain is the fact that the shoulder girdle is a common region for referral from sites extrinsic to the shoulder girdle such as the cervicothoracic spine[82,83] and nonmusculoskeletal sources, such as the heart and diaphragm (see Appendix 1).[84]

The cause of local pain in the shoulder remains elusive, and frequently the level of pain experienced varies substantially among individuals, as previously alluded to in the Evaluation/Examination section. Central sensitization and central motor alterations could contribute to explain this disparity[85] (**Evidence and Research 25-5**).

EVIDENCE and RESEARCH 25-5

Central Sensitization and Central Motor Alterations with Rotator Cuff Tendinopathy

Gwilym et al[85] demonstrated that a significant proportion of individuals with RC tendinopathy have pain radiating down the arm and hyperalgesia to pinprick stimulus of the skin. Furthermore, the presence of either hyperalgesia or referred pain preoperatively is associated with a worse outcome from subacromial decompression 3 months after surgery.[85] Two other studies compared pain thresholds between individuals with and without unilateral RC tendinopathy and found hypersensitivity at local and remote sites bilaterally in the symptomatic population, suggesting central sensitization.[86,87] These findings suggest that central sensitization is present in a proportion of people diagnosed with RC tendinopathy, and that the pain experienced may not always relate to local pathology.

Another potential influence in the development or maintenance of pain is the presence of central motor alterations. Ngomo et al.[88] have shown that individuals with RC tendinopathy demonstrate decreased corticospinal excitability of the infraspinatus muscle on the affected side compared to their unaffected side. Corticospinal hyperexcitability at rest and hypoexcitability during voluntary activation have also been reported for the deltoid muscles in individuals with chronic full-thickness tears of the RC.[89] These altered muscle cortical representations show adaptive changes in the central nervous system associated with RC tendinopathy and may contribute to the neuromuscular deficits associated with this disorder.

If a *source* of the pain is determined to be located in the shoulder girdle, treatment may involve a combination of interventions, including manual therapy, physical agents or electrotherapeutic modalities, neuromuscular reeducation, and therapeutic exercise aimed at the shoulder girdle region. A clinical example can illustrate the use and interaction of physical therapy interventions. **Display 25-4** outlines hypothetical examination and evaluation findings of a person diagnosed with RC tendinopathy. Current research evidence provides considerable confidence for people diagnosed with RC tendinopathy to expect an equivalent outcome to surgical intervention with a well-structured and graduated exercise program, with the additional generalized benefits of exercise, less sick leave, a faster return to work, and reduced health care expenses[94,95] (**Evidence and Research 25-6**).

DISPLAY 25-4

Clinical Case of Rotator Cuff Impingement (Primary Rotator Cuff Disorder)

Examination and Evaluation

History

A 35-year-old, right-handed man complains of right shoulder pain. His occupation requires him to sit at a visual display terminal 8 to 10 hours each day, 5 days each week. He uses his mouse in his right hand. He also engages in cross-country skiing, climbing, and kayaking. A primary activity limitation includes inability to sleep on his right shoulder due to pain at night that awakens him briefly two to three times each week. His participation restrictions include inability to participate in any recreational activity using his right arm overhead. Work is not disrupted at this time, although he does experience a fatiguing discomfort between his shoulder blades while working at the computer about two-thirds into his workday.

Postural Alignment

Moderate forward head, moderate abducted, anterior tilted, and downwardly rotated scapulae, with the right scapula slightly depressed, bilateral humerus in moderate abduction (R > L), and moderate thoracic kyphosis

Cervical Clearing Examination

Slight stiffness in cervical rotation to the right, otherwise negative for shoulder girdle signs or symptoms

Passive ROM

Arm elevation in the plane of the scapula—150 degrees
Lateral rotation at 90 degrees of abduction—90 degrees
Medial rotation at 90 degrees of abduction—40 degrees
Elbow, forearm, wrist, hand—WNL

Active ROM

Active arm elevation in flexion—145 degrees
Active arm elevation in abduction—140 degrees
Total scapular upward rotation is 45 degrees

Scapulohumeral Rhythm

Faulty scapulohumeral rhythm is present. The scapula is slow to elevate from the initial depressed position and is still depressed relative to the left at 90 degrees of flexion, but excessively elevates in the last half of flexion. In addition, the scapula fails to fully upwardly rotate and is only rotated upward 10 degrees at 90 degrees of flexion. The patient experiences pain from 90 degrees to end range. Pain is reduced with manual assistance of elevation and upward rotation of the scapula.

Muscle Length

Moderate shortness in the GH lateral rotators and rhomboids and lengthened right upper trapezius and middle trapezius.

Joint Mobility

Hypomobile GH posterior and inferior glide, ST upward rotation, and AC joint anteroposterior glide

Muscle Performance (Tests Performed on Right Only)

GH lateral rotators: 3+/5 (pain)
GH abductors: 4−/5 (pain)
Supraspinatus (full can test)[90]: 3+/5 (pain)
Subscapularis (lift-off position)[41] 3+/5
Upper trapezius: 3+/5
Middle trapezius: 3+/5
Lower trapezius: 3+/5
Serratus anterior: 3+/5
Rhomboids/levator scapula: 5/5
Biceps: 4−/5
Triceps: 5/5

Resisted Tests

General abduction, end-range lateral rotation, and supraspinatus are weak and painful.

Motor Control

Surface EMG analysis demonstrates latent upper trapezius and serratus anterior activity, when compared to the uninjured side, during scaption.

Palpation

Tenderness was elicited over the tenoperiosteal and musculotendinous junction of the supraspinatus and AC joint.

Special Tests

Neer impingement sign[91] and Hawkins impingement tests[90] are positive
Jobe apprehension test[92] is negative
Negative drop arm test and hornblower's signs[79]
Sulcus sign[93] is negative

Assessment

This patient appears to have primary RC disorder. His body function impairments include:

- Altered mobility in periarticular soft tissues limiting posterior and inferior glide of the GH joint
- Reduced muscular extensibility in GH lateral rotators, further contributing to limited GH posterior glide
- Reduced muscular extensibility in scapular downward rotators, limiting scapular upward rotation
- Lengthened scapular elevator and upward rotator group, affecting length–tension properties of muscles participating in the upward rotator force couple
- Decreased muscle performance of the elevator or upward rotator, affecting the muscle's participation in the active force couples
- Altered motor control patterns in scapular rotators
- Positive signs of injury to subacromial tissue, particularly supraspinatus (i.e., positive impingement sign, weak and painful resisted tests, palpation).

Summary of Pathomechanics

This patient is vulnerable to developing impairments that contribute to impingement syndrome. The prolonged faulty posture he sustains during an 8- to 10-hour workday can lead to altered passive, active, and neural subsystems of the movement system. The faulty joint alignment can contribute to GH impingement because of the altered relationship between the ST articulation and GH joints. Prolonged faulty postures can lead to altered muscle length–tension properties, which can contribute to altered movement and recruitment patterns. For example, if the scapula is chronically abducted, downwardly rotated, depressed, and anteriorly tilted at rest, the axioscapular upward rotators could adaptively lengthen and the axioscapular downward rotators and scapulohumeral muscles could adaptively shorten. When he raises the arm overhead, as is required for rock climbing and kayaking, the patient's scapula may not sufficiently upwardly rotate and the humeral head may translate excessively superior in the glenoid fossa. This movement pattern could result in impingement of subacromial structures against the AC ligament and the acromion process.

EVIDENCE and RESEARCH 25-6

Graded Exercise Versus Surgery for Treatment of Rotator Cuff Tendinopathy

There is evidence in the literature that surgery does not confer additional benefit at 1-, 2-, or 5-year follow-up for the treatment of RC tendinopathy[96–99] and a structured exercise program significantly reduces the need for surgery.[100] Also, surgery (acromioplasty or acromioplasty and RC repair) is not associated with an improved outcome over exercise alone for atraumatic partial-thickness tears (less than 75% thickness tear of the supraspinatus)[101] or atraumatic full-thickness RC tears.[102] All these studies used graduated exercise designed to target the RC musculature, with the number of formal treatment sessions ranging from 6 to 19. Some studies also included motor control exercises, scapular exercises, and shoulder stretches as part of the plan of care. One study specifically permitted and recommended pain up to a level of 5/10 (where 10 represented maximal pain) when performing the exercises, provided that the pain level reverts back to resting pain level experienced *prior* to exercise *by* the next exercise session.[100] In addition, the authors have suggested that it is conceivable that the average of 6 to 12 weeks of relative rest following subacromial decompression surgery for RC tendinopathy and the subsequent graduated rehabilitation may be the beneficial mechanism, and not the actual operative procedure itself.[103–105]

EVIDENCE and RESEARCH 25-7

Injection Therapy for Treatment of Refractory Shoulder Pain

In the United Kingdom, physical therapists have been performing joint and soft-tissue injections to support exercise prescription and manual therapy since the 1990s, and, more recently, physical therapists have started to perform ultrasound-guided procedures.[108–110] Electromyographic studies have shown that shoulder pain inhibits the RC muscles and that effective pain relief from subacromial injection of local anesthetic can improve outcomes of exercise therapy.[111] As these treatments (injection therapy, exercise, and manual therapy) probably work by different mechanisms, the combined treatment approach has been found to be more effective than the single components.[108] Both corticosteroids and analgesics have been shown to reduce tenocyte proliferation[112,113] that may be a feature of irritable RC tendinopathy.[114] However, corticosteroids have been associated with reduced RC tissue strength in rats[115] and potential tendon apoptosis,[116] and as research studies have not demonstrated differences between corticosteroid and analgesic subacromial injections,[117–119] it may be clinically more appropriate, when considering injection therapy, to initially try subacromial analgesic injections followed by graduated rehabilitation.

Guiding principles for the spectrum of RC tendinopathies are modification of painful activities, an exercise strategy that does not trend pain levels upward over time, reeducation of movement patterns that contribute to tissue stress, controlled reloading, gradual progression from simple to complex shoulder movements, education of long-term management and ideally, prevention of future recurrence.

Pain reduction is a priority in managing irritable RC tendinopathy. People with irritable RC tendinopathy commonly report combinations of constant pain, night pain, and persistent pain following minimal activity that continues for a protracted period. It is important to advise people with irritable RC tendinopathy to *temporarily* restrict activities of the affected limb that exacerbate symptoms (relative rest). In addition, any exercise program should be carefully planned and delivered so as not to trend increased pain levels. This may include devising exercises that support the arm, are performed slowly, and are also typically performed through a reduced shoulder ROM. There is evidence to suggest that sustained isometric contractions performed in the direction of the pain and weakness help to control pain.[106,107] If a combination of relative rest, isometric exercises, and carefully graduated exercise is not helpful in reducing symptoms, then injection therapy with the goal to control pain and reduce potential inflammation may be considered as adjunctive intervention[108,109] (**Evidence and Research 25-7**).

Treatment of the source of the pain may include the following interventions:

- Transverse friction massage to the affected RC tenoperiosteal or musculotendinous junctions to assist in the formation of a strong and mobile scar[42]
- Active exercise, electrical stimulation in mid-range, or both to broaden the muscle (serving a purpose similar to that of transverse friction massage)[42]
- Physical agents (e.g., cryotherapy) or electrotherapeutic modalities (e.g., phonophoresis, ultrasound) used to treat the inflammatory (if acute inflammation is present).[120]

Treatment isolated to the *source* of the pain can assist in the healing process and provide relief of discomfort in the short term, but will not be able to manage the condition long term, particularly if the cause of the pain is repetitive microtrauma from faulty postures/movement patterns and/or inappropriate loading of the injured tissue. The clinician must address the underlying *cause* of the pain and functional impairment/participation restriction for long-term resolution of the condition.

It has been shown that there is an association between faulty scapulohumeral kinematics and RC disease.[11,46,47] Treating the *cause* of the RC impingement requires modifying the sustained postures and repetitive movement patterns believed to contribute to or perpetuate the faulty kinetics/kinematics. This training is far more specific than the basic activity modification described under treatment of the *source* of the pain. Altering sustained postures and repetitive movement patterns usually requires prior therapeutic exercise intervention focused on muscle performance, joint mobility, and soft-tissue extensibility. Improved physiologic capabilities provide a better foundation for optimal posture and movement control and tissue loading. For example, lower trapezius and serratus anterior muscles with an MMT grade of 3−/5 cannot fully participate in a muscular force couple to upwardly rotate, posterior tilt, and laterally rotate the scapula during arm elevation against gravity. Therapeutic exercise aimed at improving muscle performance of the upward rotators until they achieve a minimal MMT grade of 3 to 3+/5 is a prerequisite for retraining the coordinated muscular force couples required for functional movement patterns against gravity. As such, training the scapula and normalizing scapular kinematics is important prior to strengthening (loading) the RC musculature.

Shoulder rotation exercises are commonly employed to treat RC tendinopathy. Although these are frequently performed with the arm by the side, evidence derived from electromyographic studies indicates that the RC muscles can be recruited in a more specific manner when rotation is performed with the arm in 90 degrees of abduction[121,122] (see **Self-Management 25-1**). An alternate position to the position described here is in half kneeling with the humerus supported by the plinth in approximately 80 degrees of scaption. In these two positions, the RC can work, but the deltoid does not have to elevate the arm. As the RC functions to counterbalance potential destabilizing humeral head translation forces generated by muscles producing shoulder abduction, flexion, and extension, exercises incorporating these shoulder movements will preferentially target the important dynamic stabilizer function of the RC.[123]

Performing these exercises statically or dynamically in different parts of the available ROM can also address SC muscle function that is required for optimal RC function. Key to the

SELF-MANAGEMENT 25-1
Facelying Shoulder Rotation

Purpose: To strengthen the shoulder rotators and train independent motion between the shoulder blade and the arm

Starting Position: Kneel next to a weight bench; if at home, lie on your stomach adjacent to the edge of your bed. Place two or more rolled towels under your shoulder joint. Position your arm out to the side with the elbow bent to 90 degrees. Keep as much of your shoulder supported on the bench or bed as possible. Your arm should hang from your elbow down, not from your shoulder. Properly positioned, your elbow should be slightly lower than your shoulder and the "ball" of the "ball-and-socket" joint should be well supported with towel rolls.

Movement Technique:

Lateral rotation (target muscles: infraspinatus, teres minor)

- You may perform this exercise just by rotating your arm or with weight. If you are to perform this with weight, see the amount of weight you have been prescribed under dosage.
- Slowly rotate your shoulder so that your forearm moves up toward your head. Stop just short of horizontal.
- Concentrate on letting your arm move independent from your scapula. Your shoulder should "spin" in the socket. There should be no movement of your scapula.
- An alternate activity is to place your forearm on the table in the start position, slowly move your wrist off the supporting surface and hold your wrist and forearm isometrically for 5 to 10 seconds. Return your hand back to the supporting surface. Repeat for the designated number of repetitions.

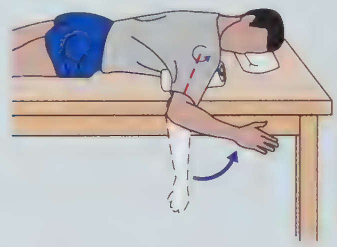
Dosage:

Weight: ____________________

Sets/Repetitions: ____________________

Frequency: ____________________

Lateral Rotation



Medial rotation (target muscle: subscapularis)

- You may perform this exercise by rotating your arm with or without added weight. If you perform this with weight, see the amount of weight you have been prescribed under dosage.
- Slowly rotate your shoulder in the opposite direction (from previously described) so that your forearm moves backward.
- Do not let your shoulder displace into the towel roll. Think of keeping your shoulder "pulled away" from the towel roll, or the "ball" in the "socket."
- Your ROM is more limited in medial rotation than lateral rotation (possibly only 10 to 20 degrees). Remember, it is quality, not quantity, that is important.

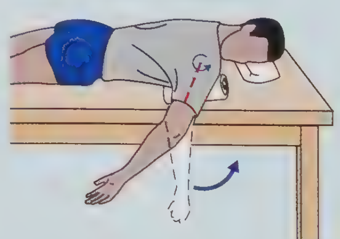
Dosage:

Weight: ____________________

Sets/Repetitions: ____________________

Frequency: ____________________

Medial Rotation



success of any RC exercise is activation of the scapulohumeral muscles (serratus anterior, rhomboid, and trapezius) to provide a stable muscular anchor for the scapula, thus preventing RC muscles, which have their origin on the scapula, from moving the scapula away from the midline into scapular internal rotation.[124]

As exercises are performed dynamically in higher ranges, SC muscles will need to function to not only counterbalance potential destabilizing translation forces produced by RC muscle contraction, but also to reposition the scapula to maintain optimal GH joint articular surface and RC muscle alignment. Active exercise treatment of RC tendinopathy is guided by strategies to manage tendon loading and to progressively restore the complex muscle coordination required for scapulohumeral rhythm and dynamic stability requirements at the shoulder.

Posture and movement education should be initiated as soon as possible to teach the patient internal locus of control over symptoms. To be successful in physical therapist management, patients must be mindful and consciously aware of how even subtle changes in posture and movements can affect symptoms.

Education and lifestyle need to be addressed as part of the treatment of RC tendinopathy. With respect to education, patients need to understand what has happened to the tendon and how this affects shoulder function and the importance of a structured exercise program, appreciating that the management of RC tendinopathy requires close attention to the relationship between pain and tissue healing. Adequate time and appropriate management are mandatory, and controlled movement/graded exercise should not create a trend in increased pain. Gradually, load and complexity of movement are introduced, as they are a necessary part of the rehabilitation process.

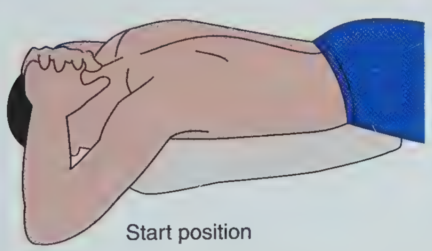
In the case presented in Display 25-4, the following impairments must be addressed to promote optimal posture and movement patterns:

- Muscle performance of the RC (see Self-Management 25-1), scapular upward rotators (see **Self-Managements 25-2** and **25-3**)

SELF-MANAGEMENT 25-2
Facelying Arm Lifts

Purpose: To strengthen the middle and lower trapezius.

Starting Position: Lie on your stomach with at least one pillow under your abdomen. Place your hands on the back of your head. Use this position for levels I through III.



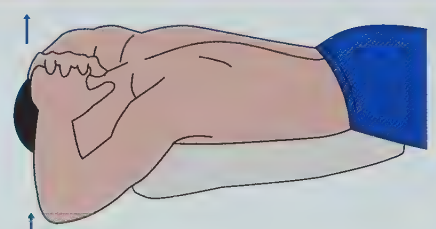
Start position

Movement Technique:

Level I: Stomach-lying elbow lifts (target muscles: middle and lower trapezius)

Barely lift your elbows. Keep your neck muscles (upper trapezius) relaxed, and contract the region between your shoulder blades (lower trapezius). Keep the contraction just enough to lift the elbows so as not to use rhomboids to adduct the shoulder blades.

- Hold the contraction for 5 seconds.
- Lower the elbows and repeat.
- Stop when your neck muscles become more tense; this is an indication that the middle and lower trapezius are fatiguing and that you should stop and rest.



Level I, end position

Dosage:

Sets/Repetitions: ______________________

Frequency: ______________________

Level II: Stomach-lying elbow lift with arms extended (target muscles: middle and lower trapezius)

Barely lift your elbows. Keep your neck muscles (uppter trapezius) relaxed, and contract the region between your shoulder blades (lower trapezius). Keep the contraction just enough to lift the elbows so as not to use rhomboids to adduct the shoulder blades.

- Slowly extend your elbows so that your arms are straight. Bend your elbows so that the hands return to the position behind your head.
- Relax your elbows to the table.
- Stop when your neck muscles become more tense; this is an indication that the middle and lower trapezius are fatiguing and you should stop and rest.

(continued)

SELF-MANAGEMENT 25-2
Facelying Arm Lifts (*continued*)

Level II, mid-position

Dosage:

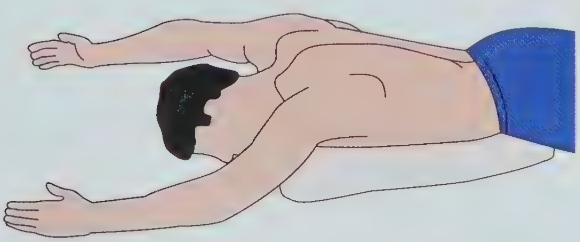
Sets/Repetitions: ______________________

Frequency: ______________________

Level III: Stomach-lying elbow lift with arm extension overhead (target muscles: middle and lower trapezius)

Barely lift your elbows. Keep your neck muscles (upper trapezius) relaxed, and contract the region between your shoulder blades (lower trapezius). Keep the contraction just enough to lift the elbows so as not to use rhomboids to adduct the shoulder blades.

- As you extend your elbows while raising your arms overhead, be sure not to tense your neck muscles (upper trapezius) during this level of exercise. If you are unable to keep your neck muscles relatively relaxed, you may not be ready for this level of exercise.
- Return your hands to your head, lower your elbows, and relax.



Level III

Dosage:

Sets/Repetitions: ______________________

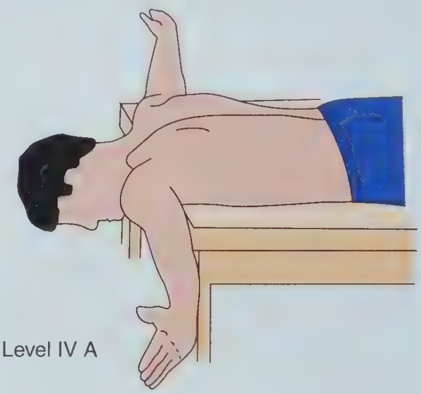
Frequency: ______________________

Starting Position: Lie on your stomach on a weight bench, piano bench, or low bed. Your chest should be suspended off the edge of the bench. Bend your knees if they extend too far off the bench. Pull your abdomen up and in. Your head should be in line with your spine with your chin tucked. Hold dumbbells with palms facing forward and thumbs up. Arms should be relaxed at chest level and resting on the floor or against the bench if the bench is tall. Keep elbows slightly bent.

Movement Technique:

Level IVA: Stomach-lying reverse horizontal fly (target muscle: middle trapezius)

- Raise the dumbbells in a semicircular motion to just below chest height. Do not lift beyond chest level.
- Lower to the starting position using the same path.
- Exhale up; inhale down.



Level IV A

Dosage:

Weights: ______________________

Sets/Repetitions: ______________________

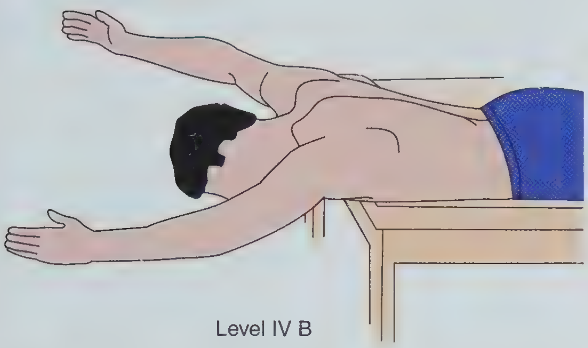
Frequency: ______________________

Level IVB: Stomach-lying diagonal reverse fly (target muscle: lower trapezius)

- Raise your elbows in a semicircular motion, diagonally upward toward the head to just below the level of the head. Do not lift the elbows above the level of the head.
- Lower to the starting position using the same path.
- Exhale up; inhale down.

SELF-MANAGEMENT 25-2
Facelying Arm Lifts (*continued*)

- Repeat in sets of 10 repetitions. Begin using a light weight when you can complete two sets of 10 repetitions maximum with proper technique.



Level IV B

Dosage:

Weight: ___________________________

Sets/Repetitions: ___________________________

Frequency: ___________________________

SELF-MANAGEMENT 25-3
Serratus Anterior Progression

Purpose: To progressively strengthen your serratus anterior

Level I: Backlying Isometric with Arm Overhead

Starting Position: Lie on your back with one to two pillows positioned above (not under) your head.

Movement Technique:
- Raise your arm overhead, close to your ear, until it reaches the pillow.
- Gently but consistently push your arm backward into the pillow and hold for 10 seconds.

Level I

Dosage:

Sets/Repetitions: ___________________________

Frequency: ___________________________

Level II: Sidelying with Dynamic Arm Slide

Starting Position: Lie on your side with two to three pillows in front of your head and shoulders. Bend your hips and knees. Rest your arm on the pillows with your elbow bent. Grasp the prescribed color of elastic band in your hand and attach the other end to your top foot.

Level II

Movement Technique:
- Slide your arm upward toward your head, keeping it in contact with the pillows.
- Slowly lower the arm back down to the starting position. Do not pull the arm back down, but slowly lower it against the resistance of the elastic.

(*continued*)

SELF-MANAGEMENT 25-3
Serratus Anterior Progression (*continued*)

Dosage:

Color of elastic: ______________________

Sets/Repetitions: ______________________

Frequency: ______________________

Level III: Standing Back to the Wall and Arm Lift

Starting Position: Stand with your feet about 2 to 3 inches from the wall. Your head should be against the wall. If you cannot bring your head against the wall, place one or two small, rolled hand towels behind your head. Pull in your stomach to rotate your pelvis backward and reduce the arch in your back. You should be able to place one hand between your lower back and the wall. If there is more space between your back and the wall, bend your hips and knees slightly to reduce the pull from your hip flexors. You should be able to reduce the arch of your back more easily.

Level III


Start

Movement Technique:

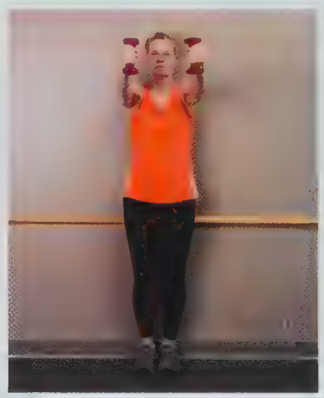
- Lift your arms in front of your body with your elbows straight.
- Try to bring the arms all the way back to the wall, but stop if you feel your back arching or your shoulders shrugging.
- Slowly lower your arms to your side, ensuring your shoulders stay back against the wall and do not roll forward.

Dosage:

Weight: ______________________

Sets/Repetitions: ______________________

Frequency: ______________________


Mid-position

- Muscle extensibility of the pectoralis minor (**Fig. 25-2**), rhomboids and levator scapula (**Fig. 25-3**), and GH lateral rotators (see **Self-Management 25-4**)
- Joint mobility of the AC, SC, GH joints, and the cervicothoracic junction, first rib articulations at T1 and the manubrium, and all thoracic vertebrae.

Often, altered length–tension properties of the scapular upward rotators exist due to prolonged posture habits (i.e., thoracic kyphosis leading to scapular tilt and lengthening of the serratus anterior and lower trapezius), and the exercises prescribed must be initiated at relatively low levels of intensity. For example, the patient should begin with level I of the lower trapezius (see Self-Management 25-2) and serratus anterior progressions (see Self-Management 25-3). Even so, improving the muscle performance of the lower trapezius, serratus anterior, and RC may not translate directly into improved function. Transitional exercises should be prescribed to train the muscle to function with the appropriate magnitude and timing during ADLs or instrumental ADLs. Examples of transitional exercises are shown in **Figure 25-4** (see **Building Block 25-1**).

Ineffective treatment of pain may result from failing to determine that the source of symptoms is not within the shoulder girdle. Even if the source is determined to come from an associated musculoskeletal region, ineffective treatment may nonetheless result from failing to recognize that the shoulder girdle may be contributing to the cycle of pain and dysfunction. For example, a patient may be diagnosed with radicular pain originating from an inflamed C5–C6 nerve root caused by a protruding nucleus pulposus at that level. However, it may be determined that faulty postures and movements of the shoulder girdle are contributing to faulty postures and movements of the cervical spine because of the shared musculature and

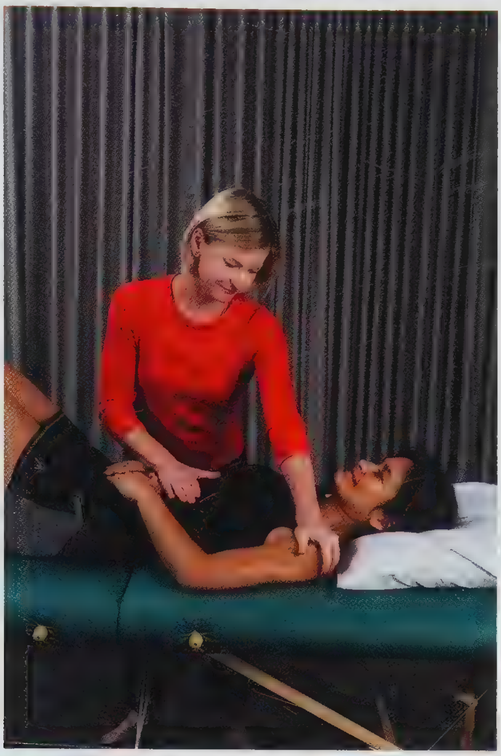


FIGURE 25-2 Manual stretch of the pectoralis minor. The hand applying the stretch force is placed over the coracoid process. A stabilizing hand can be placed over the rib cage. The force applied by the practitioner is in a posterior, superior, and lateral direction.

FIGURE 25-3 Rhomboid and levator stretch. The patient's elbow is resting on the practitioner's abdomen. The practitioner cups her hands around the scapula. By shifting the body weight from the caudal to the cranial positioned foot, a rotational force is transmitted to the scapula. The hands rotate the scapula upward like the scapular force couple.

SELF-MANAGEMENT 25-4
Lateral Rotator and Posterior Capsule Stretch

Purpose: To stretch the shoulder rotators and train independent movement between the shoulder blade and the arm

Starting Position: Slide your arm out to the side, and bend your elbow to 90 degrees. Position your forearm so that the fingers point to the ceiling. Hold your shoulder down with the opposite hand.

Movement Technique:
- Relax and let your shoulder joint rotate, allowing your forearm to move toward the floor.
- Do not let your shoulder come off the floor and move into your hand as your forearm gets closer to the floor.
- You may hold up to a 2-lb weight in your hand to assist in the stretch.

Dosage:

Hold the stretch for ______________ seconds

Sets/Repetitions: ______________

Frequency: ______________

Alternate Position: Lie on the side of your affected arm. Be sure to lie directly over your shoulder joint with your arm positioned perpendicular to your body and your elbow bent to 90 degrees.

Movement Technique:
- Using your free hand, place it on the backside of the wrist of the shoulder you are stretching. Gently perform an isometric contraction into your free hand. Hold for 6 seconds. Relax.
- On relaxing, move your forearm downward in the direction of your feet until you feel a mild stretch. Repeat the isometric contraction. Move your hand to the next barrier. Repeat three to four times.

(continued)

SELF-MANAGEMENT 25-4
Lateral Rotator and Posterior Capsule Stretch (*continued*)

A B C

FIGURE 25-4 Transitional rotator cuff (RC) exercises. **(A)** The patient places the ulnar aspects of the hands on the wall and slides the hands up the wall in the sagittal or scapular plane, depending on whether the focus is on the serratus anterior or lower trapezius, respectively. **(B)** Medial rotation bias. The patient places the palm of the hand against the doorframe and slides the hand upward and downward while maintaining a mild pressure into medial rotation against the doorframe. The patient must not push so hard that she recruits the pectoralis major, latissimus dorsi, and teres major. The goal is to use the subscapularis to encourage an increased RC force vector during arm elevation by facilitating subscapularis. **(C)** Lateral rotation bias. The patient places the dorsum of the hand against the doorframe and slides the hand upward and downward while maintaining a mild pressure into lateral rotation against the doorframe.

BUILDING BLOCK 25-1

Describe three more examples of faulty posture habits that alter scapula or humerus positions that can lead to altered length–tension properties. Name the faulty posture, the affected muscles, and which are prone to lengthening versus shortening.

joint articulations.[125] An example is a person with a depressed scapula at rest (**Fig. 25-5**) and insufficient elevation of the scapula during movement, particularly during the first half of the movement. This person may experience excessive tension on the cervical spine because of overstretching of the upper trapezius at rest and levator scapula during upward scapula

FIGURE 25-5 Slightly depressed right scapula.

rotation.[126] This excessive tension may compromise normal movement of the cervical spine and restrict cervical rotation with the arms at the side or simultaneously with movement of the shoulder girdle (e.g., driving a car and needing to look behind the shoulder). In this case, treating the cervical spine in isolation may not result in full functional recovery.[127] However, in this case, adding treatment of the posture and movement patterns of the shoulder girdle and the related shoulder impairments to the plan of care would be critical to treating symptoms originating in the cervical spine (see **Building Block 25-2**).

ROM and Joint Mobility Impairments

This category of impairments covers the scope of osteokinematic and arthrokinematic mobility from excessive ROM or joint hypermobility to reduced ROM or joint hypomobility. An example of extreme loss of mobility is adhesive capsulitis or frozen shoulder, and an example of extreme excessive mobility is GH dislocation. Mobility is a hallmark characteristic of the shoulder girdle. Even a minor alteration in mobility at any of the three joints of the shoulder girdle, cervicothoracic junction, or thoracic spine can disrupt the normal mechanics of the shoulder girdle.

For the purposes of simplifying terminology in this section, we have chosen to use the terms *hypomobility* when referring to either loss of ROM, reduced extensibility in soft tissues, or reduced joint mobility; and *hypermobility* when referring to excessive ROM, excessive muscle length, or excessive joint mobility.

Hypomobility and hypermobility impairments are intimately related. The "chicken and egg" dilemma exists when assigning causative factors; however, hypomobility is usually associated

BUILDING BLOCK 25-2

Intervention for pain originating from the cervical spine with an associated depressed scapula:

- Scapular taping into elevation and upward rotation (see "Adjunctive Interventions: Taping" later in this chapter)
- Upper trapezius and levator scapula strengthening
- Education regarding posture habits (e.g., do not allow the shoulder to assume a depressed position, keep arms supported at work station and during sustained periods of sitting such as during a movie)
- Movement retraining (i.e., initiating with upper trapezius initially to move the scapula to normal level of elevation, then retraining normal movement and recruitment patterns from an improved start position)

Upper trapezius strengthening into the short range. For patients with 3/5 muscle strength: the patient faces the wall and slides the ulnar aspect of the hand up the wall (see Fig. 25-4A). At the end range, scapula elevation is performed through available ROM (not pictured). For patients with 3+/5 to 5/5 muscle strength: patient performs an overhead press technique (start position—**Fig. A**). At end range, scapula elevation is performed through full available ROM (**Fig. B**) with scapula elevation at end range (**Fig. C**).

A B C

with a compensatory increase in motion at another joint in the kinetic chain (i.e., scapular elevation as compensation for lack of independent GH motion)[128] or a compensatory increase in a specific direction of accessory motion at the impaired segmental level (i.e., a stiff posterior GH capsule causing excessive anterior GH translation and anterior hypermobility).[129]

Hypomobility

Hypomobility cannot be treated as an isolated impairment. Numerous examples exist in the shoulder girdle complex depicting the intimate relationship between hypomobility and hypermobility. For example, if the scapula does not fully upwardly rotate during arm elevation, the arm and hand can reach the same endpoint by moving into excessive scapula elevation; or the humerus may compensate by translating excessively inferiorly.[61] When restoring balanced and coordinated motion to the shoulder girdle, mobility must be restored in the specific direction of the relatively less mobile joint. Simultaneously, the relatively more mobile segments must be protected from motion in the offending direction (i.e., external support such as bracing or taping and retraining movement patterns).

The method by which mobility is restored must be highly prescriptive and based on individual examination findings. To choose the appropriate intervention, structures responsible for the loss of mobility (i.e., muscle, periarticular tissue, bony restrictions), the direction of the loss of motion, and the severity of restriction must be determined. Any one or a combination of the three joints (SC, AC, GH) may be restricted in one or numerous directions because of articular or periarticular soft tissue or bony restrictions or loss of extensibility or adaptive shortening of myofascial tissue. If the restrictions are mild and the compensatory movements can be easily minimized, self-stretching, self-mobilization, and active exercise with mindful neuromuscular reeducation may suffice. However, if the restrictions are significant (higher levels of stiffness or involving more than one segment) or affect a specific arthrokinematic motion, manual joint mobilization, soft-tissue mobilization, and/or manual stretching may be indicated (see Chapter 7).

Stretching Stretching short or stiff myofascial tissue with a self-management program can be challenging in the shoulder girdle because of the complexity of the joint system and the ease of moving in compensatory patterns. For example, it is difficult to self-stretch a short rhomboid muscle that is limiting scapular upward rotation, because the compensatory motion may be to elevate the scapula, which does not result in a stretch to the rhomboids. Manual stretching (see Fig. 25-3) may be necessary to restore normal tissue extensibility to the rhomboids. Concurrent strengthening exercises for the scapular upward rotators (see Self-Managements 25-2 and 25-3) are encouraged until normal scapular upward rotation mobility is restored during active motion.

The same challenge can occur in attempting to stretch a short pectoralis minor that is causing excessive scapular anterior tilt during arm elevation. The traditional corner stretch (**Fig. 25-6**) can be ineffective because the head of the humerus can compensate by moving anteriorly into the relatively more flexible anterior capsule instead of stretching a short pectoral muscle. This action reflects a fundamental physical law: objects tend to move through the path of least resistance. In this case, the relatively flexible anterior capsule is the path of least resistance, and it stretches more readily than a short pectoralis minor. Even in the absence of compensatory anterior humeral head translation, research has shown that a posterior shift of the coracoid process with horizontal abduction might not be sufficient to stretch the pectoralis minor.[130] A simultaneous posterior and superior shift of the coracoid is more effective in stretching the pectoralis minor. Manual stretching (see Fig. 25-2) may be necessary until normal extensibility of the pectoralis minor is achieved. Stretching should be combined with strengthening of the lower trapezius (see Self-Management 25-2) and serratus anterior (see Self-Management 25-3) until normal movement is achieved.

FIGURE 25-6 Traditional pectoralis major and minor stretch.

In these examples, stretching the short muscle was combined with strengthening an antagonist muscle. This principle is important to restore muscle balance. In this case, stretching the pectoralis minor, rhomboid, or both muscles can be complemented with active exercise of the middle and lower trapezius and serratus anterior muscles in the shortened range.

Other common muscles in the shoulder girdle that require stretching include the GH lateral rotators and the medial rotator-adductor group. Although these often can be successfully self-stretched, special self-stabilization techniques should be employed to ensure compensatory motions do not occur. These exercises are illustrated in **Self-Managements** 25-4 and **25-5**, and **Figure 25-7**, respectively.

Stretching is ineffective if the improved flexibility does not translate into an improved functional outcome. Posture education is another important aspect to consider when treating mobility impairments. The patient must be educated to avoid postures that adaptively shorten the target soft tissues and lengthen the opposing ones. In the case of a short pectoralis minor, sitting or standing in kyphosis and forward head posture must be gradually reduced (see **Building Block 25-3**). Scapular taping can assist in improving postural habits (see "Adjunctive Interventions: Scapular Taping").

Active exercise through a functional range must be instructed and performed precisely to stretch the short soft tissues and recruit the lengthened and weak muscles with the optimal

SELF-MANAGEMENT 25-5
Latissimus Dorsi and Scapulohumeral Muscle Stretch

Purpose: To stretch the trunk muscles that attach to your arm and the muscles that originate on the shoulder blade and attach to your arm.

Starting Position:
- Lie on your back with your hips and knees bent and feet flat on the floor.

To stretch your scapulohumeral muscles, you need to prevent your shoulder blade from sliding out to the side. To do this, you need to hold the outside edge of your shoulder blade with the opposite hand.

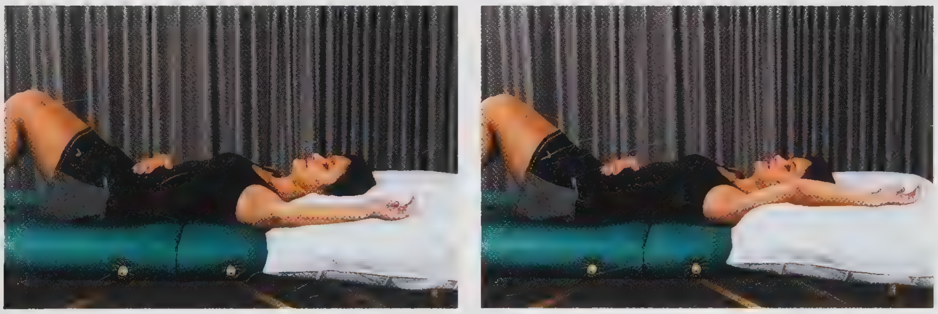
Movement Technique:
- Raise your arm over your head, keeping the arm close to your ear. When you feel your back arch or your shoulder blade slide out to the side, stop the movement.
- Rest your arm on the appropriate number of pillows so that your arm may relax in the position previously determined.
- Hold the stretch for the prescribed amount of time, and lower your arm back to your side. Keep your shoulder back as you lower your arm, and do not let it roll forward.

Dosage:

Hold the stretch for ______________________ seconds

Sets/Repetitions: ______________________

Frequency: ______________________



A B

FIGURE 25-7 Active pectoralis major stretch. **(A)** The patient rests her abducted and laterally rotated arms on pillows in the scapular plane. The pillows should be of sufficient height to prevent glenohumeral anterior translation. **(B)** The patient slides her arms upward until she feels a stretch across the pectoralis region. A static stretch can be maintained at the end position.

BUILDING BLOCK 25-3

What posture(s) would contribute to adaptive shortening of the pectoralis minor? Provide one tip to alter a postural habit to assist with long-term tissue changes for the pectoralis minor.

length–tension relationships. Though originally depicted as an exercise to promote function of the RC, Figure 25-4 can also be used to orient the scapula into upward rotation, placing the rhomboid in an elongated position. The kinematics of the scapula must be closely observed, and biofeedback provided to the patient regarding any deviation from the optimal scapular motion to ensure a lengthening stimulus is applied to the rhomboid muscle.

Effects of Immobilization Loss of ROM due to reduced muscle extensibility and joint hypomobility can occur as a result of imposed immobilization following an injury or self-immobilization resulting from pain, fear, or a deconditioned state. Immobilization should never be prolonged because of the tendency to develop myofascial shortening,[131] loss of capsular extensibility,[132] muscular,[133] tendon,[134] cartilage[135] changes, and disturbed motor control.[136] Immobilization resulting in hypomobility can cause widespread tissue changes, activity limitation, and participation restriction.

Movements associated with (increased) pain tend to be avoided, leading to increasing disability in the long run. To prevent self-imposed immobilization during painful periods or during the "rest" phase of healing, a cognitive-behavioral approach can be combined with carefully prescribed ROM exercises. Though it is beyond the scope of this text, a comprehensive review of the literature by Craske et al.[137] discusses exposure therapy, an inhibitory learning approach. Many techniques discussed can be used in combination with graded exposure from a mechanical perspective to reduce fear associated with movement.

Pain and fear avoidance can lead to deconditioning and incoordinated motor control which can lead to further pain during arm movements. In the early phases of tissue healing, a traditional gravity-lessened exercise in which GH motion is achieved is the Codman exercise, also called the pendulum exercise (**Fig. 25-8**). This exercise adds traction to the GH joint, stretches the capsule, avoids active abduction, and minimizes the common faulty movement pattern of scapular elevation during exercise against gravity. The rhythmic pendulum movements are believed to modulate pain.[138]

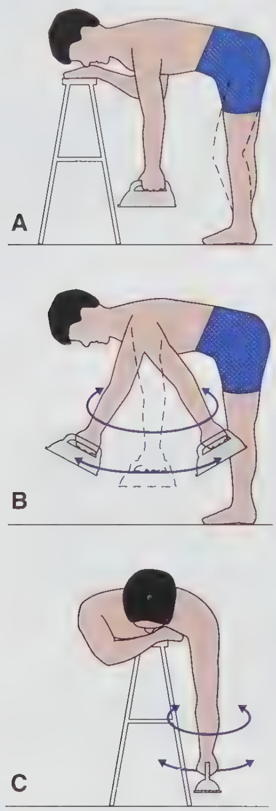


FIGURE 25-8 Pendulum exercise. **(A)** The patient should bend forward at the hips approximately 90 degrees, and his knees should be slightly bent to allow greater hip flexion and minimize stress to the low back. The patient should place the hand not being used in the exercise on a firm surface (e.g., stool) and place his head on the hand. This permits relaxed movement and concentration on the indicated movement of the involved shoulder. The involved arm should dangle freely, and a weight can be held in the hand. Use of an iron as a weight is suggested for home exercise. A weight adds traction to the glenohumeral (GH) joint and widens the pendulum arc. The patient should maintain the thoracic spine in neutral to prevent excessive scapula abduction, so as to transmit the forces from the weight to the GH joint rather than the scapulothoracic joint. **(B** and **C)** Pendulum exercises are done passively; no muscular action of the GH joint is required. Instead, muscular effort of the trunk and hips allows the body to sway and the arm to swing in sagittal, frontal, and transverse planes of motion. The exercise can be progressed to active exercise by actively swinging the arm in the same planes and arcs of motion. (Adapted from Cailliet R. Shoulder Pain. Philadelphia, PA: FA Davis, 1966.)

Hypermobility

Glenohumeral joint stability is provided by several mechanisms: static stabilizers including bony surfaces, the capsuloligamentous structures, the glenoid labrum, the negative intraarticular pressure, and the dynamic stabilizers (the RC) that actively center the humerus in the glenoid.[139–142]

To effectively treat hypermobility or instability in the absence of a traumatic onset, the hypomobile segments must also be identified. Hypermobility does not improve despite aggressive exercise protocols if it is occurring in response to a less mobile segment. For example, the GH joint may become hypermobile in the anterior direction in response to a hypomobile scapula in the direction of SC retraction. Consider all the shoulder girdle and thoracic segments that must move in harmony to achieve functional movements. If one of the segments is hypomobile, this will impose excessive motion on one or more other segments. Consider the scenario of reaching behind the back (see **Building Block 25-4**).

When reaching behind the back, if the scapula fails to move three-dimensionally into a more adducted and downward rotated position, it becomes a barrier to the head of the humerus. If the goal is to reach behind the back, the humerus may compensate by translating into the anterior capsule. Lack of scapular adduction is the result of reduced SC retraction and/or AC lateral rotation; lack of scapular downward rotation is the result of reduced SC depression and/or anterior/inferior rotation and/or AC downward rotation. Attention to restrictions in these joints in the related directions is pivotal to treatment of the anterior GH hypermobility.

This is just one functional example of how the humerus may compensate with excessive anterior translation, but if this compensation is repeated throughout daily activities, hypermobility results in the GH joint in the anterior direction. Treatment must focus on the underlying *cause(s)* of the hypermobility by improving mobility of the relatively less mobile segments and concurrently reducing mobility at the relatively more mobile segments. Improving the muscle performance, length–tension properties, and motor control of the dynamic stabilizers in the relatively more mobile direction is the recommended approach to decrease excessive or abnormal mobility. Specific exercise to remedy impairments associated with faulty movement patterns must be included in the plan of care. Ultimately, the functional movement patterns causing the hypermobility must be addressed (e.g., retraining scapular adduction and downward rotation at the appropriate time in the coordinated hand behind back movement pattern).

An impairment commonly associated with a faulty movement pattern that contributes to an anterior GH hypermobility is impaired muscle performance and altered length–tension

BUILDING BLOCK 25-4

Break down the composite motions at the GH, AC, and SC joints necessary to achieve the hand behind the back position.

properties of the GH medial rotators. Among the dynamic stabilizers, the subscapularis provides the greatest degree of stabilization of the abducted and externally rotated humerus (i.e., cocking phase of pitching), a position known to be critical for shoulders with anteroinferior instability.[143–145] This contention is supported by electromyographic findings.[146–148]

To isolate subscapularis function from the other medial rotators (i.e., pectoralis major, latissimus dorsi, and teres major), its unique function must be promoted by carefully prescribing the posture and movement parameters of the activity chosen.

An exercise to improve the muscle performance and length–tension properties of a lengthened subscapularis is prone medial rotation (see **Self-Management 25-6**). If the subscapularis can produce enough force to rotate the arm against gravity, prone is the desired position for the patient to perform medial rotation.[61] Prone medial rotation poses a greater challenge to the subscapularis to prevent the humerus from translating anteriorly than a supine position, in which gravity assists the humerus posteriorly. Theoretically, if the other medial rotators dominate the subscapularis during this exercise, anterior translation during medial rotation will occur. Decker et al.[149] demonstrated that internal rotation (IR) at 90 degrees of abduction produced less pectoralis major activity compared to 0 degrees of abduction. Pectoralis major and latissimus dorsi activity increase when performing IR exercises in an adducted position or while moving into an adducted position during the exercise.[150] Thus, IR at 90 degrees of abduction is recommended if attempting to strengthen the subscapularis while minimizing larger muscle group activity.

The goal in this case is to strengthen the subscapularis to prevent abnormal or excessive anterior translation of the head of the humerus during GH medial rotation and during other functional movement patterns. Resolution of this impairment does not necessarily translate into a functional outcome unless the muscle is specifically trained during functional activities. The subscapularis muscle is kinesthetically limited, and it cannot be palpated or recorded with surface EMG. The clinician's best indication that it is working is to observe or palpate movement of the head of the humerus during functional activities. Because movement occurs rapidly and the movement is difficult to observe, videotaping the movement can be useful for carefully analyzing movement.

If the humeral head appears to be translating excessively anteriorly during function, particularly if symptoms of instability or pain are present, the clinician must determine whether the problem is caused by impairments in active range of motion (AROM), passive range of motion (PROM), or neuromuscular coordination, or some combination (most typical). An active impairment may be caused by insufficient subscapularis force capability and/or length–tension properties.

Poor neuromuscular coordination (motor control) may be due to poor timing between the cuff muscles and torque producers. Methods to improve motor control include verbal, visual (e.g., patient views a videotape of their performance to gain understanding of the movement pattern), or tactile feedback to provide knowledge of results. Verbal cueing might include "think of sucking the ball into the socket," or "imagine the ball is on a skewer and you are sliding it into the socket." These verbal cues might augment the concavity compression role of the subscapularis and improve GH stability.

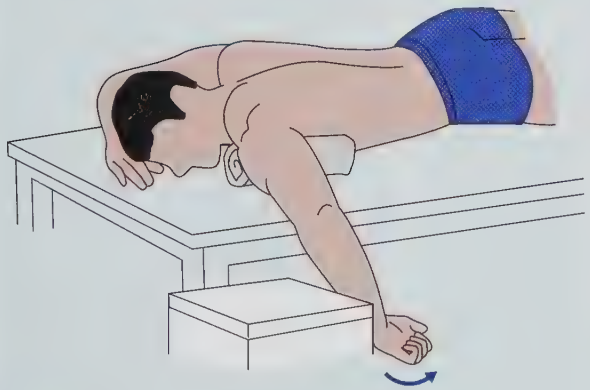
Passive impairment may include laxity in the anterior capsuloligamentous structures with correlating relative stiffness in the posterior structures. Postural faults may include increased thoracic flexion preventing adequate scapular adduction during horizontal arm abduction, or limited thoracic rotation in a more global movement (such as with the cocking phase of pitching), and thereby leading to excessive GH anterior translation. Attention to the posture and associated movement of the thoracic spine may be critical to ultimately improve the GH movement pattern.

SELF-MANAGEMENT 25-6
Subscapularis Isometric Exercise

Purpose: To strengthen the subscapularis in the short range

Starting Position: Kneel next to a weight bench; if at home, lie on your stomach adjacent to the edge of your bed. Place one or two towels rolled under your shoulder. Position your arm out to the side with elbow bent to 90 degrees. Keep as much of your shoulder supported on the bench or bed. Your arm should hang down from your elbow, not your shoulder. Rotate your arm backward as far as you can before you feel the "ball" drop out of the socket. Position a garbage can or another object sufficient to support your arm.

Movement Technique:
- Raise your hand ½ in off the garbage can, and hold it for 10 seconds.
- Be sure the "ball" does not drop out of the socket.
- Lower your hand back to the garbage can.



Dosage:

Sets/Repetitions: ____________________

Frequency: ____________________

Impaired Muscle Performance

As discussed in the examination/evaluation section, impaired muscle performance can result from numerous causes. This section discusses therapeutic exercise intervention for each major cause of impaired muscle performance.

Neurologic Pathology

Neurologic pathology can lead to sensory or motor changes and can occur at the nerve root level or as a result of a peripheral nerve injury. Thorough examination and evaluation can determine the anatomic site of the neurologic deficit. A thorough discussion of thoracic outlet syndrome can be found in Chapter 24.

Alterations in neurologic function at the nerve root level from cervical involvement can be a source of impaired muscle performance in the shoulder girdle musculature. For example, mechanical dysfunction of the C4 or C5 levels can affect the C5 nerve root, and may result in weak abduction, flexion, medial, or lateral rotation.[151] Strength-related activities will not improve muscle performance in the shoulder until the cause of neural impairment at the level of the cervical spine is addressed (see Chapter 23, The Cervical Spine, for concepts related to therapeutic exercise intervention of the cervical spine). If the underlying cause of impaired muscle performance is due to impairment of the nerve root, the position of the cervical spine with respect to the trunk and the shoulders is extremely important when performing shoulder exercises.

Another common neurologic deficit involving the shoulder girdle is injury of a peripheral nerve resulting from traction, compression, trauma, or surgery. Nerves that are vulnerable to injury are depicted in **Display 25-5**. Nerve injury often results in weakness of the innervated muscles. Injury to the long thoracic nerve is discussed to demonstrate the resulting muscle performance impairments and the related therapeutic exercise intervention.

Long Thoracic Nerve Injury The long thoracic nerve is purely a motor nerve that originates from the ventral rami of the fifth, sixth, and seventh cervical roots. It is the sole innervation to the serratus anterior muscle. The fifth and sixth cervical roots, along with the dorsal scapular nerve, pass through the substance of the scalenus medius muscle, whereas the seventh cervical root passes anterior to it.[158] The nerve then travels beneath the brachial plexus and clavicle to pass over the first rib. From there, it descends along the lateral aspect of the chest wall, where it innervates the serratus anterior muscle. The nerve extends as far inferior as the eighth or ninth rib. This long, relatively superficial course makes it susceptible to injury (**Evidence and Research 25-8**).

DISPLAY 25-5

Peripheral Nerve Injury/Entrapment Sites for the Shoulder Girdle

Nerve	Site of Injury/Entrapment
Suprascapular	Suprascapular notch[152,153]
Axillary	Between teres major and minor (quadrangular space)[154]
Long thoracic	Middle axillary line[155]
Spinal accessory	Jugular foramen or posterior triangle[156,157]

EVIDENCE and RESEARCH 25-8

Mechanisms of Nerve Injury to the Long Thoracic Nerve

The stretching capacity of a peripheral nerve is estimated at 8% to 15%.[159–160] In research into human cadavers, in which the head was turned to the opposite shoulder while elevating the ipsilateral arm, the long thoracic nerve could be stretched twice its length.[161] Pathomechanics postulated to cause injury to the long thoracic nerve include entrapment of the fifth and sixth cervical roots as they pass through the scalenus medius muscle, compression of the nerve during traction to the upper extremity by the undersurface of the scapula as the nerve crosses over the second rib, and compression and traction to the nerve by the inferior angle of the scapula during general anesthesia or passive abduction of the arm.[159,162,163]

One additional plausible cause of injury is traction to the nerve in the presence of a depressed scapula on the rib cage (e.g., carrying a heavy bag with the strap over the shoulder). Depressed scapula is often seen as a sequela in cervical dysfunction to the C5, C6 segmental levels.[164]

Injury to the long thoracic nerve manifests as weakness of the serratus anterior, a critical muscle for normal scapular mechanics. A hallmark sign for long thoracic nerve injury is scapular winging at rest that is exaggerated during arm elevation, arm lowering, or pushing. The pathomechanics that contributed to the injury must first be resolved before strength-related activities can be effective. In the case of a traction injury to the long thoracic nerve, the postures and body mechanics that cause depression of the scapula must be addressed. Strength exercises for the scapular elevators (e.g., upper trapezius) are often necessary. Taping the scapula into elevation may also be required to relieve the tension on the nerve (see Adjunctive Interventions: Scapular Taping).

To develop a working prognosis, one must consider the anatomy of the long thoracic nerve. From its origin at the root of C5–C7 to the insertion into the serratus anterior, the nerve travels approximately 35 cm. Recovery of the nerve is a very slow process: about 1 cm per week. Recovery may occur between a few months and 2 years.[159] Initially, neuromuscular electrical stimulation (NMES) can be used to prevent muscle atrophy.[165] NMES can be used with biphasic pulses in burst mode applied via electrodes over the motor points of the affected serratus anterior.[166] Self-Management 25-3 can be used in conjunction with NMES for the prevention of atrophy initially and later to reeducate the serratus anterior as motor function returns.

Passive ROM exercises can be prescribed and manual joint mobilization techniques can be applied to the GH joint and ST articulation to prevent loss of mobility in the early stages. As reinnervation of the muscle occurs, a progressive strengthening exercise program must be introduced. Several exercises elicit high serratus anterior activity.[167–171] **Display 25-6** lists commonly prescribed exercises.

A general rule of thumb to consider in functionally strengthening the serratus anterior is that its activity tends to increase in a somewhat linear fashion with arm elevation.[35,168,170–173] Though one would not initially consider performing shoulder IR and ER at 90 degrees of abduction (see Self-Management 25-1) to generate serratus anterior activity, these are excellent choices

DISPLAY 25-6

Commonly Prescribed Serratus Anterior Exercises

- D1 and D2 diagonal proprioceptive neuromuscular facilitation (PNF) pattern flexion (see Chapter 15)
- D2 diagonal PNF pattern extension (see Chapter 15)
- Supine scapular protraction
- Supine upward scapular punch
- Military press
- Push-up plus
- GH, IR, and external rotation (ER) at 90-degree abduction
- Shoulder flexion, abduction, and scaption with ER above 120 degrees.

because the role of the serratus is to stabilize the scapula against the forces exerted by the RC.[168] For example, the force exerted by the supraspinatus at the supraspinous fossa has the ability to downwardly rotate or internally rotate the scapula if this force is not counterbalanced by the ST musculature. Following the principle of specificity of training, when possible, the exercise should duplicate the function of the serratus anterior.

Decker et al.[167] compared several common exercises designed to recruit the serratus anterior. The authors identified that the three exercises that produced the greatest serratus anterior EMG signal were the push-up with a plus, dynamic hug (see **Fig. 25-9**), and punch exercises (similar to a jabbing protraction motion; see **Fig. 25-10**).

Despite the high activation levels of the serratus anterior during protraction patterns, this author recommends caution in promoting the protraction function of the serratus anterior. Normal upper quarter (UQ) kinematics involve a combination of scapula upward rotation, posterior tilt, and external rotation.[35] The clavicle retracts during normal UQ elevation, which is coupled with scapula external rotation (an important function of the serratus as well as an important kinematic to prevent subacromial impingement).[21,35,63,170–174] Training scapular protraction movement patterns could be detrimental to restoring ideal shoulder girdle kinematics.

An alternative exercise that has been shown to be an effective method to strengthen the serratus anterior is the wall slide (see Fig. 25-4).[173] Interestingly, the wall slide produces similar serratus anterior activity compared to scapular abduction above 120-degree abduction with no resistance.[173] One advantage of the wall slide compared to scapular abduction is that, anecdotally, patients report that the wall slide is less painful to perform. This may be because during the wall slide, the upper extremities are supported against the wall, making it easier to perform while also assisting with inferior glide and compression of the humeral head within the glenoid. Thus, this may be an effective exercise to perform during the earlier protective phases of rehabilitation.

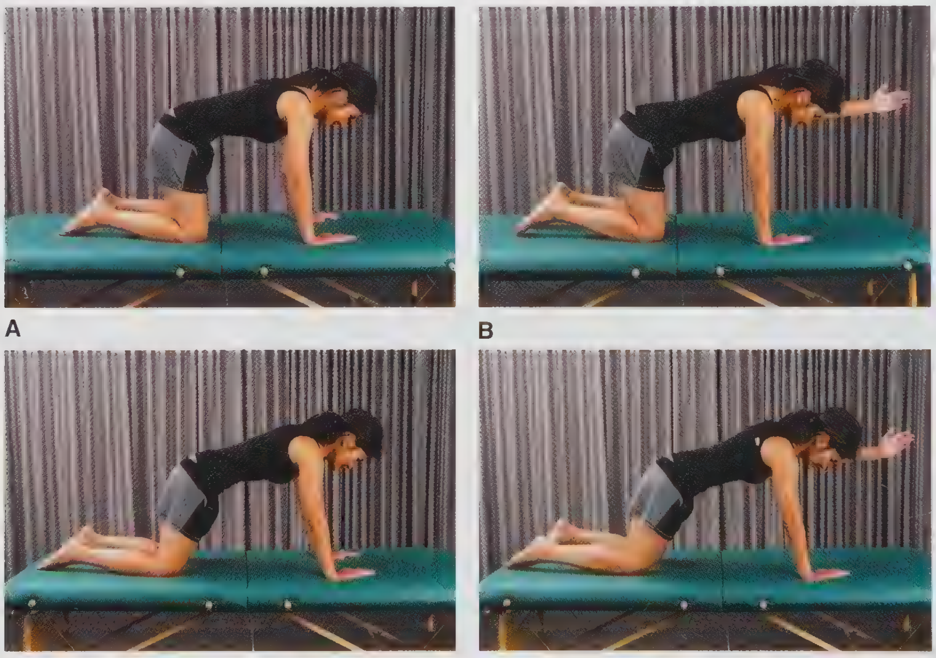
The hand-knee position is an alternative position to provide resistance to the serratus anterior. **Figure 25-11** illustrates an initial progression on hands and knees. The goal with this exercise is to support the body weight through the affected upper extremity without scapular adduction or winging. Stepping the knees behind the hips increases the weight the arms must support, thus increasing the strength demand on the serratus anterior (see Fig. 25-11C and D). This exercise can be progressed to a push-up position. The desired position for a "serratus push-up" is modified from the traditional "pectoral push-up" by positioning the olecranon and antecubital fossa in the sagittal plane. This modified position is also called a "triceps push-up" or a "pilates"

A B C

FIGURE 25-9 Dynamic hug for the serratus anterior begins with elbows flexed 90 degrees and arms at side **(A)**. The next motion is elbow extension with humeral internal rotation **(B)**. The ending position is with the humerus in full internal rotation, elbows flexed slightly, and humerus moving into horizontal adduction similar to a "hugging" motion until full acromioclavicular protraction is reached **(C)**.

A B

FIGURE 25-10 Bilateral serratus anterior punch to 120-degree abduction begins with hands by the side **(A)** before extending elbows and elevating shoulders up to 120 degrees of elevation and full protraction **(B)**.



A B C D

FIGURE 25-11 Progressive serratus strengthening exercises. **(A)** The patient assumes a quadruped position, with the hips directly over the knees and the shoulders directly over the hands. The scapula should be flat against the rib cage in neutral position. **(B)** The patient then lifts the opposite hand slightly off the ground. The supporting shoulder girdle should not demonstrate any alteration in scapular position. **(C)** The patient assumes a quadruped position, with the hips slightly in front of the knees and shoulders directly over the hands. The scapula should be flat against the rib cage in neutral position. **(D)** The patient then lifts the opposite hand slightly off the ground. The supporting shoulder girdle should not demonstrate any alteration in scapular position. **(E)** "Serratus push-up." The patient assumes the position shown. The hips should be in neutral with respect to the sagittal plane. This subject is in more hip flexion than is desirable. The scapula should be resting against the rib cage in a neutral position. The elbows should be in the sagittal plane with the olecranon process facing posteriorly and the antecubital fossa facing anteriorly. The fingers should be directed forward with the wrist in extension; a small towel roll may be placed under the palm of the hand to reduce the amount of wrist extension if full wrist extension is uncomfortable. **(F)** The patient slowly lowers his body toward the floor while maintaining neutral pelvis and spine alignment. The elbows should flex in the sagittal plane (sometimes called a triceps push-up). The scapula should abduct and adduct during the movement. Evidence of winging or lack of abduction indicates the load is too great or the muscle has fatigued. **(G)** The patient is positioned as in **(E)** and **(F)**, but the legs are straight. **(G,H)** The exercise proceeds as in **(E)** and **(F)**.

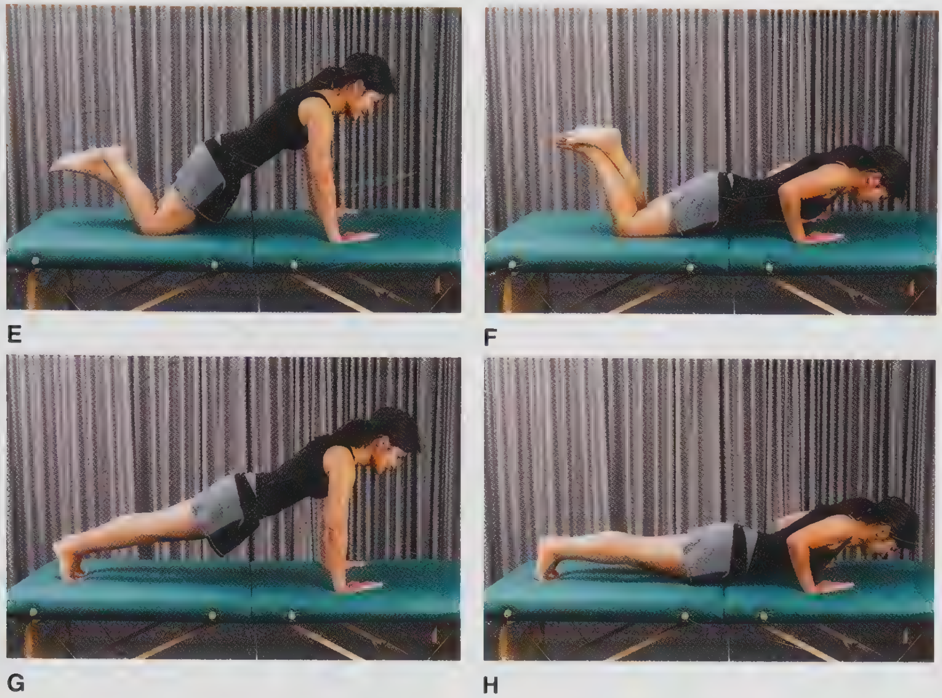


FIGURE 25-11 (*continued*)

push-up. To progress the level of difficulty, the exercise can be performed first in the bent-knee position (see Fig. 25-11E and F) and then progressed to a straight-body position (see Fig. 25-11G and H) if higher levels of performance using the serratus anterior are required. Though the "plus" movement of the scapula during a push-up does generate high serratus activation levels,[167–171,175] caution is recommended in promoting this additional movement due to the aforementioned reasons.

The clinician must consider the most critical function(s) to restore and consider the posture, mode, movement, and dosage parameters based upon the examination findings. A clinical example detailed in **Display 25-7** can provide a platform for prescribing a therapeutic exercise intervention (see **Building Block 25-5**).

DISPLAY 25-7

Clinical Scenario for Traction Injury to Long Thoracic Nerve

A 39-year-old female homemaker injured her long thoracic nerve from constantly carrying a diaper bag and her 25-lb toddler on her left side. The MMT grade of her serratus anterior at the time of initial examination is 3/5. Her functional goals are to be able to perform ADLs and instrumental ADLs of a full-time homemaker. She is not involved in any upper extremity sports or recreational activities.

BUILDING BLOCK 25-5

Based upon the clinical example described in Display 26-7, outline three progressive exercises for the serratus anterior for this patient, starting with her baseline muscle performance up to a grade of 4/5.

Muscle Strain

Muscle strain results from an injurious tension. Muscle strain can result from a sudden and excessive tension (macrotrauma) or from a gradual and continuous tension imposed on a muscle (microtrauma). Both types of muscle strain commonly occur in the shoulder girdle.

An example of a muscle strain caused by sudden and excessive tension imposed on a muscle is a sudden fall onto the shoulder or outstretched arm, resulting in a RC strain or complete tear. The examination may reveal weakness in some or all portions of the RC. Selective tissue tension tests may also reveal pain with resistive testing and stretch, depending on the severity of the strain.

Treatment of strains should follow the guidelines for tissue healing outlined in Chapter 11. After a short period of rest during the early repair phase (5 to 7 days),[176–178] low-load muscle contraction can be introduced in the repair-regeneration phase to impose a load on the healing tissue along lines of stress. Exercise during this phase is crucial for the regeneration on the molecular level and for correct orientation of the regenerating myofibers.[179–183] Initially, submaximal isometric contractions at various positions within the pain-free range can be prescribed (2 to 7 weeks)[182,183] Alternatively or in addition, concentric-eccentric dynamic exercise can be prescribed. Dosage parameters related to the load, starting, and ending positions, and ROM depend on the severity of the strain. More aggressive strength regimens can be gradually introduced in the later stages of the repair-regeneration phase to prepare the muscle for the final phase of healing (**Fig. 25-12**). The type of contraction and specific movement pattern required of the muscle should be trained as early as possible. For example, prevention of excessive humeral head superior translation is a specific and necessary function for the RC during arm elevation (concentric) and the

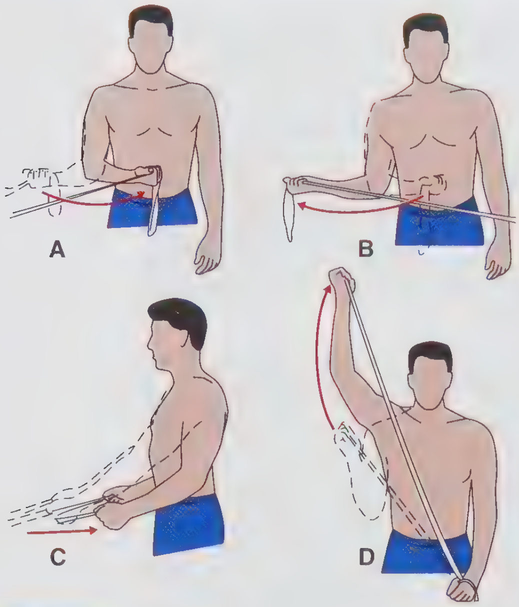


FIGURE 25-12 Higher-level rotator cuff exercise using elastic tubing. The therapist must ensure precise motion at the glenohumeral (GH) joint and provide biofeedback to the patient regarding the path of instant center of rotation (PICR) of the scapulothoracic (ST) joint during these movements. **(A)** Medial rotation. Caution must be taken to prevent scapula abduction and medial rotation during GH medial rotation. **(B)** Lateral rotation. Caution must be taken to prevent scapula adduction during GH lateral rotation. **(C)** Extension. Caution must be taken to move the elbow only slightly posterior to the midaxillary line to prevent excessive anterior displacement of the humeral head. **(D)** Flexion. Caution must be taken to ensure optimal PICR of the ST joint during arm elevation and control over superior translation of the humeral head.

return from arm elevation. The final phase of healing (7+ weeks) should include activity-specific exercises related to the patient's functional goals. Complex functional movement patterns can be trained, and a gradual return to sport-specific activities, such as returning to a pitching program (**Display 25-8**),[184,185] can be accomplished. Quality of movement during exercise and functional activities must be emphasized and used as a guide for progression at any stage.

Another form of strain common in the shoulder girdle is the type resulting from gradual and continuous tension (microtrauma). For example, strain to the middle and lower trapezius often results from a habitual position of abducted and downwardly rotated scapulae found in thoracic kyphosis. Subjective and objective characteristics of middle/lower trapezius strain include[61]:

- Symptoms of "burning" pain along the course of the middle or lower trapezius may be experienced. If the strain is not accompanied by adaptive shortening of the anterior muscles, pain is not constant and can be relieved in the recumbent position. However, change of position does not affect the symptoms of a person with associated adaptive anterior shortness.
- Heavy breasts that are not adequately supported.
- Positional weakness in the middle and lower trapezius.
- Adaptive shortening of the pectoralis major and minor and other internal rotators.

DISPLAY 25-8

Nine-Level Rehabilitation Throwing Program*

Level	Throws/Feet	Throws/Feet	Throws/Feet
1	25/25	25/60	
2	25/25	50/60	
3	25/25	75/60	
4	25/25	50/60	25/90
5	25/25	50/60	25/120
6	25/25	50/60	25/150
7	25/25	50/60	25/180
8	25/25	50/60	25/210
9	25/25	50/60	25/240

**This program is designed for athletes to work at their own pace to develop the necessary arm strength to begin throwing from a mound. The athlete is to throw 2 days in a row and then rest for 1 day. It is not important to progress to the next throwing level with each outing. It is preferred that a number of outings at the same level be completed before progressing. It is important to throw with comfort, which may necessitate moving back a level on occasion.*

DiGiovine NM, Jobe FW, Pink M, et al. An electromyographic analysis of the upper extremity in pitching. J Shoulder Elbow Surg 1992;1:15–25.

Treatment in the early healing phase should include support in the form of taping (see the "Adjunctive Interventions: Taping" section), posture garment (**Fig. 25-13**), or supportive brassiere to relieve the tension on the middle and lower trapezius. If shortness affects the shoulder medial rotator and adductor group, gradual stretching (see Fig. 25-7, Self-Managements 25-2 and 25-4) is indicated before strengthening the middle and lower trapezius. Stretching allows the middle and lower trapezius to be strengthened at the appropriate length.

Exercises to strengthen the middle and lower trapezius muscles should not only consider the function of these muscle fiber directions, but also the length at which the muscles are being strengthened. The lengthened range must be avoided to prevent further strain to the muscle. Lengthened muscles produce less force or torque in the short range; therefore, initial exercises may need to be performed in gravity-lessened positions. The gravity-lessened position decreases the load on the lengthened muscle so it can produce sufficient force or torque in the short range. **Figure 25-14** depicts a strengthening exercise for the lower trapezius in a gravity-lessened position. Prone horizontal abduction between 90 and 135 degrees of abduction in ER has been shown to demonstrate high levels of middle and lower trapezius activation.[168] The progressive exercises shown in Self-Management 25-2 demonstrate a progression of load using these positions to activate the middle and lower trapezius fibers. Exercise prescription can proceed to this progression once when force capability can be produced in the short range against the higher loads imposed by longer lever arms and the introduction of gravity. Figure 25-4 and Self-Management 25-4, Level III can be used, with the emphasis on optimal length–tension properties of the lower trapezius, timing of activation with respect to the

FIGURE 25-13 Posture garment.

upper trapezius and serratus anterior optimal ST kinematics, and concentric/eccentric control.

One of the ultimate goals is to alter length–tension properties of both lengthened and shortened muscles. New length–tension properties of the affected musculature should be achieved if the following conditions are met:

- Strengthening in the shortened range is combined with proper support for the middle and lower trapezius.
- Stretch is applied to the anterior musculature (i.e., pectoralis minor, pectoralis major, short head of biceps).
- Education is provided regarding improved postures, movement patterns, workstation ergonomics, and body mechanics.

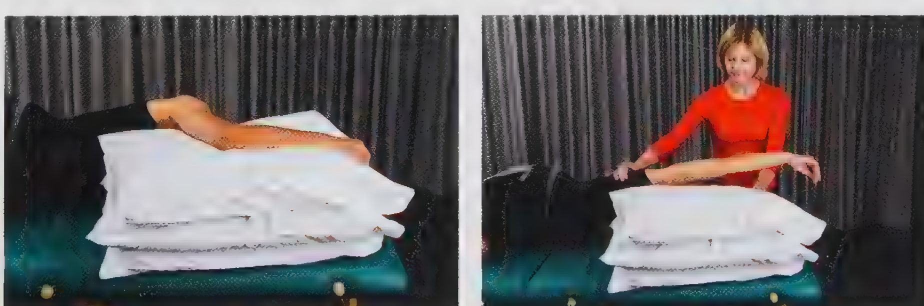
Use of these concepts and principles will result in alleviating the precipitating pathomechanics to allow the strain to heal.

Disuse, Deconditioning, and Reduced Conditioning

In some cases, muscles become weak because of disuse or deconditioning or may not be able to produce enough force or torque to enable an individual to achieve higher levels of performance. Impaired muscle performance due to disuse or lack of conditioning can manifest as alterations in performance of ADLs, instrumental ADLs, recreation, leisure activity, or sports. Muscle performance impairments can be caused by many forms of disuse or deconditioning:

- Gradual development of subtle alterations in agonist–antagonist relationships caused by habitual postures or repetitive movement patterns, which can create problems related to muscle balance (e.g., insidious onset of shoulder impingement without evidence of anatomic impairments as a precipitating factor)[61]
- Generalized weakness from prolonged rest or reduction in activity, preventing performance of ADLs and instrumental ADLs (e.g., dressing, meal preparation, housework)
- Decreased power output preventing maximal performance of a high strength-demand sport, such as swimming, tennis, or baseball/softball.

The shoulder girdle poses a challenge for the clinician prescribing a general strength-conditioning program because of the potential for creating muscle imbalances. A conditioning program should include exercises for all major muscle groups. The posture and movement of the technique are critical to a successful program. For example, if a biceps curl is done with poor technique (i.e., anterior scapular tilt is increased during the elbow flexion motion) rather than optimal technique (i.e., scapula remains neutral with respect to tilt during the elbow flexion motion with proper stabilization from the axioscapular muscles), the patient risks development of impaired muscle length–tension properties of the scapular stabilizers, which could cause secondary impairments or pathology (e.g., subacromial impingement from a scapula functioning in excessive anterior tilt). This risk increases if the same faulty posture is used during a variety of other exercises. **Display 25-9** summarizes exercises that are recommended for inclusion in a general shoulder girdle conditioning program.



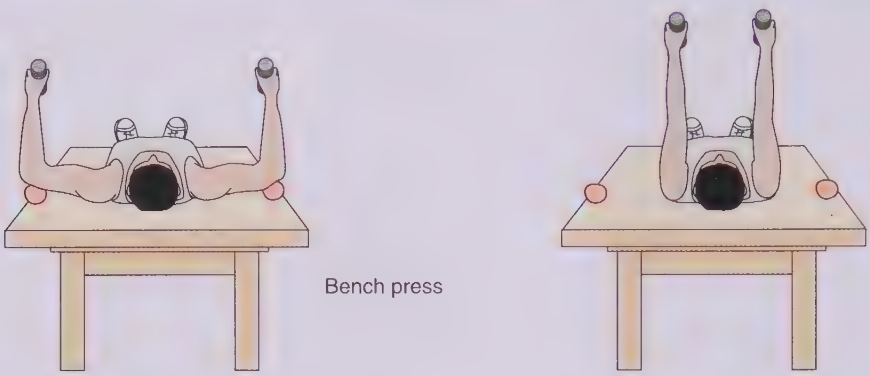
A B

FIGURE 25-14 Gravity-lessened position to strengthen lower trapezius. **(A)** Position the patient in sidelying with as many pillows as necessary to support the arm in the sagittal or scapular plane. The arm rests on the pillow at 90 degrees of elevation with the elbow bent. **(B)** Slide the arm upward toward full elevation. The scapulothoracic and glenohumeral joint path of instant center of rotation should be monitored for any deviations. Once full available upward rotation is achieved, the patient lifts the arm 1 to 2 in off the pillow. An isometric contraction of the lower trapezius is held for the specified duration. Care must be taken to lift the entire arm, and not just the elbow.

DISPLAY 25-9

Shoulder Girdle Conditioning Program

- Bench press (flat, incline, decline)



Bench press

- Prone middle and lower trapezius via prone horizontal abduction at 90 and 135 degrees

Prone middle trapezius — Prone lower trapezius

- Latissimus pulldown

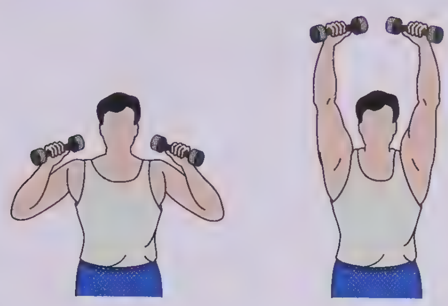
- Lateral deltoid raise—in frontal plane or scaption (through full ROM)

Wall arm lift scapular plane — Lift through full range to wall

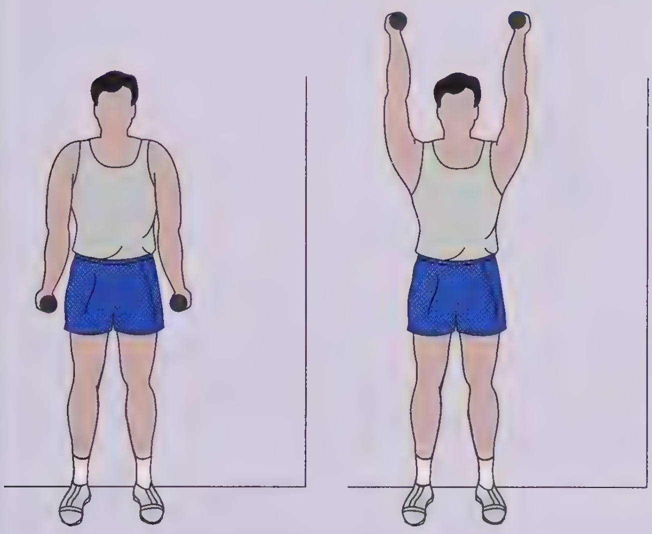
DISPLAY 25-9

Shoulder Girdle Conditioning Program (*continued*)

- Military press

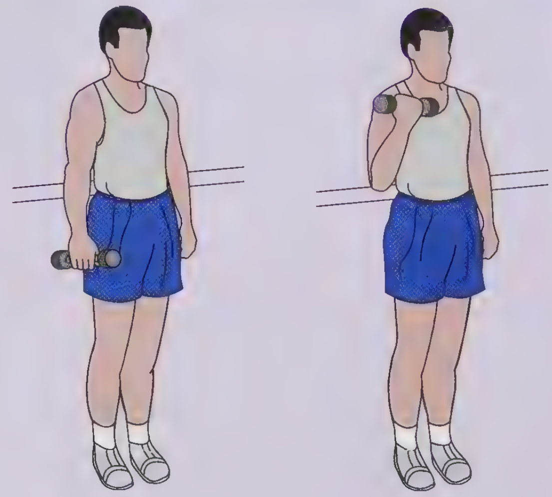


- Front deltoid raise (through full ROM)

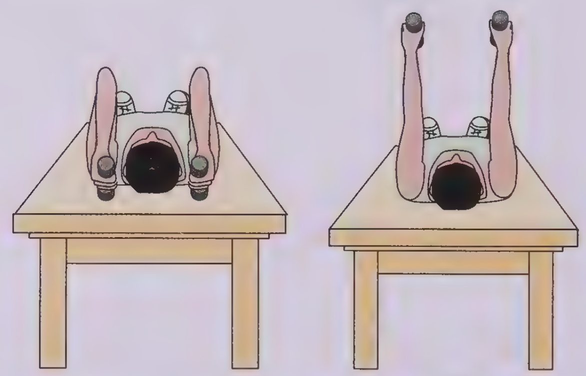


Wall arm lift sagittal plane

- Biceps curl



- Triceps extension



In the case of a high-level athlete or strenuous industrial worker, general conditioning exercises may not be enough to improve performance of the desired activity. The choice of exercise (e.g., dynamic, isokinetic, isometric) used in training depends on the performance level and the specific activities to which the individual wishes to return. The prescription of high-level strength-conditioning exercises must be specific for mode, contraction type, and velocity whenever possible. For example, when strength training the medial rotators in the pitching athlete, the type of contraction should duplicate the eccentric contraction used in the cocking phase to decelerate motion and a concentric contraction used in the acceleration phase to create pitching velocity.[185] Examples of techniques or activities that can provide concentric and eccentric contraction training include manual resistance by the physical therapist in the clinic, plyometric equipment, and a home program using elastics (**Fig. 25-15**).

Prevention of injury is a major concern for the athlete or industrial worker. In designing a training program for these persons, the clinician should prescribe exercises to improve the muscle performance of the muscles required for the sport or occupation and prescribe exercises to strengthen opposing muscles to prevent muscle imbalances. For example, sports such as baseball may require training for the shoulder medial rotators. If strengthening for the opposing lateral rotators and scapular adductor and upward rotators (i.e., middle and lower trapezius) is not performed, muscle imbalances may develop and lead to impairments.[61] In addition, the clinician should ensure that all the medial rotators are stimulated in a conditioning program and that the larger pectoralis major and latissimus dorsi do not predominate and create an imbalance within the medial rotator group. Specific exercise for the subscapularis as shown in Self-Management 25-6 can be prescribed along with more general medial rotation exercises to maintain muscle balance.

One important component of muscle performance includes muscle endurance. Postural faults in the upper quadrant are often attributed to lack of muscle endurance. However, little or no muscle activity has been found in upper quadrant muscles during relaxed standing posture.[186] Postural faults are commonly caused by alterations in muscle length whereby some

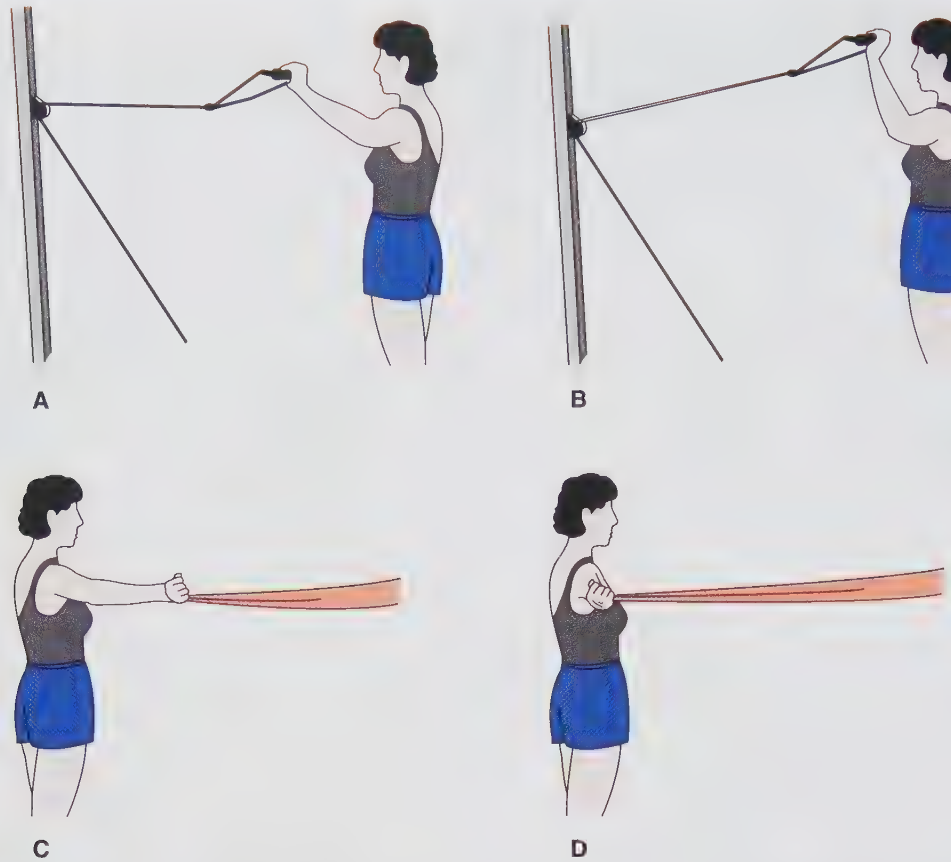


FIGURE 25-15 Plyometric exercise for rotator cuff. **(A** and **B)** Starting and ending positions for dynamic plyometric shoulder external rotation (using Impulse Inertial Exercise System). **(C** and **D)** Starting and ending positions for dynamic plyometric horizontal abduction using elastic tubing. Monitor the patient to prevent excessive anterior translation of the head of the humerus during horizontal abduction.

muscles become adaptively lengthened and others adaptively shortened. The altered lengths of muscles do not provide the optimal support to the shoulder girdle structure.

Impairments in muscle endurance have also been implicated in shoulder and neck symptoms. However, despite the methodologic problems associated with quantifying muscle fatigue,[187] most authorities agree that muscle fatigue is not solely responsible for occupational neck and shoulder complaints.[188,189] Indeed, it has been shown that the trapezius, for example, is under constant muscle tension in myalgic subjects,[190] but that a combined program aimed at restoring ideal muscle length–tension properties, muscle force, endurance, and coordination is more applicable than focusing on muscle endurance alone.[191]

Generally, research indicates that prevention and treatment of neck and shoulder symptoms require a multidimensional approach to reduce the workload on muscle.[192–195] Suggested interventions include ergonomic changes in the workstation and appropriate pacing of activity combined with rest[196]; additionally, measures to reduce stress and anxiety in the work place should be employed.[196,197]

In the case of recovery from injury, starting a new job with greater workload demands, or trying to improve performance levels in an upper extremity for a sport, endurance may need to be developed in the upper extremity musculature. Local muscle fatigue has been shown to affect the kinematics of the joints in the shoulder girdle complex.[198] When the ADLs or instrumental ADLs require more endurance than the muscles possess, endurance must be considered while making decisions about exercise dosage. Chapter 5 provides specific dosage recommendations, but generally, resistance is modified to allow for higher repetitions of a given exercise.

Posture and Movement Impairment

Restoring optimal posture and movement patterns (motor control) to the shoulder girdle complex and the entire upper quadrant (and in many cases, the lower quadrant) should be an integral component of any exercise prescription for the shoulder girdle. Attention to posture and movement patterns is a required component of exercise to remedy-related impairments. The etiology of an overuse injury may be a result of poor structure or function in any of the joints included in the shoulder complex. Additionally, function of the cervical and thoracic spine is important to the maintenance of shoulder girdle complex function. Examination of the structure and function of each of these related regions joints will lead the clinician to the pathomechanics underlying the overuse injury.

Posture

Optimal resting alignment of the shoulder girdle is described in Chapter 9. This alignment facilitates ideal joint positions and resting lengths of the axioscapular, scapulohumeral, and axiohumeral muscles. The resting length of a muscle can be a factor in its participation in active force couples.[61,199] Head, spine, and pelvis alignment affect alignment of the shoulder girdle. For example, forward head, kyphosis, lordosis, and anterior pelvic tilt encourage protracted clavicular position and anterior tilt, and downwardly rotated scapulae.[61] Habitual faulty alignment such as this places the middle and lower trapezius on stretch. Adaptive lengthening can ensue, in turn affecting the length–tension properties of these muscles and thereby affecting their performance in scapular force couples.[47,200]

Optimal alignment of the shoulder girdle complex requires education of habitual cervical, thoracic, and even lumbar and pelvic postures during standing, sitting, and sleeping. Equally important is the education of preferred postural patterns in the patient's environment, such as factory assembly line, desk and chair, kitchen counter, car, baby changing table, are critical to successful postural changes. Support through bracing, taping, and supportive brassieres may be necessary to facilitate the reeducation process and reduce strain on lengthened muscles.

Movement

Restoration of the optimal kinematics during active motion requires knowledge about the kinesiology of the shoulder girdle complex. If the ideal is known, the clinician can devise a program of exercises to alleviate impairments and retrain movements to approach the ideal standard. The goal is to achieve movement as close to the ideal kinematics as possible to enhance the health and longevity of the biomechanical system. The references and reading list at the end of the chapter provide sources for more information about electromyographic or cinematographic analysis of the shoulder girdle during common movement patterns, sport activities, and therapeutic exercises.

THERAPEUTIC EXERCISE INTERVENTIONS FOR COMMON DIAGNOSES

Although comprehensive descriptions and intervention plans for all diagnoses affecting the shoulder girdle are beyond the scope of this book, a few diagnoses are discussed. An overview of the pathogenesis or pathomechanics, examination findings, and proposed treatment plan, with an emphasis on exercise, is provided for each selected diagnosis.

Rotator Cuff Disorders

For the purposes of this text, the broad category of RC disorders includes such medical diagnoses as subacromial impingement syndrome (SIS), posterior superior impingement (PSI), anterior superior impingement (ASI), and functional/microinstability leading to RC tendinosis/tendinopathy. Although each of these classifications merits a separate detailed review of pathogenesis and pathomechanics, associated impairments, and treatment concepts, it is beyond the scope of this text to do so. Comprehensive understanding of RC disorders can be established by means of reviewing the literature cited in this section.

Rotator cuff disorders can be broadly classified as acute or chronic in origin, though acute, avulsive tears of healthy rotator cuff tendons (RCTs) are considered to be rare.[201–203] Most authors believe that RC tears that appear to be of sudden onset after trauma are extensions of underlying chronic tears or tears of previously degenerated tendons.[201–203]

Tendinopathy predominantly develops from excessive compression, tensile load, or a combination of both. Analysis of the possible underlying drivers will direct not only the mechanical intervention, but also assist with addressing the stage of pathogenesis, both of which will be discussed in subsequent sections (**Evidence and Research 25-9**).

EVIDENCE and RESEARCH 25-9

Rotator Cuff Pathology and Pain

It is important to understand that observed structural failure in the RCTs is not always symptomatic. Frost et al.[204] reported that people with and without symptoms of RC tendinopathy demonstrated equivalent RC pathological changes. Asymptomatic professional baseball pitchers demonstrate substantial RCT pathology in their pitching and catching shoulders,[205] and ultrasound studies of men without symptoms identified structural changes in 96% of those scanned including subacromial bursal thickening, supraspinatus tendinosis and partial-thickness tears, as well as labral pathology.[206] Reasons why some people experience pain as well as the source of the pain remain uncertain.

Numerous classification systems have emerged in an attempt to logically categorize staging and mechanistic factors of RC disorders.[104,207–212] There is considerable overlap and opposing models within these systems, and their terminology is not synonymous; therefore, these systems cannot be used interchangeably to discuss classification of RC disorders. For the purposes of this chapter, the following summary will be used for terminology.

Pathomechanics

Three common types of chronic RC disorders have been described in the literature: (1) extrinsic or subacromial (compression), (2) intrinsic (tensile), and (3) extrinsic internal impingement (compression/tensile).

Extrinsic or subacromial (also known as primary impingement) includes diagnoses that can be attributed to mechanical compression of the subacromial structures. Medical diagnoses that are included in this category are primary or *SIS* and bursal surface RC tears.[207] The prevalence of a compression mechanism for the RC is less frequent than initially proposed, and not likely the predominant mechanism.[213] This has led to the evolution in terminology from *subacromial impingement syndrome* to the label of *subacromial pain syndrome*. Underlying mechanisms leading to SIS could include faulty scapular mechanics such as insufficient posterior tilt, external rotation, or upward rotation of the scapula; or excessive superior glide of the humeral head.[214]

The second type includes those disorders that can be attributed to tensile overload of the RC and is commonly referred to as **intrinsic** RC pathology. Throwing or racket sport athletes are at high risk for this type of RC injury because of the high, repetitive eccentric forces incurred by the posterior RC musculature during the deceleration and follow-through phases of overhead sport activities.

Another possible mechanism of tensile loading is chronic loading that occurs in a depressed and downwardly rotated scapula from weak serratus or upper trapezius. In this posture (see Fig. 25-5), the cranial orientation of the scapula is lost and the superior capsuloligamentous structures and cuff tendons are placed under tensile load to support the head of the humerus (**Fig. 25-16**).[215,216]

A common medical diagnosis that is included in this category is undersurface RC tears.[217] Tears can be classified as partial or incomplete, complete, or massive.[103] Incomplete tears do not extend through the entire thickness of the tendon. Complete tears extend through the full thickness of the tendon or muscle. A massive tear indicates more than one RCT or muscle is torn.

Another term, extrinsic **internal** impingement, has been used in the literature to describe a third mechanism of RC disease. This pathomechanic is differentiated from SIS or intrinsic impingement in that this condition implies that there is a problem with keeping the humeral head centered in the glenoid fossa during movement of the arm.[218] This is generally caused by weakness in the RCT muscles (functional instability) combined with a GH joint capsule and ligaments that are too loose (microinstability). Two types of external/intrinsic impingement have been described: (1) PSI and (2) ASI.

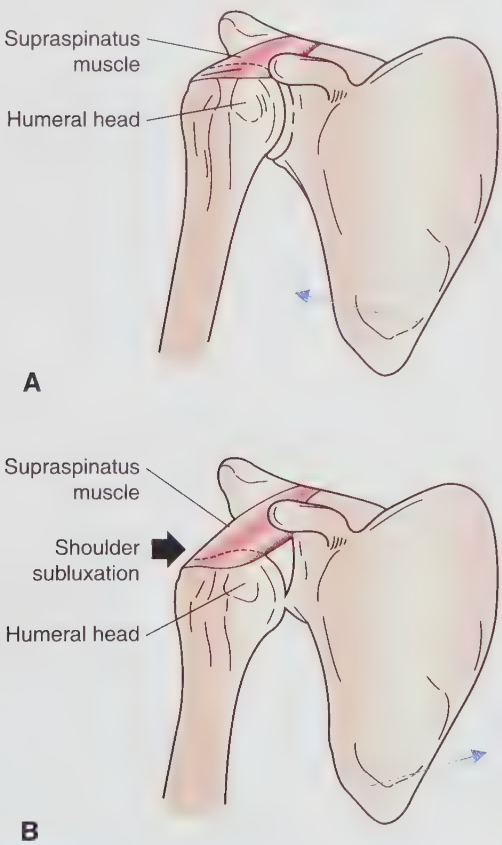


FIGURE 25-16 **(A)** The humeral head is maintained in the glenoid via slight upward orientation of the glenoid and the supraspinatus muscle. **(B)** Chronic tensile loading of the supraspinatus when the scapula rotates downward and the glenoid fossa loses its cranial orientation.

Posterior superior impingement is described as an intra-articular impingement that occurs in all shoulders in the abducted externally rotated position. In this 90–90 degree position, the undersurface of the posterosuperior RC contacts the posterosuperior glenoid labrum and may become pinched (compressed) between the labrum and greater tuberosity implying a labral impingement as opposed to subacromial impingement.[219–221] Jobe[222] hypothesized that the internal impingement in throwers might progressively worsens because of anterior microinstability created by gradual repetitive stretching of the anterior capsuloligamentous structures.

In contrast to PSI, the anterosuperior impingement is significantly less common. It involves an impingement of the subscapularis tendon between the anterior humeral head and the anterosuperior glenoid and labrum during forward flexion of the arm. Habermeyer et al. stated that a forcefully stopped overhead throwing motion might generate a RC lesion.[223] For a detailed etiology of these two types of impingement, the reader is referred to Kirchhoff et al.[224] It is important to treat the underlying "micro-instability" in patients with extrinsic/internal impingement. See summary of RC disorders in **Display 25-10**.

Because the position of the glenoid is directly related to the position of the scapula, relatively small changes in the action of the axioscapular muscles can affect the alignment and forces involved in movement around the GH joint.[61] Optimal 3D mechanics of posterior tilt, external rotation, and upward rotation are vital for optimal centering of the humeral head during elevation. With respect to humeral horizontal abduction and external rotation, the scapula moves into retraction and external rotation to maintain humeral head centering. Conversely, during humeral horizontal adduction and internal rotation, the scapula moves into protraction and internal rotation for humeral head centering.

Athletes with shoulder pathology consistently demonstrate abnormalities in scapular positioning, suggesting that motor control is an important factor to consider in extrinsic etiology of RC disorders.[175,225–229] Muscle function has been investigated in healthy shoulders[170,172,175] and in shoulders with GH instability[227,228] or impingement.[175,229] Most authors suggest that alterations exist in muscle activity of the scapular muscles in persons with RC disorders.

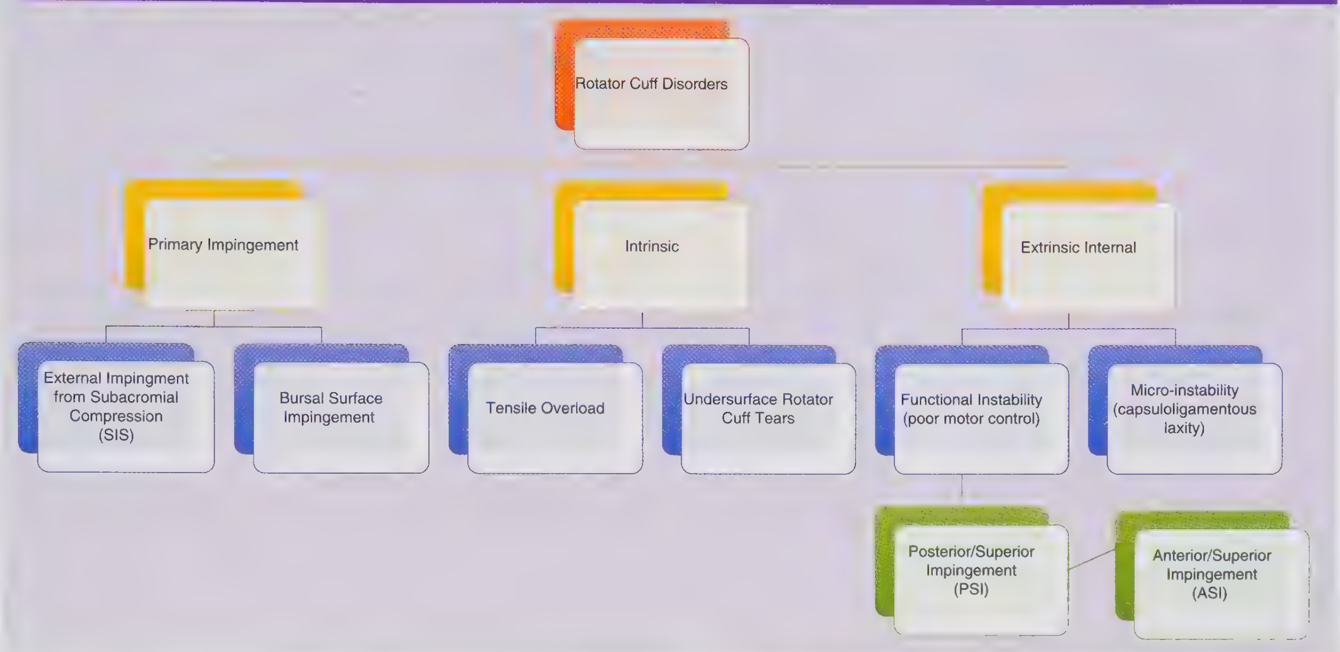
Research supports[226] a relationship between shoulder injury and the temporal recruitment patterns of the scapular rotators, suggesting that injury reduces the consistency of muscle recruitment. In addition, they suggest that injured subjects have muscle function deficits on their unaffected side, indicative of the possibility that muscle function deficits may predispose athletes to injury. Hence, promotion of motor control of scapular mechanics may be an important factor in the prevention of RC disorders.

Muscle dysfunction has also been investigated in the integrated deltoid–RC mechanism in persons with subacromial impingement.[230] The middle deltoid and RC muscles were evaluated during isotonic scaption from 30 to 120 degrees. Overall, the impingement group demonstrated decreased mean muscle activity in comparison with the group of normal subjects, particularly in the infraspinatus and subscapularis during the first portion of arm elevation. The inferior force vector is provided by the infraspinatus and subscapularis, thus humeral head depression during the critical first portion of elevation may be insufficient in persons with subacromial impingement.

This body of research suggests that dysfunction in scapular mechanics or deltoid–RC muscle function is present in persons

DISPLAY 25-10

Rotator Cuff Disorders



with RC disorder. Yet, it must be considered that many RC disorders involve more than one etiologic factor. Consequently, it is critical for the physical therapist to identify all intrinsic and extrinsic factors to effectively manage RC disorders.

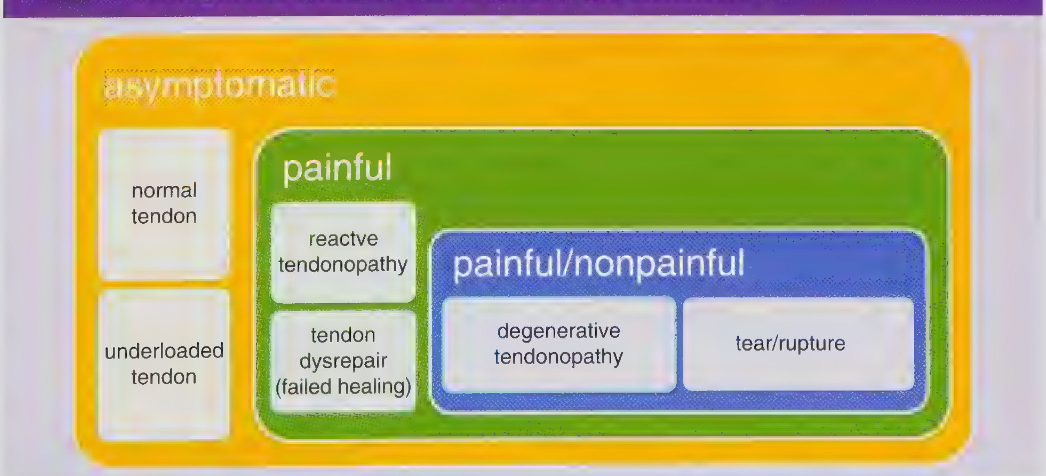
Pathogenesis

Recently, research into tendon pathology has both broadened and confused our understanding of tendon pathology. The new term "tendinopathy" has replaced the old term of "tendonitis" as a result of this research and a better understanding of pathophysiological mechanisms. Inflammatory cells have not been detected in tendinopathy tissue.[231] It is not possible for this text to provide a comprehensive review of current tendon research, but rather provide a synthesis of a continuum as is currently accepted. Understanding pathogenesis helps the clinician in clinical decision-making regarding the most appropriate intervention based on the stage of tendon pathology combined with the underlying pathomechanics leading to the pathology.

Numerous researchers have presented various theories regarding the pathogenesis of tendinosis/tendinopathy. Cook and Purdam[211] presented a model to define the continuum of tendon pathology. Although the continuum was based on evidence from lower limb tendons, it has been adapted for RC pathology.[114] This continuum may involve normal or underloaded tendons (see **Display 25-11**). The normal RCT and the underloaded tendon

DISPLAY 25-11

Pathogenesis of Rotator Cuff Disorders: The Continuum



may be subject to tissue overload if subject to an activity level in excess of that normally placed on the tendon. If this load is transient, the tendon can return to its preload state. This state is termed normal tendon overload and is a normal response to loading RC tissue through activity and exercise.

If the applied load exceeds the physiological capacity of the RC, the effect may be tendon upregulation. The first stage may be *reactive tendinopathy* and is predominantly seen in an acutely overloaded tendon where there is increased swelling within the tendon, and possible bursal effusion. Pain may be present, and this may be constant or intermittent and is position and activity dependent.

The RC may fail to control superior translation of the humeral head, which may lead to a secondary compression and irritation of the superior fibers of the tendon against the coracoacromial ligament and the undersurface of the acromion.[232] Cook and Purdam[211] defined the next stage in the continuum as *tendon disrepair*, which manifests similarly to reactive tendinopathy. Tendon disrepair may be characterized by substantial areas of swelling and tendon degeneration.

Cook and Purdam[211] have classified the final stage as *degenerated tendon*, and is associated with substantial structural failure in the form of large partial-thickness, full-thickness, and massive RC tears.[233]

Therapeutic Exercise Intervention of Rotator Cuff Disorders

Treatment principles for nonoperative RC disorders are based on the underlying pathomechanics combined with pathogenesis, presenting impairments, and activity limitations. Treatment for secondary RC disorders should consider impairments related to hypermobility and instability problems in addition to impingement. Patient education, pain reduction, appropriate tendon loading, and reinjury prevention form the basis of symptomatic RCT rehabilitation.

The following section will focus on rehabilitation concepts related to tendon loading.

Healthy or Underloaded Tendons To maintain optimal health and function, tendons require appropriate ongoing mechanical stimulation (**Evidence and Research 25-10**). Chronically underloaded tendons in a sedentary population may result in asymptomatic degeneration and tears, which undoubtedly will increase with age.

EVIDENCE and RESEARCH 25-10

Training and Repetitive Strain and Tendinopathy

Habitual loading (as occurs in response to training) will result in a higher rate of collagen synthesis for 24 to 48 hours. This results in tendon hypertrophy.[234] The rate of degradation also increases with training to ensure that the overall turnover is high, but not to the same extent as the increase in synthesis, which allows for a small—but consistent—positive net balance of collagen.[235] Habitual training thus results in a higher turnover of collagen whereas inactivity lowers collagen synthesis and turnover.[236] This result illustrates why activity even in the presence of tendinopathy might be better for the regeneration of the tendon tissue than complete inactivity.

Treatment for an underloaded RC involves gradual, controlled loading of the tendon. To maximize the benefit of tendon-loading activities, the load, duration, and intensity of activity placed on the RCTs must be carefully controlled, structured, and monitored. In addition, the therapist's role is to promote ideal biomechanics by instruction in optimal thoracic, scapular, and humeral movement patterns.

Reactive Tendinopathy Load reduction, together with pain management, is a key component in the management of reactive tendinopathy. Attention to remediating pathomechanics leading to compressive or tensile loading will assist in decreasing irritability of the reactive tendon. Examples include patient education, exercise prescription, and training modifications such as altering sustained postures of scapula downward rotation (tensile loading) with exercise and taping; reducing superior or anterior humeral glide relative to the scapula (compressive loading) with appropriate scapular and RC training; and avoiding more vigorous activities that involve the stretch shortening cycle (compressive and tensile loading).

Pain management requires reeducation of activity with "controlled stress" to maintain pain levels to 1 to 2 out of 10 (worst imaginable pain) on a visual analog scale of pain. Additionally, pain should not be trending worse and pain should not be worse upon waking. Sleep should supply restorative/repair processes reflected in reduced pain levels upon waking.

Isometric exercises can help to reduce pain in reactive tendinopathy. Naugle[237] reviewed the evidence of the role of exercise in reducing pain and found that, "isometric exercise appears to exert a generalized pain inhibitory response." The author found that long duration, low to moderate intensity contractions (25% to 50% maximal voluntary contraction) had optimal analgesic effect. Although there are limitations of utilizing these suggestions on tendinopathy, Cook and Purdam[238] discuss isometric exercises relative to tendon loading; ". . .these loads can be repeated several times a day, utilizing 40 to 60 seconds holds, four to five times, to reduce pain and maintain some muscle capacity and tendon load. In highly irritable tendons, shorter holding time and fewer repetitions per day may be indicated."

This contraction should be done in a position where there is no tendon compression, usually in the mid-range of the muscle (see **Fig. 25-17**).

During this period of relative rest, adjunctive therapies such as modalities, taping (see Adjunctive Interventions: Taping in subsequent section), and manual therapy (see Chapter 7) may be considered to reduce pain and restore shoulder movement and function.

Tendon Dysrepair Ongoing pain management and the other components of management for reactive tendinopathy remain important components for the treatment of tendon dysrepair. Graduated tendon reloading including concentric, isometric, and eccentric exercise is introduced during this stage. Evidence supports opposing effects of GH external and internal rotation on subacromial pressure with external rotation lowering pressure.[239] Given this evidence, consideration should be given to pain levels during movements into flexion, abduction, and/or internal rotation. Additionally, exercises that activate the RC to depress the humeral head may also be warranted (see Fig. 25-4).[240]

Degenerative Tendon Pain control and restoring normal movement are the principal aims of managing the degenerated tendon.[241] Clinical investigations have suggested that even in

A B

FIGURE 25-17 Exercises that involve pressing your arm against a wall can help reduce pain related to the tendons that make up the rotator cuff. With the arm forward flexed 45 degrees and elbow at a 90-degree angle, put the palm of your hand on the side of a wall or doorframe that's in front of you **(A)**. Press your palm against the wall or doorframe for several seconds. For the second exercise, move your hand so that the backside of the hand is facing the wall **(B)**. With your arm flexed to 45 degrees and elbow at a 90-degree angle, press your hand against the wall for 40 to 60 seconds. Repeat each exercise four to five times several times a day.

the presence of substantial structural pathology, range of movement and power may be improved when pain is reduced.[242–244] Subscapularis contributes 30% and infraspinatus contributes 10% of the abduction torque during arm elevation, so even in a full-thickness tear to the supraspinatus, arm elevation can be achieved with improved function in those two cuff muscles (see Self-Management 25-1).[245]

Movement Impairment Because shoulder movement requires normal scapular mechanics,[246–250] the ability to effectively strengthen the serratus anterior and all portions of the trapezius is vital for effective management of RC disorders (see Display 25-12). EMG analysis of the trapezius and serratus anterior muscles have been performed during therapeutic exercises.[167–169,250–253] The EMG data presented in **Display 25-12** may assist physical

DISPLAY 25-12

Activation Exercises for Trapezius and Serratus Anterior Based on EMG Analysis

Exercises for Upper Trapezius

- Shoulder shrug (**Fig. 1**)[168]

Exercises for Middle Trapezius

- Prone arm lift with arm overhead (Self-Management 25-2, Level IV B)[168]
- Prone horizontal extension with lateral rotation (Self-Management 25-2, Level IV A)

Exercises for Lower Trapezius

- Prone arm lift with arm overhead (Self-Management 25-2, Level IV B)[168]
- Prone shoulder lateral rotation at 90-degree abduction (Self-Management 25-1)[168,253]
- Prone horizontal extension with lateral rotation (Self-Management 25-2, Level IV A)[168]

Exercises for Serratus Anterior

- *Note*: In general, exercises that create upward rotation of the scapula were found to produce much more EMG activity in the serratus anterior than straight scapular protraction exercises.[167–169]
- Shoulder abduction in the plane of the scapula above 120 degrees.[168,169]
- Diagonal exercise with a combination of flexion, horizontal flexion, and external rotation.[168]

Exercises for Simultaneous Activation of the Trapezius and Serratus Anterior

- Prone arm lift with arm overhead (Self-Management 25-2, Level IV B)[168]
- Shoulder abduction in the plane of the scapula[168]

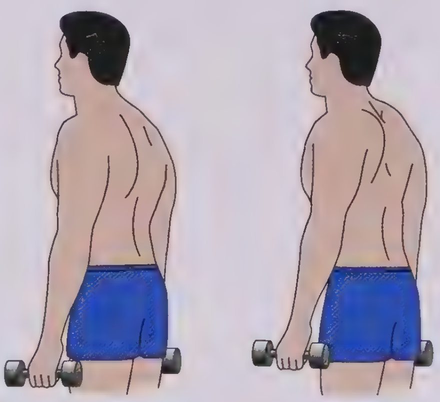


FIGURE 1 Shoulder shrug.

therapists in developing exercise programs that will optimally activate the trapezius and serratus anterior muscles. Because the results of the studies presented were obtained by studying subjects without pathology of the shoulder girdle rather than patients with RC disorders, caution is warranted in extrapolating these findings to a patient population. Exercises may need to be modified to accommodate a painful shoulder. **Display 25-13** summarizes additional exercises for activation of the scapular rotators that are illustrated in this chapter. A clinical example of RC disorder is provided in Display 25-4 with general treatment guidelines presented in **Displays 25-14** and **25-15**, and more specific exercise recommendations in **Display 25-16**.

Treatment Principles for Postoperative Rotator Cuff Disorders

Tears of the RC can be managed with nonsteroidal anti-inflammatory drugs, intra-articular or subacromial glucocorticosteroid injection, oral glucocorticosteroid treatment, physical therapy, and open or arthroscopic surgery. To date, there is little evidence to support or refute the efficacy of common interventions for tears of RC in adults.[254] Rowe[255] stated, "the majority of RC lesions should respond satisfactorily to conservative measures," noting a few exceptions. According to Mantone et al.,[256] there are instances in which early surgical management would be indicated. The first is the 20- to 30-year-old active patient with an acute tear and severe functional deficit from a specific event. The second is the 30- to 50-year-old patient with an acute RC tear secondary to a specific event. These patients are best treated with early operative intervention. The third instance is the highly competitive athlete, particularly one who is involved in overhead or throwing sports. These patients need to be treated operatively because RC repair is necessary for restoration of the normal strength required to return these athletes to the same competitive preoperative level of function.

Patients who fail conservative management may require some sort of surgical intervention. Surgical intervention occurs along a continuum, ranging from arthroscopic debridement to an open RC repair. A decision to attempt a surgical repair of the tear should be informed on an assessment of the (1) individual patient's functional requirements, (2) size of the tear, and (3) the amount of fatty infiltration into the muscle;

DISPLAY 25-13

Additional Exercises Designed for Isolation of Scapular Rotator Muscles

Exercises for Upper Trapezius

- Upper trapezius strengthening (Building Block 25-2)

Exercises for Middle and Lower Trapezius Activation

- Facelying arm lifts (Self-Management 25-2)
- Wall slides (Fig. 25-4)
- Back-to-wall arm slides in abduction (**Fig. 1**)
- Isometric scapula upward rotation (**Fig. 2**)

Exercises for Serratus Anterior

- Serratus anterior progression (Self-Management 25-3)
- Progressive serratus strengthening exercises (Figs. 25-9, 25-10, 25-11)

FIGURE 1 Back to wall, arm slides in abduction. With the back to the wall, the elbows and humerus should be in the scapular plane. Thumbs can touch the wall to ensure that the humerus remains in the scapular plane. The patient slides the arms up the wall, and stops when the scapula deviates into excessive elevation. The goal is to achieve full scapular plane elevation with the ideal arthrokinematics at the GH joint and ST articulation.

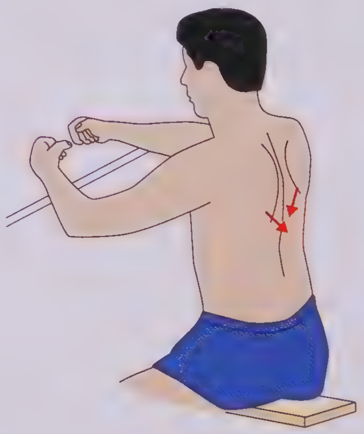


FIGURE 2 Alternative isometric scapular upward rotation. The arms can be positioned in as much elevation as is available. The cue should be to "gently squeeze your shoulder blades together." Caution should be taken to prevent excessive rhomboid or latissimus dorsi contribution.

DISPLAY 25-14

Phases of Rehabilitation for Rotator Cuff Disorders

Phase 1

Decrease Pain	Mid-range isometrics, reduce compressive and tensile loads, avoid SSC

Phase 2

Increase Strength	Heavy slow resistance in non-compressive positions

Phase 3

Increase Functional Stregnth	Progress into functional tasks with focus on optimal movement patterns

Phase 4

Increase Power	Reduce repetitions and increase speed

Phase 5

Develop Stretch Shortening Cycle	Add plyometrics

Phase 6

Sport Specific	Add sport specific drills in OKC or CKC as appropriate

Normal tendon overload is pain-free and is a normal response to loading rotator cuff tissue through activity and exercise.

DISPLAY 25-15

Adjunctive Interventions for Reactive Phase of Rotator Cuff Disorders

Phase 1
Reactive Phase – 1-Degree Goal is pain reduction

Analgesic [illegible] (CS) injection (primarily for pain control, CS may decrease cell proliferation and protein production)	Reduce Swelling [illegible]	[illegible]

DISPLAY 25-16

Specific Therapeutic Exercise Intervention for Rotator Cuff Disorder

Muscle Length

- Passive manual stretch to rhomboids (see Fig. 25-3)
- Self-stretch to GH lateral rotators (see Self-Management 25-4)

Muscle Performance

- Strengthen middle and lower trapezius in the short range (see Self-Management 25-2)
- Strengthen serratus anterior in the short range (see Self-Management 25-3)
- Strengthen RC (see Self-Management 25-1)

Posture and Movement

- Ergonomic modifications at workstations
- Transitional exercises to improve kinematics of GH and ST joints in elevation (see Fig. 25-4)
- Surface EMG training during simple elevation movements to restore temporal relationships in scapular rotators
- Functional retraining for ADLs with focus on motor control and integrated scapula and deltoid–RC function
- Functional retraining for instrumental ADLs (sports and recreation) with focus on motor control and integrated scapula– and deltoid–RC function
- Alter sport-specific training as needed to promote optimal motor control and biomechanics

the presence of fatty streaks has been associated with negative surgical outcomes.[257,258]

Based upon the review of 14 trials in a Cochrane Database of Systematic Reviews for surgical repair for RC tears, no firm conclusions about the effectiveness or safety of surgery for RC disease could be made.[259] There is "Silver" level evidence from six trials that there are no significant differences in outcome between arthroscopic and open subacromial decompression, although four trials reported earlier recovery with arthroscopic decompression.[259]

If surgery is performed, the postoperative exercise regimen after anterior acromioplasty and repair of the RC is determined by the strength of the RC. Methodical planning and cooperation by the patient, surgeon, and physical therapist are necessary to plan a program with a successful outcome. The patient will have greater confidence if clear objectives are developed. Preoperatively, the surgeon and physical therapist should explain to the patient that it will take up to 12 months for mature healing of the tendons. However, during this time, activities will be progressively advanced, and strict adherence to the physical therapist's instructions will ensure the most successful outcome. The physical therapist must understand the specific anatomic considerations and limitations to plan a safe and effective postoperative rehabilitation program. Only the surgeon knows the strength and stability of the repair and therefore should work closely with the physical therapist in developing the aftercare program of each patient.

The algorithm shown in **Display 25-17** provides guidance for rehabilitation after a standard RC repair.[103] Because of the unique anatomic arrangement and function of the RC,

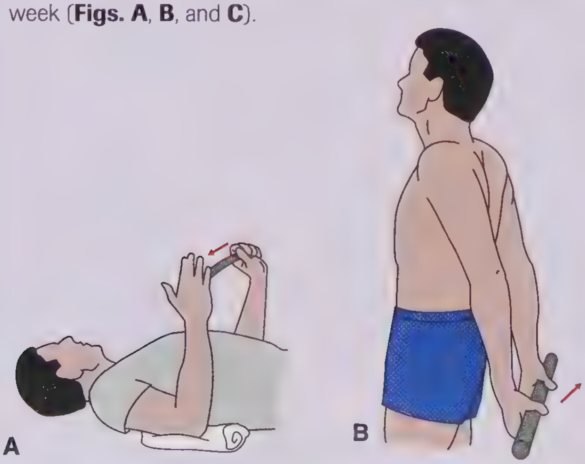
DISPLAY 25-17

Rehabilitation After Rotator Cuff Repair

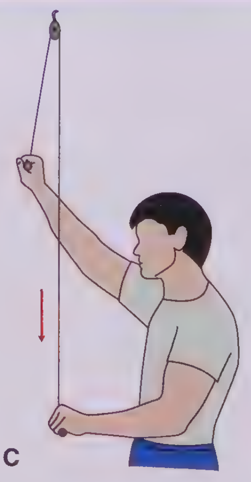
This protocol is a guideline only; actual progression will be based on clinical presentation.

Protective Phase (1 to 4 weeks)

- Sling protection is used for 2 to 3 days and up to 6 weeks at night.
- Pendulum exercises (see Fig. 25-8) are initiated within the first 48 hours and should be performed three times a day.
- Self-assisted ROM exercises are initiated at the end of the first week (**Figs. A**, **B**, and **C**).



A B

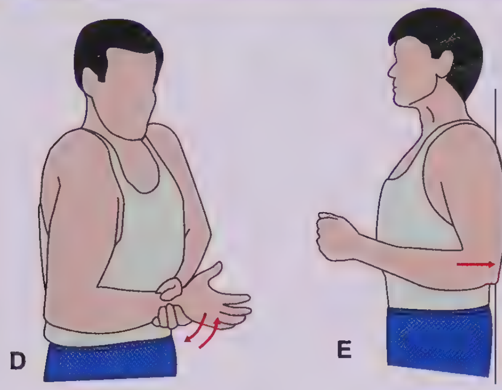


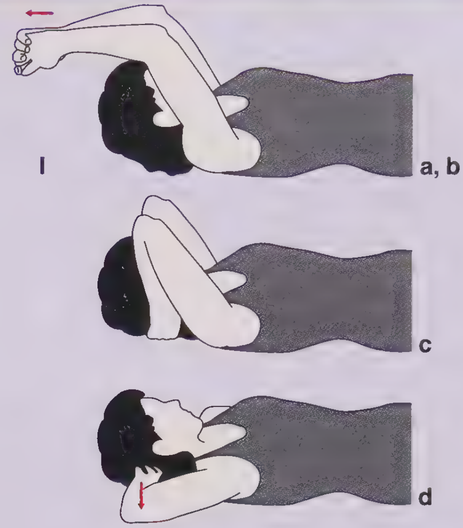
C

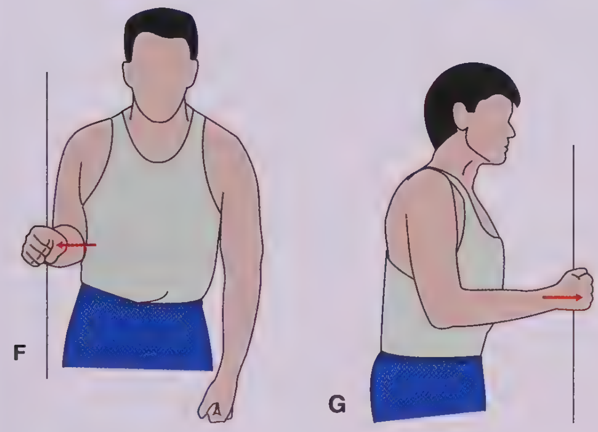
- Most surgeons DO NOT want the surgical arm elevated above 70 degrees in any plane for the first 4 weeks postoperatively.
- Gentle isometric exercise may be introduced as early as 1 week postoperatively, but is highly dependent on the extent of the surgery (**Figs. D–G**).

DISPLAY 25-17

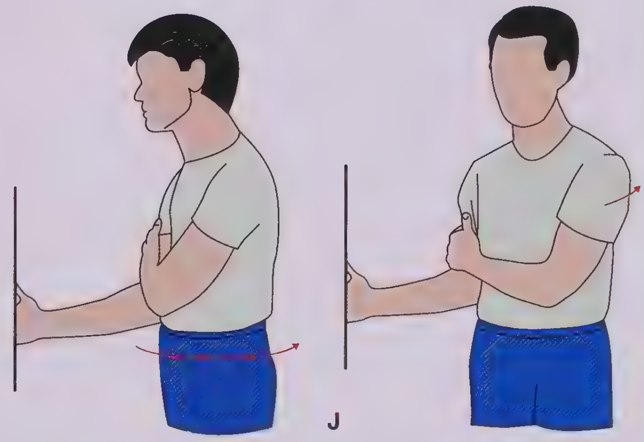
Rehabilitation After Rotator Cuff Repair (*continued*)





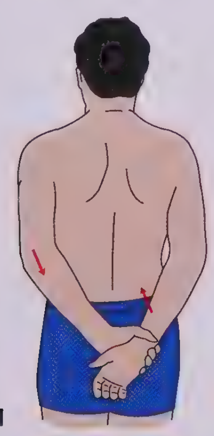


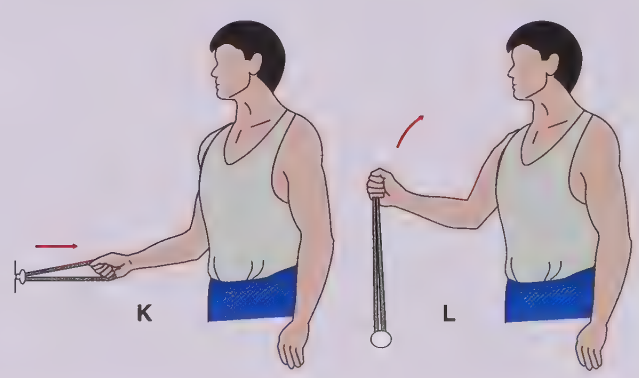
- Consult the surgeon for timing on introducing isometrics.
- Scapular pinches every hour with good upright posture.
- Maintain good upright shoulder girdle posture at all times—especially during sling use.



Early Intermediate Phase (4 to 8 weeks)

- Additional self-assisted ROM exercises are prescribed 6 weeks after surgery (**Figs. H, I, J**).
- If motion is restricted at this time, gentle passive stretching by the physical therapist is indicated.
- Mobilization of GH, SC, AC joints as needed to restore joint mobility (this may be started earlier if needed).
- ROM goals should be up to 90 degrees of flexion and abduction without excessive clavicular elevation.
- Isometric exercise is progressed to active ROM as patient symptoms permit (**Figs. K** and **L**).





(*continued*)

DISPLAY 25-17

Rehabilitation After Rotator Cuff Repair (*continued*)

Late Intermediate Phase (8 to 12 weeks)

- ROM goals should be full ROM in all planes, flexion, abduction, external rotation, internal rotation.
- Continued mobilization of GH, SC, AC joints as needed to fully restore joint mobility.
- Light resistance with resistive tubing is added to dynamic exercise for flexion, extension, ER, and IR.
- More aggressive exercise for serratus anterior and trapezius (Display 25-13) is introduced.

Advanced Rehabilitation Phase (12 weeks and beyond)

- A more aggressive RC strengthening program is introduced (Self-Management 25-1).
- Add weights to all exercises as tolerated.
- Continue to seek full ROM in all planes with attention to motor control and scapulohumeral rhythm.
- Swimming is allowed at 5 months after surgery.
- Submaximal sport-specific training is progressed to maximal training by the end of 1 year after surgery.

General Precautions and Contraindications

- Flexion should precede abduction when restoring active motion.
- The patient should avoid leaning on the arm or carrying more than 5 lb of weight in the early and intermediate phases of rehabilitation.
- Patients with complete tears of the supraspinatus should avoid lifting more than 15 lb in the first year postoperatively.
- Skiing, skating, roller-blading, and other such activities are forbidden in the first year after surgery to avoid reinjury from a fall.

(A) Assisted lateral rotation in supine. A towel is placed under the elbow to keep the humerus in neutral and prevent excessive anterior displacement. The patient pushes the involved arm into lateral rotation, using the uninvolved arm to supply the power. **(B)** Assisted extension. The patient pushes backward into extension, using the uninvolved arm to supply the power. Caution should be used to prevent excessive GH extension and anterior displacement of the GH joint. **(C)** Pulley-assisted elevation in both flexion and scaption planes. The uninvolved arm supplies the power to raise the involved arm. Caution should be used to prevent excessive scapular elevation as compensation for lack of GH mobility. The motion should be stopped as soon as a deviation in the path of instant center of rotation (PICR) of the GH joint or ST articulation is noted. This exercise can be progressed to active assisted elevation when directed by the physician. **(D)** Assisted medial rotation. The patient is instructed to medially rotate the arm by pushing the arm backward, followed by pulling the hand upward toward the scapula. Caution should be used to prevent excessive scapular anterior tilt and GH anterior displacement. **(E)** Assisted abduction. The patient is instructed to (a) lie on the back, (b) lock the fingers together and stretch the arms overhead (the uninvolved arm powers the involved arm), (c) bring the hands behind the neck, and (d) flatten the elbows (reverse by sliding the hands overhead and down). Caution should be taken while abducting to ensure the scapulae are in a neutral position and the clavicle retracts as the arm abducts. **(F)** Assisted lateral rotation in a doorway. The patient is instructed to stand in a doorway facing the doorframe. The elbow is flexed to 90 degrees. The palm is on the wall. The elbow is held in adduction. The body turns gradually until the patient faces into the room. Caution should be taken to ensure proper scapular alignment during the lateral rotation process. **(G)** Isometric medial and lateral rotation. **(H)** Isometric extension. **(I)** Isometric abduction. **(J)** Isometric flexion. **(K)** Resistive exercise for shoulder extensors. Caution should be taken to prevent thoracic flexion or scapular anterior tilt. The range should be limited to extension to the midaxillary line to prevent contractions of the rhomboid in the short range. **(L)** Resistive exercise for shoulder flexion. The motion is upward into flexion as if throwing an "upper cut" punch. Caution should be taken to monitor the ST kinematics.

rehabilitation after surgery is considered to be more difficult than that of any other joint. In most patients, the muscles involved in the precisely integrated force couples used in upper extremity movements have suffered from months of atrophy and disuse. Early in the rehabilitation process, careful exercises may be prescribed to prevent significant atrophy of key scapular muscles that perform upward rotation, posterior tilt, and/or external rotation functions (Fig. 2 in Display 25-13). Toward the latter stages of rehabilitation, precise integration and coordination of motor control must be restored to all the muscles involved in the functional movements used by the individual. Postoperative care after repair for a massive RC tear is far more conservative, requiring longer periods of immobilization and slower return to function.

Often repair of a torn RC effectively improves comfort, active motion, and strength in most patients. According to Romeo et al.,[260] female patients 66 years of age and older are more likely to have an unsatisfactory result. In addition, an associated biceps tear in female patients is a poor prognostic factor.[260] Overall, better results are seen in patients with less than 5 cm^2 tear, in patients with an intact biceps tendon,[260] with minimal fatty degeneration in each cuff muscle (particularly the infraspinatus and subscapularis), and with a low index of global fatty degeneration.[257,258]

Glenohumeral Hypermobility/Instability

It is not within the scope of this text to discuss diagnoses and treatments of the entire spectrum of GH joint hypermobility/instability; therefore, this section focuses on anterior GH hypermobility leading to GH subluxation. Hypermobility and subluxation are difficult to diagnose and terminology can best be understood if joint stability is considered in terms of a continuum of stability (**Fig. 25-18**).[259] Jobe et al.[104] first described the etiology of secondary RC disease, or hypermobility, as a continuum (see **Display 25-18**).

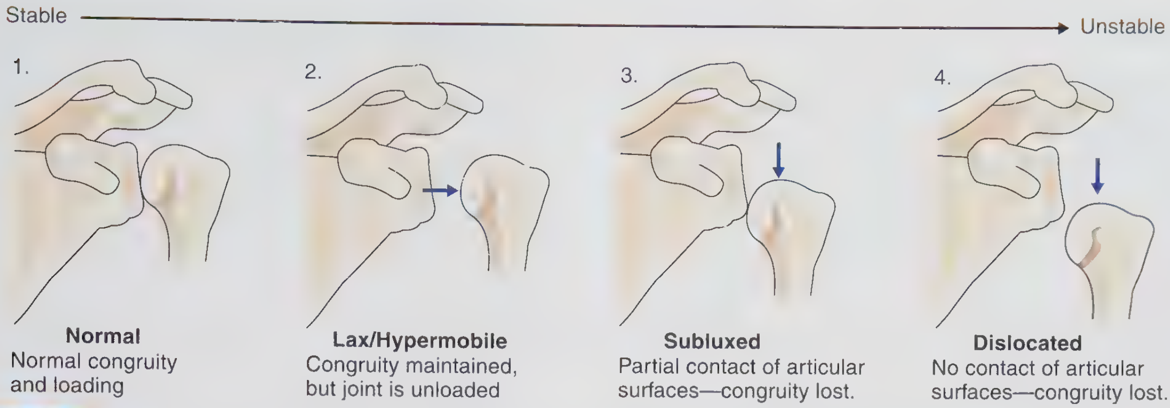


FIGURE 25-18 Continuum of shoulder stability. (Adapted from Strauss MB, Wrobel LJ, Neff RS, Cady GW. The shrugged-off shoulder: a comparison of patients with recurrent shoulder subluxations and dislocations. Physician Sports Med 1983;11:96.)

DISPLAY 25-18

Jobe's Instability Continuum[104]

- RTC weakness
- [illegible]
- [illegible]
- subluxation (inability of the humeral head to center in the glenoid during motion)
- RTC/labral tearing (late stage)

In the absence of trauma, the etiology of GH hypermobility is a circular cause and consequence scenario. Whether the cause or consequence, one should consider that habitual impairments in posture and repetitive movement patterns can result in microtrauma to static and dynamic stabilizers and dysfunction in the relationship between the GH, AC, and SC joints. Attenuation of the static and dynamic stabilizers contributes to mild hypermobility, increasing the demand on the stabilizing function of the RC. This may lead to a vicious cycle of excessive translation of the humeral head, mechanical impingement, and attenuation of the subacromial structures.[193,194,202,261] Left unchecked, mild hypermobility can progress to subluxation and dislocation.

Glenohumeral stability is achieved through a number of different mechanisms, involving the articular geometry, the static capsuloligamentous complex (CLC), the dynamic (muscular) stabilizers, and neuromuscular control.[210] The specific contributions of the shoulder musculature to joint stability are listed in **Display 25-19**.[246,266–270]

DISPLAY 25-19

Contributions of the Shoulder Musculature to Joint Stability

- Passive muscle tension from the bulk effect of the RC muscle
- Rotator cuff contraction causing compression of the articular surfaces
- Joint motion that secondarily tightens the passive ligamentous constraints
- Barrier or restrain effect of the contracted RC muscle
- Redirection of the joint force to the center of the glenoid surface by coordination of muscle forces from both GH and ST joints
- ST muscle balance
  - Efficient compressive forces on the RC are partially dependent upon the stability of their origins on the scapula[262]
  - Scapular position affects length–tension properties of the RC
  - Scapula upward rotation, posterior tilt, and lateral rotation is necessary to maximize subacromial space[263–265]

Diagnosis of Hypermobility/Instability

Early diagnosis and treatment of GH hypermobility can prevent serious pathology resulting from dislocation or impingement. However, mild GH hypermobility is difficult to diagnose, because the "microinstability" of the humeral head occurs during active movement without the signs or symptoms associated with subluxation or instability (i.e., positive apprehension or relocation signs). Excessive passive joint mobility in specific directions combined with displaced kinematics of the GH joint during active arm elevation or GH rotation confirm the diagnosis of hypermobility. The most common abnormal GH motions are excessive superior translation during arm elevation, excessive anterior translation during lateral rotation and arm horizontal abduction,[271] and abnormal anterior translation during medial rotation. Excessive translation can be confirmed by palpating the humeral head during active motions and comparing the motion to that on the unaffected side.

The diagnosis of unidirectional instability or multidirectional instability is based on complaints of pain and activity limitation combined with positive apprehension, relocation, and/or sulcus signs.[272,273]

Treatment for Glenohumeral Hypermobility/Instability

Treatment of hypermobility involves addressing the hypomobile adjacent segments simultaneously. For example, a common examination finding for the anterior hypermobile or subluxating shoulder is posterior capsular stiffness (indicated by restricted GH medial rotation and restricted posterior glide of the humerus) and possibly a coexisting anteriorly displaced humerus at rest. The stiffness of the posterior capsule can restrict posterior translation of the humeral head, occurring primarily during the osteokinematic motions of medial rotation and flexion. The posterior capsular stiffness can also contribute to an anteriorly displaced rest position of the humeral head. In this position, it is more vulnerable to moving into an excessive anterior translation during lateral rotation and abduction. Specific joint mobilization of the posterior capsule combined with passive self-stretching of the GH lateral rotators is the best treatment for hypomobility (see Self-Management 25-4).

As passive mobility is restored, the restoration of precise active mobility must closely follow. The GH joint needs to be trained to move in a precise kinematic pattern without abnormal or excessive anterior translations. This often must occur in conjunction with restoring the normal kinematics of the ST articulation (explained later in this section). The subluxating shoulder may require a period of immobilization to decrease pain. Abduction and lateral rotation positions must be avoided to prevent stretching of the anterior capsule. Pain-free isometric exercises for the scapulohumeral and axioscapular muscles should begin as soon as tolerated to avoid the disuse or deconditioning effects of prolonged immobilization.

Active ROM exercises can be initiated against gravity as the patient regains strength and motor control. Abnormal movement patterns, such as excessive scapular elevation, should be discouraged.

Gradually, resistive exercises can be initiated targeting the pectoralis major, latissimus dorsi, teres major, and subscapularis to provide dynamic restraint to anterior translation into the anterior capsule. However, the main target muscle should be the subscapularis because of its insertion anterior to the GH joint and its proximity to the axis of rotation of the GH joint. Careful observation of the humeral head PICR during medial rotation is a good indicator of the participation of the subscapularis in the medial rotation force couple. Anterior translation of the humerus during medial rotation indicates a lack of subscapularis participation. In addition, proper scapular stabilization by the serratus anterior and lower trapezius will prevent excessive anterior tilt of the scapula. Exercises should be prescribed to isolate subscapularis function as much as possible (see Self-Management 25-6).

Infraspinatus and teres minor strengthening can also be targeted to prevent excessive anterior translation of the head of the humerus.[274] For the infraspinatus and teres minor to provide a stabilizing force on the GH joint, stability of the ST articulation is a prerequisite. If the scapula is not stabilized by the axioscapular muscles, when the infraspinatus and teres minor contract, instead of providing a posterior force to the GH joint, contraction of the infraspinatus and teres minor can contribute to further anterior displacement. This occurs by reverse action on the scapula; instead of compressing the GH joint into the glenoid fossa, the resultant force pulls the scapula toward the humerus and forces the head of the humerus anteriorly. During any lateral rotation exercise, care must be taken to ensure scapular stability exists by encouraging serratus anterior, middle, lower trapezius, and rhomboid activity. This will result in lateral rotation of the humerus without excessive scapular movement.

Isokinetic or plyometric upper extremity exercises (see Fig. 25-15) can be incorporated into the resistive training program of individuals returning to a high level of function. Again, it is recommended that the clinician closely monitor proper stabilization of the scapula during resisted movements at the GH joint. Initial movements should be slow and controlled, with a gradual increase in speed of movement.

If the kinematics are closely monitored, movements into full lateral rotation and abduction should not be contraindicated. If excessive anterior translation occurs because of lack of force-generating capability from the axioscapular or RC muscles and poor motor control, extremes of ROM should be avoided. More neuromuscular reeducation of the movement in a slow, controlled manner is indicated.

Sport-specific exercises can be gradually incorporated into the treatment program to prepare the patient for transition to functional activity (**Fig. 25-19**). Muscle fatigue and close attention to the kinematics of the GH joint is the guide to progression. Control over the translatory motions of the GH joint should be emphasized over general strength gains.

The literature supports the notion that motor control is critical in restoring function to the unstable shoulder.[275–278] Research indicates that peak torque gains occur in persons trained with EMG biofeedback in purely functional patterns with no emphasis on "strength exercising." Functional gains and abolition of pain were greater and occurred earlier in the group trained functionally with EMG biofeedback than the group trained in more traditional strength regimens.[275]

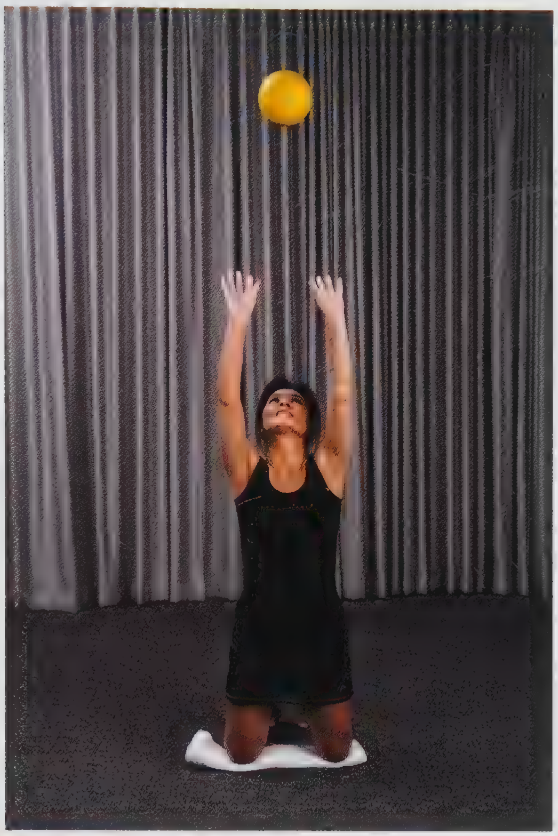


FIGURE 25-19 Sport-specific exercise for a person with glenohumeral hypermobility: ball tossing upward to simulate a set in volleyball.

Frozen Shoulder

Frozen shoulder is defined as slow onset pain near the insertion of the deltoid muscle with loss of internal rotation initially followed by more than 50% loss of external rotation and abduction of less than 90 degrees.[279] The pathophysiology of frozen shoulder is capsular fibrosis and inflammation with chondrogenesis.[280] Although inflammation may be present at the onset of the condition, signs and symptoms last long after the inflammatory process has subsided. As such, the term "adhesive capsulitis" has come into question, with the preferred term describing this condition being "frozen shoulder."[280] Factors associated with frozen shoulder include female gender,[281] older than 40 years,[281] trauma,[282] diabetes,[283] prolonged immobilization,[284] thyroid disease,[285] stroke or myocardial infarction,[286,287] RC disease,[288] cervical radiculopathy,[288] suprascapular nerve entrapment,[288] and the presence of autoimmune diseases.[289] The prevalence of frozen shoulder in the general population is slightly >2%,[290] increasing to 10% to 38% in patients with diabetes and thyroid disease.[291,292] Seventy percent of patients with frozen shoulder are women, and 20% to 30% of those affected subsequently develop a frozen shoulder in the opposite shoulder.[293]

Numerous authors have described classification systems to further define frozen shoulder.[170,171] Most recently, Itoi et al[280] recommend utilizing two categories (see **Table 25-3**):

- The primary idiopathic stiff shoulder develops without any trauma. It results in limited motion and use of the arm.[280] Inflammation and pain can cause reflex inhibition of the shoulder muscles, similar to inhibition of the quadriceps after injury to the knee. There is disagreement in the literature as to whether the underlying pathologic process is an inflammatory condition[294–296] or a fibrosing condition.[297] It appears that synovial inflammation may start the cascade of excessive collagen formation, resulting in a stiff, fibrotic shoulder.[289,296,298,299]
- Secondary stiff shoulder describes stiffness and loss of motion that is due to a known cause, such as after a surgery, trauma, or immobilization.[280]

Diagnosis

Frozen shoulder has been staged based upon arthroscopic findings as described in **Table 25-4**.[300,301] These stages represent a continuum of the disease rather than discrete, well-defined stages. The course associated with frozen shoulder typically lasts from 1 to 3 years.[284,302] There is a relationship of the length of each stage to the length of the remaining stages in that the shorter the initial inflammatory component, the shorter the second and third stages and overall course of the condition. Thus, early intervention can reduce the overall duration of the condition. The role of the physical therapist is to hasten the progression through the stages and limit the severity of the earlier stages so that the patient can move to the final stages as quickly as possible with the least amount of impairment, activity limitation, and participation restrictions.

TABLE 25-3

Classification of Frozen Shoulder

CLASSIFICATION	CAUSE	EXAMPLES
Frozen shoulder (primary stiff shoulder)	Unknown Predisposing conditions	Diabetes mellitus, Dupuytren contracture, thyroid disorders, myocardial infarction, Parkinson disease
Secondary stiff shoulder	Intra-articular	Chondral lesion, labral tear, loose bodies
	Capsular	After capsular injury, surgery, joint immobilization
	Extra-articular	Muscle tightness, heterotopic ossification, skin scarring of burns
	Neurologic	Injuries to the cervical spine or brachial plexus

Itoi E, Arce G, Bain GI, et al. Shoulder stiffness: current concepts and concerns. Arthroscopy 2016;32(7):1402–1414. doi:10.1016/j.arthro.2016.03.024.

TABLE 25-4

Frozen Shoulder Stages Based on Arthroscopic Findings

STAGE	FINDINGS
Stage 1: pre-freezing stage	■ Duration of symptoms is 0–3 months ■ Pain with active and passive ROM ■ Examination under anesthesia: normal or minimal loss of ROM ■ Arthroscopy: diffuse GH synovitis, most pronounced in anterosuperior capsule ■ Pathologic changes: hypertrophic, hypervascular synovitis, rare inflammatory cell infiltrates, normal underlying capsule
Stage 2: freezing stage	■ Duration of symptoms: 3–9 months ■ Patient presents with continued pain ■ Severe loss of ROM in all planes ■ Examination under anesthesia: ROM same as without anesthesia ■ Arthroscopy: dense, proliferative, hypervascular synovitis ■ Pathologic changes: hypertrophic, hypervascular synovitis with perivascular and subsynovial scar, fibroplasias and scar formation in the underlying capsule ■ Duration of symptoms 5–9 months
Stage 3: frozen stage	■ Continued severe loss of ROM with minimal pain ■ Examination under anesthesia: same as Stage 2 ■ Arthroscopy: No hypervascularity seen, remnants of fibrotic synovium can be seen. The capsule feels thick in insertion of the arthroscope and there is diminished capsule volume ■ Pathologic changes: "burned out" synovitis without significant hypertrophy or hypervascularity. Underlying capsule shows dense scar formation ■ Duration of symptoms: 15–24 months
Stage 4: thawing stage	■ Minimal pain ■ Progressive improvement in ROM

ROM, range of motion; GH, glenohumeral joint.

Treatment

Neviaser and Neviaser[300,301] stress the importance of an individualized treatment plan based upon the underlying etiology and stage of the disease. Patient-related instruction is a critical component in educating the patient as to the underlying etiologic factors contributing to the condition, the stage and progression of the condition, and the necessary commitment to self-management for the best outcome. The use of therapeutic exercise has been shown to be a common and effective component of intervention used for frozen shoulder.[286,303–307] The determination of the type and intensity of exercise depends on the patient's specific strength, ROM, joint mobility, motor control needs, and level of irritability. Kelley et al.[308] propose an irritability classification to assist the practitioner in clinical decisions regarding intervention.

Nonoperative Interventions The best approach to frozen shoulder is prevention. Although this syndrome is considered a self-limited process, complete recovery with no residual limitation and disability is neither ensured nor common. Fibrosis, secondary arthritis, myofascial contracture, disuse atrophy, and altered motor control patterns may be permanent. Only active use of the arm and full maintenance of GH and ST active mobility with precise shoulder kinematics at all three shoulder girdle articulations can reverse these changes.

Table 25-5 outlines basic interventions for each stage of frozen shoulder.

Stage 1 Patient-related instruction about the underlying causes of presenting signs and symptoms and the natural history of frozen shoulder is important to allay the patient's fears of more serious disease. Discussing how the painful stage progresses to painless motion restriction prepares the patient for an extended recovery. Instruction in the importance of adherence to a self-management program is vital to positive long-term outcomes.

Patients who present with painful limitation of motion are recommended oral nonsteroidal anti-inflammatory medications that are supplemented with other analgesics as necessary.[309–311] An intra-articular injection of steroid and local analgesic can be extremely useful both in the diagnosis and treatment of frozen shoulder.[312–316] In the presence of cervical discogenic pain as the genesis of the painful limitation of motion, a systematic review shows Level II evidence for the efficacy of cervical interlaminar epidural injections with local anesthetic with or without steroids vs. injection into the shoulder.[317]

After injection, passive GH ROM is reevaluated. If the patient has significant decrease in pain and increased ROM, the diagnosis of Stage 1 is confirmed. If, however, pain is improved, but ROM has not changed significantly, the diagnosis of Stage 2 is confirmed.

Patients should also be started on a supervised therapeutic exercise program to restore function by decreasing the pain and inflammatory response, increasing ROM, improving muscle performance, and reestablishing normal shoulder mechanics. The primary goal of treatment of patients with Stage 1 frozen shoulder is to interrupt the cycle of pain and inflammation.

Though little data exist to support the use of therapeutic modalities, modalities are suggested to influence pain (high-voltage galvanic stimulation, transcutaneous electrical stimulation,[311] iontophoresis, cryotherapy), reduce inflammation (iontophoresis, phonophoresis, cryotherapy), and to promote relaxation (moist heat, ultrasound).[318] Hydrotherapy can also be effectively used to break the cycle of pain (see Chapter 16).[319]

Applying the correct tensile stress to the tissues is based upon the patient's level of irritability (see **Table 25-6**). In patients with high irritability, such as the case in Stage 1, low intensity and short duration joint mobilizations are performed to alter the joint receptors' input, reduce pain, decrease muscle guarding, and increase motion.[320] Grade I and II joint mobilizations and physiologic movements (active assisted ROM) within a pain-free ROM can be used in this stage (see Chapter 7).[321]

Closed chain exercises can be performed to promote the RC function of GH stabilization (i.e., wall slides),[322] and improve

TABLE 25-5

Physical Therapy Intervention During Stages 1 to 4 of Frozen Shoulder

STAGE/GOAL	PATIENT EDUCATON	MODALITIES	STRENGTHENING	STRETCHING AND ROM	JOINT MOBILIZATION
Stage 1					
Goal: interrupt pain and inflammation; promote relaxation	Educate (pathogenesis, posture, activity modification)	As needed to control pain, inflammation, and promote relaxation	Early closed chain exercises (i.e., wall slides)	AAROM in pain-free ROM, aquatic exercise, gentle PROM, pendulum exercise	Grade I and II mobilizations
Stage 2					
Goal: minimize pain, inflammation, capsular adhesions, and restriction of ROM	Posture, necessity for HEP	As needed to decrease pain and inflammation and improve tissue extensibility	More advanced scapular training, specific RC strengthening	AROM, PROM	Grade II and III mobilizations
Stages 3 and 4					
Goal: Increase ROM	Posture, necessity for HEP	To promote relaxation, tissue extensibility, and reduce treatment discomfort	More specific scapular training to reestablish force couples, continued RC strengthening	More specific AROM to reestablish scapular and GH mechanics; more aggressive stretching (PNF, STM, low-load, prolonged stretch)	Grades III and IV

AAROM, active assisted range of motion; AROM, active range of motion; PROM, passive range of motion; HEP, home exercise program; PNF, proprioceptive neuromuscular facilitation; RC, rotator cuff; STM, soft-tissue mobilization.

TABLE 25-6

Irritability Classification

HIGH IRRITABILITY	MODERATE IRRITABILITY	LOW IRRITABILITY
High pain (≥7/10)	Moderate pain (4–6/10)	Low pain (≤3/10)
Consistent night or resting pain	Intermittent night or resting pain	No resting or night pain
Pain prior to end ROM	Pain at end ROM	Minimal pain at end ROM with overpressure
AROM less than PROM secondary to pain	AROM similar to PROM	AROM same as PROM

ROM, range of motion; AROM, active range of motion; PROM, passive active range of motion.
Modified from Kelley MJ, McClure PW, Leggin BG. Frozen shoulder: evidence and a proposed model guiding rehabilitation. J Orthop Sports Phys Ther 2009;39:135–148.

extensibility of the affected muscles, capsule, and ligaments. Stretching should be done in the pain-free range and may be held from 1 to 5 seconds, two to three times a day. Scapular stabilization exercises can be modified to allow the patient to activate the scapular muscles in pain-free positions (see Display 25-14, Fig. 2, and Self-Management 25-3, Level 1, can be modified with more pillows to allow the patient to work in a less extreme range of upper extremity elevation). This type of exercise should be initiated as early as possible to promote GH stability and optimal ST force couple recruitment. Scapula taping (see "Adjunctive Interventions: Taping") can be used to help promote scapular stability and GH mobility. The home exercise program should include passive ROM exercises in *pain-free* ROM and pendulum exercises to promote capsular stretch (Fig. 25-8).

Postural training is incorporated to discourage forward head and thoracic kyphosis, which places the scapula in anterior tilt, internal rotation, and clavicular protraction.

Stage 2 The continuum of symptoms presenting in this stage may include pain in the paracervical and periscapular region as a result of compensatory scapular elevation. In this stage, the individual may learn to use ST, elbow, or trunk motions to substitute for lost GH motions.[149] "Hiking" of the shoulder girdle is evident during elevation of the arm as a result of capsular stiffness and RC weakness disallowing normal GH mechanics.[149] Anterior and superior translation of the humeral head may result from a decrease in capsular volume.[323] The limitation of ROM is in a capsular pattern with lateral rotation the most limited, followed by abduction and medial rotation.[324]

The goal of the second phase of rehabilitation is to continue to decrease inflammation and pain, and to minimize capsular restriction and secondary weakness of the RC and scapular upward rotator force couple. Passive joint mobilizations are used to stretch the CLC to allow normal GH mechanics. Contracture of the rotator cuff interval (RCI) has been shown in patients with frozen shoulder.[325–327] The RCI forms the triangular-shaped tissue between the anterior supraspinatus tendon edge and the upper subscapularis border, and includes the superior GH ligament and the coracohumeral ligament. Stretching, soft tissue and joint mobilization should target the RCI and the CLC. It has been proposed that an inferior glide with the arm at the side, while in external rotation, stretches the RCI.[308]

Johnson et al.[328] found significant improvement in external rotation ROM in patients with frozen shoulder after performing posterior glide mobilizations for 1 minute at end range of abduction and external rotation. High-grade mobilizations (Grade III and IV) are used to promote elongation of shortened fibrotic soft tissues. High-grade mobilizations should be performed with the joint positioned at or near its physiologic end range. It should be noted that immediate gains with mobilization represent transient tissue preconditioning and must be followed up with a self-management program.[329,330] Stretching passively or with hold-relax techniques to the posterior capsule can be addressed with a home exercise as shown in Self-Management 25-4.

Once passive motion is improved, it must be followed up with active exercises to maintain the ROM. If strength is fair or above, active exercises against gravity can be introduced in the sagittal and frontal planes as well as the plane of the scapula. The therapist must pay careful attention to ensure restoring motor control patterns to promote 3D scapular kinematics (versus elevation or excessive upward rotation) and control over GH superior glide.[149] Careful isolated strengthening of the RC, serratus anterior, middle, and lower trapezius is indicated (see Self-Managements 25-1, 25-2, and 25-3).

Taping the ST articulation can significantly help to limit scapular substitution patterns and force greater mobility at the GH joint during functional activity (see "Adjunctive Interventions: Taping" section).[331] Taping the ST articulation may transfer improvements made in mobility and force or torque production with specific exercise to ADLs and instrumental ADLs, including specific movement patterns necessary for sport.

Stages 3 and 4 In these stages, pain may resolve spontaneously.[332] Physical examination will reveal a stiff shoulder with faulty SH kinematics.[333] The goal of physical therapy is to improve GH mobility and restore SH rhythm. In this phase, irritability level reduces and more aggressive stretching and joint mobilization are tolerated and should be a focus of treatment. **Figure 25-20** provides an example of a self-mobilization technique. Full active ROM is the goal, because any residual limitation may reinitiate the cycle. Low-load, prolonged stretch produces plastic elongation of tissues as opposed to high tensile resistance seen in high-load, brief stretch.[334,335] Heat may be used for relaxation, ultrasound may be used to promote tissue extensibility in the axillary fold, and cryotherapy may be used to reduce treatment discomfort. It is important to note that biologic remodeling occurs over long periods (months) as opposed to mechanically induced change which occurs within minutes.[336] Strengthening of the RC and SH muscles continues in this phase to reestablish coordinated force couples (see Self-Managements 25-1, 25-2, and 25-3), although positions

FIGURE 25-20 Self-mobilization of the glenohumeral joint into lateral distraction.

may still require modification because of ROM limitations in the GH joint.

Operative Treatment Conservative treatment will often be successful in patients with Stage 2 frozen shoulder; however, some patients in late Stage 2 and Stage 3 may have a refractory motion loss. In patients who continue to have a refractory motion loss that creates disability, operative treatment may be considered. Operative treatment is demanding, and proper patient selection, anesthesia, and postoperative analgesia are critical to its success. Operative treatment of patients with frozen shoulder includes closed manipulation and arthroscopic release. Closed manipulation is contraindicated in patients with significant osteopenia, recent surgical repair of soft tissues about the shoulder, or in the presence of fractures, neurologic injury, and instability.

Historically, arthroscopy has been of little diagnostic and therapeutic value in patients with frozen shoulder.[282] However, it has been suggested that the arthroscope may be helpful for delineation of disorders, documentation of the result of closed manipulation, and treatment of concomitant intra-articular and subacromial disease.[296,323,337,338] The goal of physical therapy treatment after surgery is to maintain ROM achieved under anesthesia and to decrease pain and inflammation. In the recovery room, the arm is placed in the quadrant position while the patient is still under scalene block anesthesia. A second scalene block is administered during an overnight hospital stay so the patient can tolerate exercise through the ROM.[339,340] Continuous passive motion is recommended throughout the night.[341] After discharge, the patient should receive outpatient physical therapy 5 days per week for the next 2 weeks, then three times per week until treatment is completed. Treatment includes high frequency of interventions directed toward ROM, modalities for pain and inflammation, and hydrotherapy. Strengthening exercises are gradually incorporated into the program, as outlined previously.

ADJUNCTIVE INTERVENTIONS: TAPING

Complex muscular relationships exist among the scapula, humerus, cervical, thoracic spine, lumbar spine, and pelvis. Faulty scapular alignment contributes to a variety of syndromes affecting the upper quadrant. Scapular taping can improve the resting alignment of the scapula on the thorax, thereby improving joint alignment of the related joints and length–tension properties of the shared musculature between the scapula and other regions of the upper quadrant. Scapular taping can be a useful adjunctive intervention when used with therapeutic exercise for the treatment of many upper quadrant diagnoses.[55,342]

Patients can perform exercises and ADLs or instrumental ADLs while taped with the added benefit of improved joint alignment and length–tension properties of the scapular musculature as well as tactile biofeedback. The benefit of scapular taping over an off-the-shelf brace is that taping allows the specific three-dimensional correction of each patient's unique alignment faults. Short-term taping (2 to 3 weeks) may assist in improved neuromuscular control of faulty movement patterns, whereas long-term taping (8 to 12 weeks) may affect muscle length–tension properties. Taping the ST articulation has several goals:

- To improve initial alignment, which promotes improved movement patterns
- To alter length–tension properties by stretching tissues that are too short and reducing tension placed on tissues that are too long
- To provide support and reduce stress to myofascial tissues under chronic tension
- To provide kinesthetic awareness of scapular position during rest and movement
- To guide the kinematics during movement

Each piece of tape provides a specific corrective force on the scapula. Any one piece can be used in conjunction with other directional pieces to provide a multidimensional correction of the alignment of the scapula. The goal is to tape the scapula into improved alignment. If, however, the patient has significant kyphosis, forward-head, or forward-shoulder posture, 100% correction should not be attempted. It is instead recommended to moderately correct the faulty alignment, because too much change in a short period may not be well tolerated by an individual with a chronic postural problem.

The tape product is specialized for taping the body for alignment and movement. It has the best combination of adhesive, extensible, yet stiff properties. The undertape is called Cover-Roll stretch, a hypoallergenic tape applied to protect the patient's skin from the overtape, called Leukotape (Beirsdorf Inc., Norwalk, CT). On the shoulder girdle, the Cover-Roll stretch often is adequate alone, particularly on a small-framed person with minimal to moderate postural faults.

The description of taping that follows details one method of taping, but other methods of taping can be used on the scapula and the humerus.[76] The goals of improved alignment and function are common to various techniques. Improved alignment and function during ADLs and instrumental ADLs and exercise can be achieved with proper taping techniques, and therefore taping can be a useful adjunctive intervention to therapeutic exercise and functional retraining.

Scapular Corrections

The following illustrations depict corrections of scapula position.

- Correcting scapular depression and improving scapular elevation (**Fig. 25-21**)
- Correcting scapular downward rotation and improving scapular upward rotation (**Fig. 25-22**)
- Correcting scapular abduction and improving scapular adduction (**Figs. 25-23** and **25-24**)
- Correcting scapular winging
  - Tape as for correction of scapular downward rotation (see Fig. 25-21) and abduction (see Fig. 25-23)
- Correction of scapular anterior tilt (**Fig. 25-25**)
- Correcting scapular elevation (see **Fig. 25-26**)

Prevention of Allergic Reaction

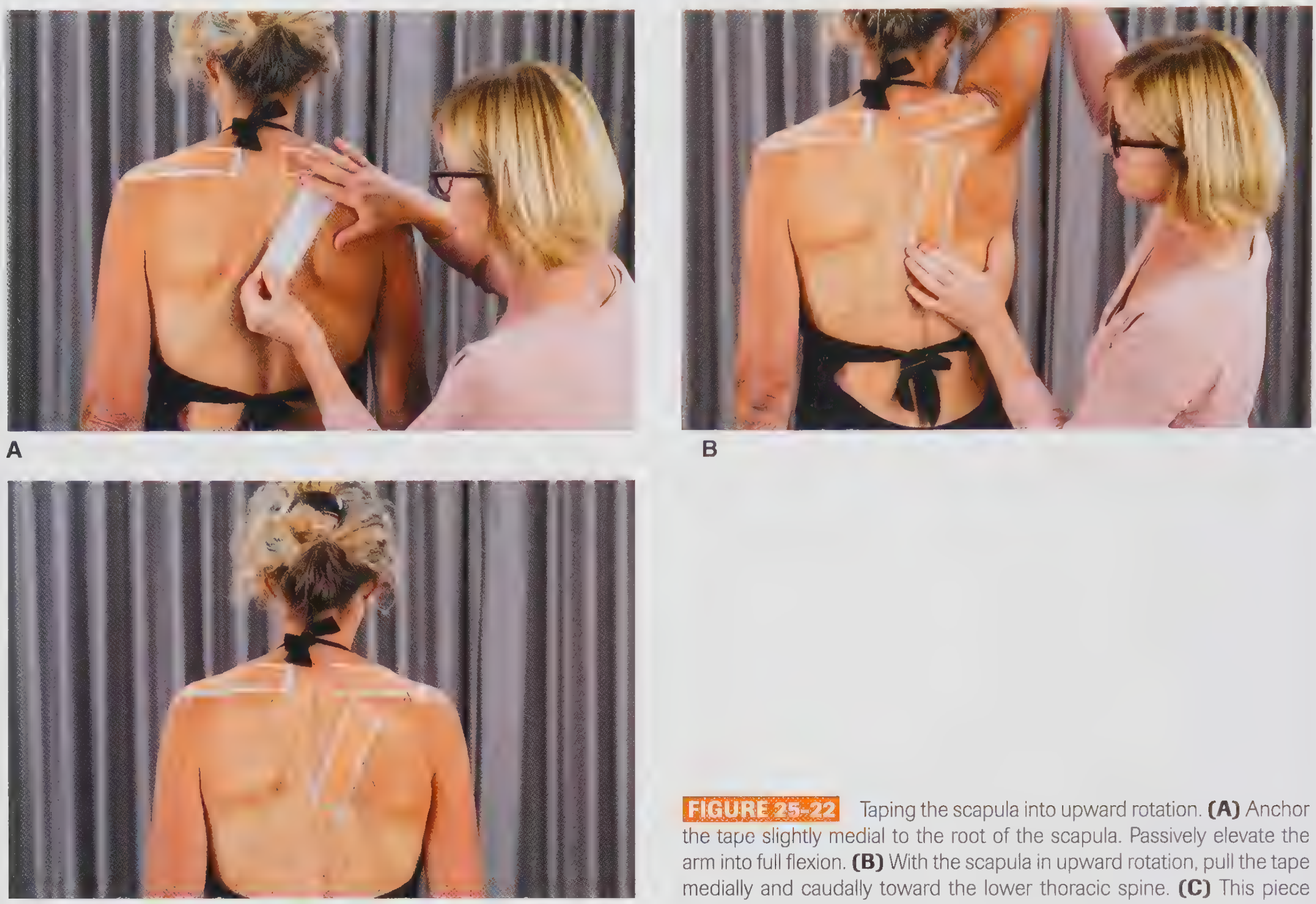
A common side effect of taping is an allergic reaction to the tape adhesive or skin breakdown. The following are troubleshooting tips to help prevent adverse reactions to taping:

- Use only Cover-Roll stretch, which is hypoallergenic. The allergic reaction is usually to the adhesive in the Leukotape.
- Use a skin preparation solution before application of the tape. A recommended skin preparation solution is milk of magnesia. A thin coat applied to the skin should completely dry before the tape is applied to allow easier tape removal.
- Ensure that all tape residue is removed before the next tape application.
- Warn patients of potential skin irritation. Instruct patients to remove the tape immediately if any itching or burning sensations develop.

A

B

FIGURE 25-21 Correction of scapula depression. **(A)** Anchor the tape to the lateral edge of the acromion process. Passively elevate the scapula, ensuring the acromial end rotates upward. Pull the tape medially toward the cervical spine along the suprascapular space, following the fiber direction of the upper trapezius. Do not cross the cervical spine. Apply a piece in a similar direction on the opposite side to prevent lateral shearing across the cervical spine. **(B)** Repeat the application until the correction is made. Often, if tape is applied to correct additional alignment faults, this piece needs to be repeated to ensure that other tape applications have not pulled the scapula into depression.



A B C

FIGURE 25-22 Taping the scapula into upward rotation. **(A)** Anchor the tape slightly medial to the root of the scapula. Passively elevate the arm into full flexion. **(B)** With the scapula in upward rotation, pull the tape medially and caudally toward the lower thoracic spine. **(C)** This piece provides a center of rotation for scapular upward rotation.

FIGURE 25-23 Taping the scapula into adduction. Tape as in Figure 25-22, but add a piece following the fiber direction of the middle trapezius as shown on the left scapula of this subject.

Prevention of Skin Breakdown

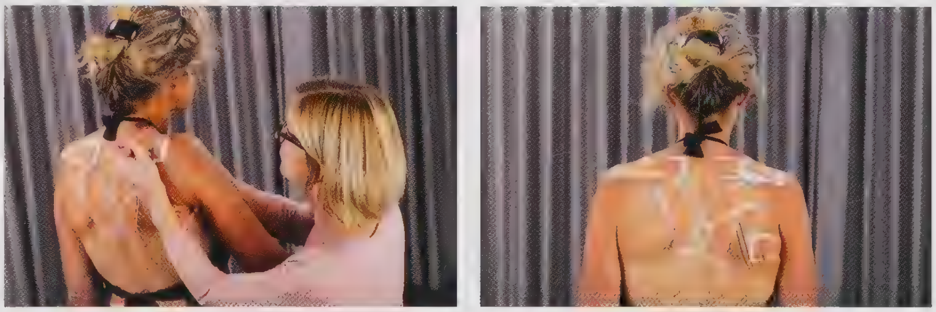
Skin breakdown often occurs because of excessive friction between the skin and the tape. Follow these guidelines to minimize skin breakdown:

- Do not cross the midline of the spine with the tape.
- Do not cross more than one joint at a time.
- Tape the scapulae bilaterally, particularly in elevation.
- Use a skin preparation solution before taping.
- Remove all tape residue before the next taping. Use Leukotape to dab off most of the residue, and follow up with adhesive tape remover.
- If skin breakdown occurs, allow the skin to heal fully before reapplying the tape. This may take 1 week or longer.

If taped properly, patients can often tolerate taping for 3 to 5 days. Showering with the tape is allowed, but soaking the tape is not recommended. For a person engaged in aggressive activities, the tape is more likely to loosen and not be as effective for as many days as it is for a less active individual.

A B C

FIGURE 25-24 This is an alternative or adjunctive technique for taping the scapula into adduction. A second piece of tape can be used to prevent excessive abduction. **(A)** Anchor the tape proximally in the axilla and just anterior to the lateral border of the scapula. **(B)** Pull the tape posteriorly and caudally while adducting and upwardly rotating the scapula. **(C)** Attach the tape to the medial border of the inferior scapula. As the patient elevates the arm, a pull is felt in the axilla if the scapula begins to abduct.



A B

FIGURE 25-25 Taping the scapula into posterior tilt. **(A)** Anchor the tape to the coracoid process. While tilting the scapula posteriorly, pull the tape posteriorly, caudally, and medially (opposite to the direction of pull of the pectoralis minor). **(B)** Anchor the tape to the spine of the scapula. Place another piece of tape as for correction of downward rotation (see Fig. 25-22) and scapular abduction (see Fig. 25-23), being sure to cover the inferior pole of the scapula to control tilt.

FIGURE 25-26 Taping scapula into depression. Use this technique to correct scapula elevation. Anchor the tape to the anterior border of the upper trapezius (not shown). Pull the tape posterior and caudal and anchor to the spine of the scapula.

KEY POINTS

- Critical to the management of the shoulder girdle complex is a thorough understanding of the anatomy and kinesiology of each of the four articulations comprising the complex.
- Precise kinematics at each of the four articulations and the integration of all four articulations with respect to joint function, force couples, and precise motor control to coordinate motion are required for optimal function of the shoulder complex.
- Because the shoulder girdle is one link in a kinetic chain, the function of the shoulder girdle affects and is affected by the function of other regions of the upper and lower quadrants.
- Treatment of impairments, although often necessary for improved function, should be complemented by functional retraining modified to the level of ability at a given time in the rehabilitation process.
- Ideal total body posture is a prerequisite for optimal movement in the shoulder girdle complex.

- A thorough understanding of the integrated approach to therapeutic exercise in the shoulder girdle is key to successful outcomes of shoulder girdle conditions.
- Three common types of chronic RC disorders have been described in the literature: (1) extrinsic or subacromial (compression), (2) intrinsic (tensile), and (3) extrinsic internal impingement (compression/tensile).
- Rotator cuff disorders can be broadly classified as acute or chronic in origin, though acute, avulsive tears of healthy RCTs are considered to be rare. Most authors believe that RC tears that appear to be of sudden onset after trauma are extensions of underlying chronic tears or tears of previously degenerated tendons.
- Frozen shoulder has been staged based upon arthroscopic findings as described in Table 25-4.
- Treatment of frozen shoulder should be individually based on the etiologic causes and stage of the disease (Table 25-5).
- Early intervention is key to successful outcome of frozen shoulder. Complete recovery with no residual limitation or disability is neither ensured nor common.
- Scapular taping can improve resting posture and proprioception, and thereby affect movement of the shoulder girdle complex.

CRITICAL THINKING QUESTIONS

1. What are the 3D kinematics of the scapula during arm elevation?
2. What are the 3D kinematics at the AC joint?
3. What are the coupled motions of the scapula during:
   a. Clavicle elevation
   b. Clavicle posterior rotation
   c. Clavicle retraction
4. What conjunct GH motion is a prerequisite to restoring full upper extremity elevation?
5. Why is the RC–deltoid function contingent on the scapular upward rotation force couple?
6. Which muscles can limit scapular upward rotation mobility?
7. Which muscles must have normal force or torque and length–tension relationships to achieve full upward scapular rotation ROM?
8. What is the timing of onset of the scapular muscles during scapular upward rotation to produce the ideal kinematics for scapular rotation?
9. What musculature is shared by the shoulder girdle and cervical spine? What joints are linked by the shared musculature?
10. If the upper trapezius is overstretched, as in a depressed scapula, in what direction is cervical spine rotation limited? What treatment do you propose to correct this problem?
11. If the levator scapula is adaptively shortened, as in a downwardly rotated scapula, in what direction is cervical spine rotation limited? What treatment do you propose to correct this problem?
12. How can cervical nerve root involvement affect the function of the shoulder girdle?
13. Using the case described in Display 25-4, determine the dosage parameters for improving muscular force or torque of the RC (using the exercise described in Self-Management 25-1).
14. What is the most critical intervention to promote healing of a strained muscle caused by adaptive lengthening from faulty postures?
15. How can poor technique during a biceps curl contribute to an anterior tilted scapula?
16. Adapt Self-Management 25-1 dosage parameters to focus on endurance.
17. In what alignment does the scapula rest to develop an elongated serratus anterior? How does this elongation contribute to a faulty kinematics of the scapula during scapular upward rotation?
18. Why is restoring the scapular kinematics important in the long-term recovery of impingement syndrome?
19. How can taping the scapula help adhesive capsulitis to recover? What taping techniques would you use?
20. Using Case Study No. 4 in Unit 7, develop a comprehensive exercise program. Describe each exercise according to the therapeutic exercise intervention model described in Chapter 2. You can follow the format used in the Selective Intervention at the end of Chapter 26.

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CHAPTER

26

The Elbow, Forearm, Wrist, and Hand

LORI THEIN BRODY

Therapeutic exercise texts have often minimized or excluded the elbow, wrist, and hand, deferring evaluation of this region to other health care providers. This complex region is a challenging and specialized area of rehabilitation. Although numerous texts describe the anatomy, kinesiology, pathology, and surgical repair of this area, few sources relate pathology, impairments, and activity limitations with physical therapy intervention at the distal upper extremity level.[1] This chapter discusses common impairments and activity limitations of the elbow, wrist, and hand and the related therapeutic interventions. A brief review of anatomy and kinesiology provides the basis for the interventions chosen. Further details on the anatomy and kinesiology of this region can be found on thePoint.lww.com/BrodyHall4e.

ANATOMY*

Although the anatomy of a given joint is closely related to anatomy of adjacent joints, the elbow, wrist, and hand are discussed separately in the following sections.

Elbow and Forearm

Osteology

The primary osteologic considerations at the elbow and forearm are the humerus, radius, and ulna (**Fig. 26-1**). The articulation of the humerus with the ulna and the radius forms the elbow joint.[2] The key aspects of elbow and forearm osteology include:

- The spool-shaped trochlea of the humerus articulates with the trochlear notch of the ulna medially, and the rounded humeral capitulum articulates with the radial head laterally.
- The humeral medial epicondyle is a subcutaneous, blunt projection, easily palpable during elbow flexion, with a posterior shallow groove accommodating the ulnar nerve.
- The lateral epicondyle is also subcutaneous, with its anterolateral surface serving as the origin of the wrist extensor muscles.

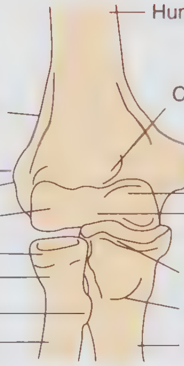


FIGURE 26-1 Elbow osteology with significant bony landmarks. (From Stroyan M, Wilk KE. The functional anatomy of the elbow complex. J Orthop Sports Phys Ther 1993;17:280.)

- The radius is the shorter and more lateral of the two forearm bones, with the radial tuberosity serving as the distal insertion of the biceps brachii.
- The ulna is the longer of the two forearm bones and serves as the major distal component of the elbow joint proper, with its hook-shaped anterior surface articulating with the humeral trochlea.

Arthrology

The elbow joint is comprised of several articulations: the humeroulnar, the humeroradial, and the proximal and distal radioulnar. Because of these multiple articulations, it is considered to be a compound synovial joint. The major ligamentous structures are as follows:

- The ulna deviates laterally relative to the humerus due to the asymmetry in the trochlea. This results in a slight frontal plane valgus angle, often called the carrying angle. This angle allows objects to be carried away from the side of the body while walking. Normal carrying angle can range anywhere from 7 to 20 degrees.[2]
- The ulnar collateral ligaments (UCLs), with anterior, posterior, and oblique components.[3] (see **Fig. 26-2**).
- The thick, cordlike anterior portion of the UCL is the primary stabilizer against valgus forces from 20 to 120 degrees of motion.

*Portions of this section are from Brody LT. Athletic injuries about the elbow. In: Wadsworth C, ed. The Elbow, Forearm, and Wrist [home study course]. LaCross, WI: Orthopedic Section, APTA, 1997. Reproduced with permission.

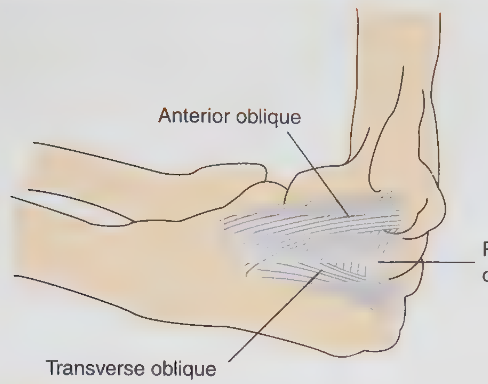


FIGURE 26-2 Ulnar collateral ligaments of the elbow. (From Zarin B, Andrews J, Carson W. Injuries to the Throwing Arm. Philadelphia, PA: WB Saunders, 1985.)

- The radial collateral ligament is a triangular, fan-shaped band blending distally with the annular ligament (surrounding the radial head) and the origins of the extensor carpi radialis brevis (ECRB) and supinator muscles.[3]
- The interosseus membrane is a broad fascial sheath running distomedially, connecting the radius and ulna and providing attachments for the deep forearm muscles.

Myology

Despite only a few muscles having a direct action at the humeroulnar joint, numerous muscles attach about the elbow and can be a source of pain and disability. Although many muscles perform multiple actions, they are classified by the articulation of their primary action. Muscles and their innervation can be found in **Table 26-1**.[4]

Wrist

The bony features of the carpal bones reflect their function. The inner surfaces of the outer carpals are covered with articular cartilage while their outer surfaces are rough, providing attachment for connective tissues. The inner bones have two-thirds of their surfaces covered by articular cartilage, and only the palmar and dorsal surfaces are irregular, providing for ligamentous attachments. A brief overview of anatomy and kinesiology is expanded on thePoint.lww.com/BrodyHall4e.

Osteology

The wrist joint is a complex area that includes eight carpal bones, the distal radius and ulna, and the bases of the metacarpal bones (**Fig. 26-3**). Proximally, the distal radius and radioulnar disk articulate with the scaphoid, lunate, and triquetrum. Laterally, the scaphoid is the largest bone in the proximal carpal row. The distal carpal row consists of the trapezium, trapezoid, capitate (the most central and largest of all carpal bones), and the hamate (**Fig. 26-4**). Key aspects of wrist osteology include the following.

- The scaphoid spans the intercarpal joint, linking the proximal and distal rows, making this bone prone to injury.
- The proximal pole of the scaphoid is susceptible to avascular necrosis following a fracture, as vascular innervation comes from the proximal portion of the scaphoid.[5]
- The lunate bone is the most frequently dislocated bone in the wrist, and perilunate instability following a wrist injury must be evaluated.[6,7]
- The triquetrum articulates with the lunate laterally, the hamate distally and laterally, and the pisiform medially and the articular disk proximally.
- The pisiform is a small pea-shaped bone that is sesamoid in nature and has several soft-tissue attachments.

TABLE 26-1

Muscles of the Elbow and Forearm

MUSCLE	ORIGIN	INSERTION	ACTION	SPINAL LEVEL	PERIPHERAL NERVE
Pronator teres	Medial epicondyle and coronoid process of ulna	Middle lateral radius	Forearm pronation	C7	Median
Supinator	Lateral epicondyle	Lateral upper ⅓ of radius	Forearm supination	C6	Radial
Biceps brachii	Coracoid process; scapular supraglenoid tubercle	Radial tuberosity	Shoulder flexion; elbow flexion	C5–C6	Musculocutaneous
Brachialis	Distal ½ of anterior humerus	Coronoid process of ulna	Elbow flexion	C5–C6	Musculocutaneous and radial
Brachioradialis	Proximal ⅔ of lateral supracondylar ridge of humerus	Lateral radial styloid	Elbow flexion	C6	Radial
Triceps	Infraglenoid tubercle of scapula; proximal posterolateral humerus; distal ⅔ or posteromedial humerus	Olecranon process	Elbow extension	C7–C8	Radial

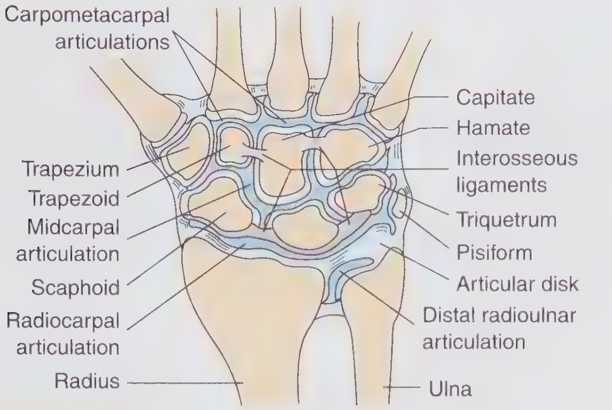


FIGURE 26-3 Wrist osteology. Cross section of the wrist and pertinent bony and soft tissues.

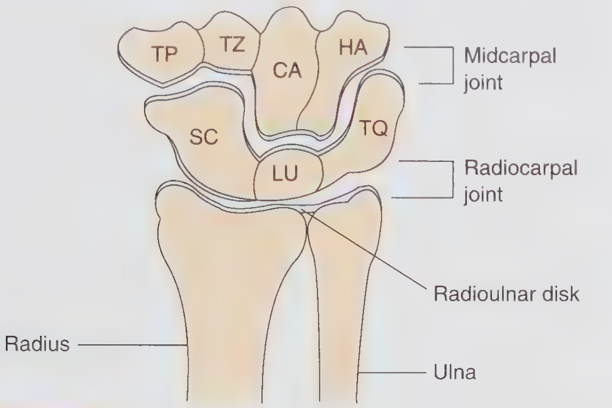


FIGURE 26-4 Wrist complex. The radiocarpal joint is composed of the radius and the articular disk, with the scaphoid (SC), lunate (LU), and triquetrum (TQ) bones. The midcarpal joint is composed of the scaphoid, lunate, and triquetrum with the trapezium (TP), trapezoid (TZ), the capitate (CA), and hamate (HA) bones.

- Distally, the trapezium articulates with the first and second-metacarpals, while lateral and adjacent to it, the trapezoid also articulates with the second metacarpal.
- The capitate is the central and largest of all carpal bones (the "keystone" of the proximal transverse arch), with a central position allowing articulation with seven other bones and serving as a central site for ligamentous attachment.[8] The capitate is convex on all sides; as such, all carpal bones roll and glide anteriorly around the capitate to create a concavity in the palm of the hand, allowing ease in gripping objects.
- The hamate is the most lateral bone of the distal carpal row, articulating with the fourth and fifth metacarpals and containing a palmar hook which protects the ulnar nerve passing beneath.

Arthrology

The wrist is generally divided into radiocarpal, midcarpal, carpometacarpal (CMC), and intercarpal joints. The radiocarpal joint is surrounded by an articular capsule that is lined with a synovial membrane, and this joint is formed by the articulations of the distal radius and the triangular articular disk with the scaphoid, lunate, and triquetrum bones[9,10] (see Fig. 26-4). The key aspects of wrist arthrology are as follows:

- The medial portion of the radiocarpal joint includes a network of structures called the triangular fibrocartilage complex (**Fig. 26-5**).[10]
- The radiocarpal joint is reinforced by several ligaments which are true intracapsular ligaments. The radiocarpal and ulnocarpal joints are considered to be extrinsic because of attachments outside the wrist (**Fig. 26-6**).[9]
- The intercarpal joints consist of articulations between individual bones within the proximal carpal row and the distal carpal row.
- The midcarpal joint is the articulation between the proximal and distal rows. The ligaments in this area are considered to be intrinsic and are divided into interosseous and midcarpal ligaments.[11] The specific ligaments are listed in **Table 26-2**.

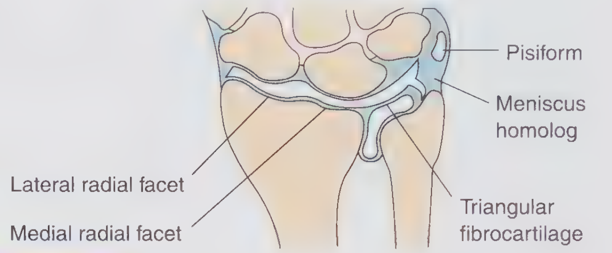


FIGURE 26-5 The proximal surface of the radiocarpal joint is formed by the medial and lateral facets of the distal radius and by the triangular fibrocartilage or articular disk. The articular disk and meniscus homologue are together part of the triangular fibrocartilage complex.

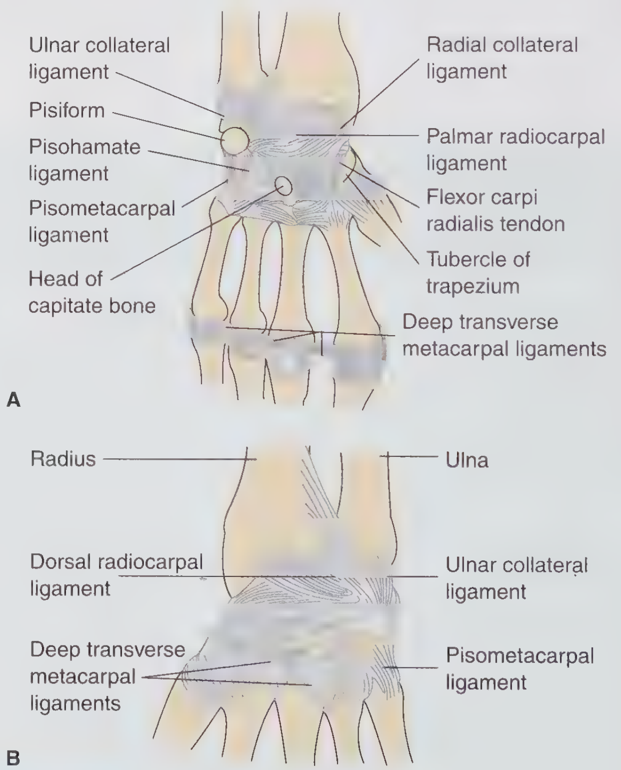


FIGURE 26-6 **(A)** Palmar aspect of the ligaments of the left wrist and metacarpal area. **(B)** Dorsal aspect of the ligaments of the left wrist.

TABLE 26-2

Intrinsic Ligaments of the Wrist

CLASSIFICATION OF INTRINSIC LIGAMENTS	LIGAMENT NAMES
Interosseous	
Distal row	Trapezium-trapezoid
	Trapezoid-capitate
	Capitohamate
Proximal row	Scapholunate
	Lunotriquetral
Midcarpal	
Dorsal[a]	Scaphotriquetral
	Dorsal intercarpal
Palmar[a]	Scaphotrapeziotrapezoid
	Scaphocapitate
	Triquetrocapitate
	Triquetrohamate

[a]Midcarpal ligaments span the proximal and distal rows on the palmar or dorsal surfaces.

From Berger RA. The anatomy and basic biomechanics of the wrist joint. J Hand Ther 1996;9:84–93.

- The CMC joints are also enclosed in a loose articular capsule, and are joined by dorsal, palmar, and interosseous ligaments.
- The first CMC joint has unique properties, as it is a saddle joint, affording great mobility of the thumb. This will be discussed in the *Hand* section.

Myology: Muscles Acting at the Wrist Joint

Several important muscles that function at the wrist have their origin at the elbow. These are the major wrist flexors and extensors. These muscles can be a source of epicondylitis from overuse activities at the wrist. Interventions should be directed at the muscle function at the wrist. A list of the key muscles can be found in **Table 26-3**.

Hand

Osteology

The key aspects of the osteology of the hand are as follows:

- Five metacarpals and 14 phalanges provide the hand's bony structure.
- Each metacarpal has a distal head, shaft, and base.[9]
- The medial four metacarpals articulate proximally with each other and with the distal row of carpal bones while the first and second metacarpals do not articulate with each other.
- The first metacarpal is saddle shaped proximally to articulate with the trapezium.
- There are three phalanges in each finger and two in the thumb.
- Each phalanx has a distal head, shaft, and proximal base.
- The thumb contains two sesamoid bones at the metacarpophalangeal (MCP) joint.

Arthrology

The MCP and interphalangeal (IP) joints have similar arthrologic structures. Each is composed of an articular capsule and synovial lining. The MCP joints contain volar ligaments, which are thick and fibrocartilaginous, loosely attached to the metacarpal, and firmly attached at the phalangeal bases.[9] Because of the incongruence of the MCP joints, the volar ligament (i.e., volar plate) does more than reinforce joint capsule. Its fibrocartilaginous structure adds surface area to the base of the proximal phalanx to more closely approximate the size of the larger metacarpal head. The volar plate also checks hyperextension. Its flexible attachments permit motion

TABLE 26-3

Muscles of the Wrist

MUSCLE	ORIGIN	INSERTION	ACTION	SPINAL LEVEL	PERIPHERAL NERVE
Extensor carpi radialis longus	Distal $^1/_3$ of lateral supracondylar ridge	Base of second metacarpal	Wrist extension and abduction	C6–C7	Radial
Extensor carpi radialis brevis	Common extensor tendon, lateral epicondyle	Base of third metacarpal	Wrist extension and abduction	C6–C7	Radial
Extensor carpi ulnaris	Common extensor tendon	Base of fifth metacarpal	Wrist extension and adduction	C7–C8	Radial
Flexor carpi radialis	Common flexor tendon of medial epicondyle	Base of second metacarpal	Wrist flexion and abduction	C6–C7	Median
Flexor carpi ulnaris	Common flexor tendon; proximal posterior ulna	Pisiform bone, hamate, fifth metacarpal	Wrist flexion and adduction	C8–T1	Ulnar
Pronator quadratus	Medial anterior distal ulna	Lateral anterior distal radius	Forearm pronation	C8–T1	Median

Other muscles with primary function at the hand also assist function at the wrist. These will be included in Table 26-4.

into flexion without restricting motion or impinging the long flexor tendons.[9] The transverse metacarpal ligament connects the volar ligaments of the second through fifth MCP joints. Collateral ligaments are found on either side of the joint and are strong, rounded cords.[10] The capsular, volar, and collateral ligament arrangement at the MCP joints is the same structure found in the IP joints (**Fig. 26-7**).

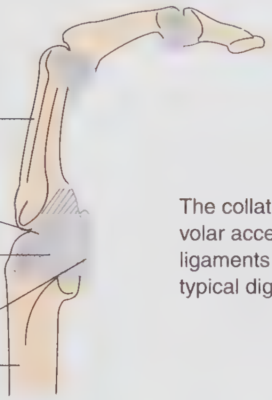


FIGURE 26-7 Ligaments of the fingers.

Myology: Muscles Acting at the Hand

The muscular anatomy of the hand can be classified as thumb and finger musculature. Many muscles contribute to the fine motor function of the wrist and hand. Although a mere listing of the muscles along with their anatomy does not address the fine motor skill necessary for hand function, it is a place to begin consideration of hand function. A listing of muscles as well as figures of some key musculature can be found in **Tables 26-4 and 26-5**, and **Figures 26-8** and **26-9**.

Regional Neurology

Several important nerves serve the elbow, wrist, and hand. These nerves may be injured locally by trauma, stretched during activities, or compressed within a confined space. For example, both the ulnar and median nerves can be entrapped at the ligament of Struthers, and elbow flexion narrows the cubital tunnel by 55%, compressing the ulnar nerve.[12] The median nerve is commonly compressed in the carpal tunnel. Compression of the radial nerve in the forearm can by caused by casts, watchbands, and similar items.[13] Understanding the area anatomy aids the clinician in determining the source of symptoms. The regional neuroanatomy and common site of compression can be found in **Table 26-6**.

TABLE 26-4

Muscles Functioning Primarily at the Hand

MUSCLE	ORIGIN	INSERTION	ACTION	SPINAL LEVEL	PERIPHERAL NERVE
Extensor digitorum	Common extensor tendon of lateral epicondyle	Middle and base of distal phalanx of digits 2–5	Extends MCP joints and assists extension of IP joints	C6–C8	Radial
Extensor indicis	Posterior ulna	Extensor expansion of index finger	Extends MCP joint and assists IP joint extension	C7–C8	Radial
Extensor digiti minimi	Common extensor tendon	Extensor expansion of fifth digit	Extends MCP joint and assists with IP joint extension	C7–C8	Radial
Palmaris longus	Common flexor tendon	Flexor retinaculum, palmar aponeurosis	Tenses palmar fascia	C7–C8	Median
Flexor digitorum superficialis	Common flexor tendon; coronoid process; radius	Middle phalanges of digits 2–5	Flexes proximal IP joints, assists MCP joint and wrist flexion	C7–C8	Median
Flexor digitorum profundus	Anteromedial ulna	Bases of distal phalanges digits 2–5	Flexes DIP joints; assists flexion of IP and MCP joints		
Flexor digiti minimi	Hook of hamate	Proximal phalanx of fifth digit	MCP flexion of fifth finger	C8	Ulnar
Opponens digiti minimi	Hook of hamate	Length of fifth MC	Opposes CMC of fifth finger	C8–T1	Ulnar
Dorsal interossei	Metacarpal bones	Radial and ulnar sides of fingers	Digit abduction and assists flexion and extension	C8–T1	Ulnar
Palmar interossei	Metacarpal bones	Ulnar and radial sides of fingers	Adduction of fingers	C8–T1	Ulnar

IP, interphalangeal joint; MCP, metacarpophalangeal joint; DIP, distal interphalangeal joint; CMC, carpometacarpal joint.

TABLE 26-5

Muscles Functioning at the Thumb

MUSCLE	ORIGIN	INSERTION	ACTION	SPINAL LEVEL	PERIPHERAL NERVE
Adductor pollicis	Capitate; second and third MC	Proximal phalanx of thumb	Adduction of CMC joint	C8–T1	Ulnar
Abductor pollicis longus	Posterior ulna and radius	First MC	Abducts and extends CMC joint	C7–C8	Radial
Abductor pollicis brevis	Trapezium and scaphoid	Proximal phalanx of thumb	Abduction of CMC and MCP joints	C6–C8	Median
Opponens pollicis	Trapezium	First MC	Opposes CMC of thumb	C6–C8	Median
Flexor pollicis longus	Interosseus membranes, medial epicondyle	Distal phalanx of thumb	Flexes IP joint	C8–T1	Median
Flexor pollicis brevis	Trapezius, trapezium, and capitate	Proximal phalanx of thumb	Flexes MCP and CMC joints of thumb	C6–C8, T1	Median and ulnar
Extensor pollicis longus	Posterior ulna	Distal phalanx of thumb	Extends IP joint	C7–C8	Radial
Extensor pollicis brevis	Posterior radius	Proximal phalanx of thumb	Extends MCP joint	C7–C8	Radial

CMC, carpometacarpal joint; MC, metacarpal joint; MCP, metacarpophalangeal joint.

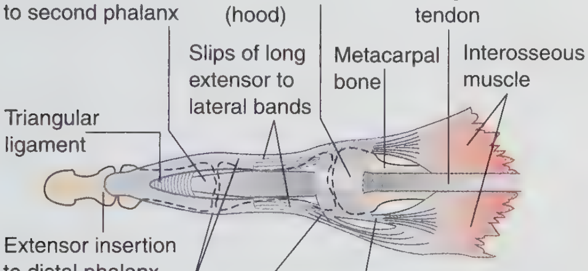


FIGURE 26-8 Dorsal view of extensor mechanism of the fingers.

Kinesiology

Elbow and Forearm

Normal range of motion (ROM) at the elbow joint is 0 to 135 degrees actively and 0 to 150 degrees passively. Much of this mobility is necessary for normal activities of daily living (ADLs). However, unlike the knee, where full knee extension is imperative for ADLs such as ambulation, full elbow extension is not frequently utilized during daily activities. For example, putting on a shirt requires a range of 15 to 140 degrees, and drinking from a cup requires a range of 72 to 130 degrees.[14] ROM in flexion is limited by anterior muscle bulk, and ROM in extension is limited by the bony articulation of the olecranon in the olecranon fossa. The extended position of the humeroulnar joint is the close-packed position, but interestingly, is the loose-packed position of the humeral radial joint. Osseous stability also occurs

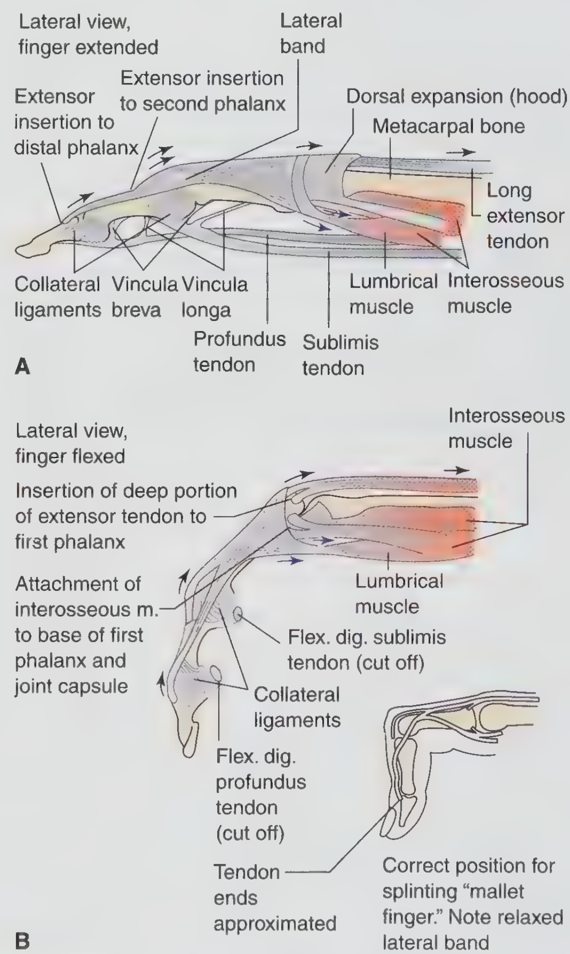


FIGURE 26-9 Intrinsic muscle anatomy. **(A)** Extended position. **(B)** Flexed position.

TABLE 26-6

Regional Neurology of the Forearm, Wrist, and Hand

	MEDIAN NERVE	ULNAR NERVE	RADIAL NERVE
Origination	Two roots from the lateral (C5–C7) and medial (C8–T1) cords	Medial cord (C8–T1) of the brachial plexus	The posterior cord (C5–C8) and is the largest branch of the brachial plexus
Upper arm	Descending along the brachial artery to enter thecubital fossa passing between the brachialis posteriorly and the bicipital aponeurosis anteriorly	Distally through the axilla along with the axillary artery and vein and the brachial artery. At the middle of the humerus, it moves medially, descending anterior to the medial head of the triceps. The ulnar nerve can become entrapped here by *the ligament of Struthers, approximately 8 cm proximal to the medial epicondyle*	Courses distally between the medial and long heads of the triceps and then passes obliquely posterior to the humerus and deep to the lateral head of the triceps to the lateral aspect of the humerus to penetrate the anterior compartment
Elbow	Passes under the *ligament of Struthers* and the *lacertus fibrosus* and enters the forearm between the *heads of the pronator teres (PT)*	Passes superficially through a groove on the dorsum of the medial epicondyle, entering the forearm in the *cubital tunnel* between the two heads of the flexor carpi ulnaris (FCU)	Passes anterior to the lateral epicondyle
Forearm	Behind and adhered to the flexor digitorum superficialis and anterior to the flexor digitorum profundus. Passing the distal margin of the PT muscle, the median nerve gives rise to two branches: the anterior interosseous nerve and the palmer cutaneous nerve	Passes superficially through a groove on the dorsum of the medial epicondyle, entering the forearm in the cubital tunnel between the two heads of the FCU. Just proximal to the wrist, it sends off a dorsal branch that continues distally across the flexor retinaculum	It bifurcates to become the posterior interosseous (only motor) and superficial radial (only sensory) nerves. The posterior interosseous nerve passes through the supinator muscle under *arcade of Frosche*, around the proximal radius, and beneath the extensor muscle mass to interosseous membrane of forearm and ends at dorsal wrist capsule; the superficial radial nerve passes beneath the brachioradialis muscle and continues distally along the *anterolateral aspect of the forearm*
Wrist	Distally, it lies deep to the flexor retinaculum passing through the *carpal tunnel*	Continues distally with the ulnar artery, beneath the most superficial aspect of the *flexor retinaculum*, and divides into superficial and deep terminal branches	Proximal to the wrist, the superficial radial nerve passes deep to curve around the radius and divides into four or five dorsal digital nerves
Hand	After passing through the tunnel, the median nerve divides into five or six branches, providing motor and sensory innervation to the hand	Superficial and deep branches provide motor and sensory innervation to the hand	Superficial radial nerve provides sensory innervations to most of the dorsum of the hand and the thumb and index fingers.

Italicized structures are areas of potential nerve entrapment.

in extreme flexion. Mid-range stability comes from ligamentous support. Motion at the humeral ulnar joint occurs primarily by gliding of the ulna on the trochlea.

Pronation and supination technically occur through the forearm at the proximal and distal radioulnar joints. The normal range of pronation and supination is 0 to 80 degrees in each direction. Pronation occurs as the radius crosses over the ulna at the proximal radioulnar joint. Although most ADLs occur with the forearm in a middle position, some activities, such as receiving change in the palm of the hand, require full supination.

Resistance to varus in full extension is provided by the bony congruity of the humeral ulnar joint on the medial side , by the radial collateral ligament laterally, and the capsule, which surrounds both joints.[10] Resistance to distraction is provided by soft-tissue components, and the anterior portion of the joint capsule provides the primary resistance to anterior displacement.

Resistance to valgus at the elbow is important due to the many throwing sports and activities that stress the medial side of the elbow. The UCL is the primary medial stabilizer; the flexor and pronator muscle groups offer a small amount of additional support. In addition, compression of the humeroradial joint offers approximately 50% of the resistance to valgus stressing.[2] Resistance to valgus stress in full extension is limited equally by the UCL, bony congruity, and the anterior capsule.[9] As the elbow moves into flexion, most of the resistance to valgus stress is provided by the anterior band of the UCL (**Evidence and Research 26-1**).

EVIDENCE and RESEARCH 26-1

A cadaveric study of the flexor pronator group relative to the UCL throughout the ROM has significant implications for rehabilitation of individuals with medial elbow injuries. At 30 degrees of elbow flexion, the pronator teres (PT)and flexor carpi radialis (FCR) muscles were entirely anterior to the UCL, and the flexor carpi ulnaris (FCU) muscle was found over or posterior to the UCL. The flexor digitorum superficialis (FDS) muscle was over the UCL in most cases. The findings were similar at 90 degrees, except the FCU muscle was completely over the UCL, and the FDS muscle was anterior to the UCL in most cases. At 120 degrees, the PT, FCR, and FDS muscles were all anterior to the UCL, and only the FCU muscle was over the UCL. This pattern suggests that the *FCU muscle is the primary dynamic medial elbow stabilizer throughout the ROM* and particularly at 120 degrees of flexion.[15,16]

Wrist

Wrist Flexion and Extension

The normal wrist ROM is from 80 degrees of flexion to 70 degrees of extension. The resting position of the wrist is between 20 and 35 degrees of extension and 10 to 15 degrees of ulnar deviation while in the close-packed position.[17] The wrist functions primarily through a range of 10 degrees of flexion to 35 degrees of extension when performing most ADLs.[18] However, some activities, such as rising from a chair, require significantly more extension.[18] Movement at the radiocarpal joint is predominantly movement of the convex proximal carpal row on the concave distal radius and articular disk, as many functions of the upper extremity are open kinetic chain. In addition, simultaneous movement of the distal carpal row on the proximal carpal row occurs and contributes to overall movement. The distal row is considered convex and articulates with the proximal carpal row in the exact same fashion that the proximal carpal row articulates with the radius.[2] Because of this, the proximal carpal row is considered to be an intercalated segment, a relatively unattached middle segment of a three-segment link, because of its position between the radius and distal carpals.[10]

Mechanically, the scaphoid plays a critical role in stabilizing the wrist by means of its position bridging the proximal and distal carpal rows (i.e., the midcarpal joint). The radiocarpal and midcarpal joints provide variable proportions of the motion during wrist extension and flexion. When the proportion contributed by radiocarpal joint exceeds that of the midcarpal joints in one direction, this pattern reverses in the other direction.[10] Wrist extension is initiated at the distal carpal row, with this row gliding on the relatively stable proximal row. As the wrist passes into extension, these rows begin to move together, with the scaphoid intervening as the bridge to this process.[10] Full extension is the close-packed position of the wrist.

In general, the distal carpal row functions as a unit because of the interlocking of articular surfaces and the ligamentous connections between the distal carpal row and the metacarpals distally.[11] The distal row tends to move in unison with the second and third metacarpals, palmar flexing when these metacarpals palmar flex and dorsal flexing when they dorsally flex. The proximal carpal row differs in its movement pattern from the distal row. In general, the bones in the proximal row move together, although greater motion occurs between the bones in the proximal row than in the distal row. This is true of the direction and magnitude of motion between the bones in the proximal row. The proximal row tends to move in the same direction as the distal row and therefore in the same direction as the second and third metacarpals.[11] Between-bone motion also occurs, and, during wrist extension, the scaphoid supinates while the lunate pronates, functionally separating these bones. This motion underlies perilunate instabilities occurring as a result of forceful extension.

Wrist Ulnar and Radial Deviation

Frontal plane motion is normally from 15 degrees of radial deviation to 30 degrees of ulnar deviation. The ulnar styloid is shorter than the radial styloid, accounting for the greater range in ulnar deviation than radial. Greater ulnar and radial deviation is possible when the wrist is in a neutral flexion-extension position. Arthrokinematic motion in radial and ulnar deviation is more complex than in flexion and extension. During radial deviation, the proximal carpal row glides ulnarly and flexes while the distal row pivots radially. During ulnar deviation, the proximal row glides radially and moves into extension while the distal row moves ulnarly.[11]

Wrist Function

The mobility of the wrist depends on the position of the fingers because of the length of extrinsic tendons crossing the wrist and hand joints. For example, wrist flexion is decreased when the fingers are simultaneously flexed because of the length of the extrinsic finger extensor muscles. Likewise, the mobility of the fingers depends on the position of the wrist, as evidenced by the inability to fully flex the fingers when the wrist is flexed.

Load transmission across the wrist is significant and varies with wrist position. With the wrist and forearm in neutral, approximately 80% of the force is transmitted across the radiocarpal joint and 20% across the ulnocarpal joint.[19] Further breakdown of the radiocarpal loads shows that approximately 45% of these forces are transmitted across the radioscaphoid joint and 35% across the radiolunate joint.[19] Forearm pronation increases the load transmitted across the ulnocarpal joint to approximately 37%, with a proportional reduction in load at the radiocarpal joint. Radiocarpal forces increase to 87% when the wrist is in radial deviation.[11]

Hand

Carpometacarpal Joints

Carpometacarpal joints two through five are similar in structure and function, but the first CMC is unique. The second through fourth CMC joints permit one degree of freedom in flexion and extension, and the fifth CMC allows some abduction and adduction as well. Motion at the CMC joints is limited primarily by the ligamentous structure. Motion increases at the CMC joints from the radial to the ulnar side of the hand.[10] Almost no motion occurs at the second and third CMC joints, the fourth is slightly more mobile, and the fifth moves through a range of nearly 10 to 20 degrees.[10] This allows the hypothenar eminence to cup and grip objects, increasing the palmar contact with the object.

The first CMC joint is saddle shaped and has two degrees of freedom and some axial rotation. This mobility allows for opposition, a key function of the thumb. The thumb is involved in nearly all forms of prehension, or handling activities, and loss of the thumb accounts for the greatest portion of disability in the hand, as approximately 70% of hand function involves the thumb.[20] ROM is approximately from 20 degrees of flexion to 45 degrees of extension and from 0 degrees of adduction to 40 degrees of abduction. Mobility at the CMC is limited by the ligamentous and interposed soft tissues.

A primary role of the CMC joints is to contribute to cupping of the hand, forming palmar arches. This hollowing allows the hand to conform to the shape of the object being held (**Fig. 26-10A** and **B**). Two arches are visible: the longitudinal arch that spans the length of the hand and the metacarpal arch that transverses the palm.

Metacarpophalangeal Joint

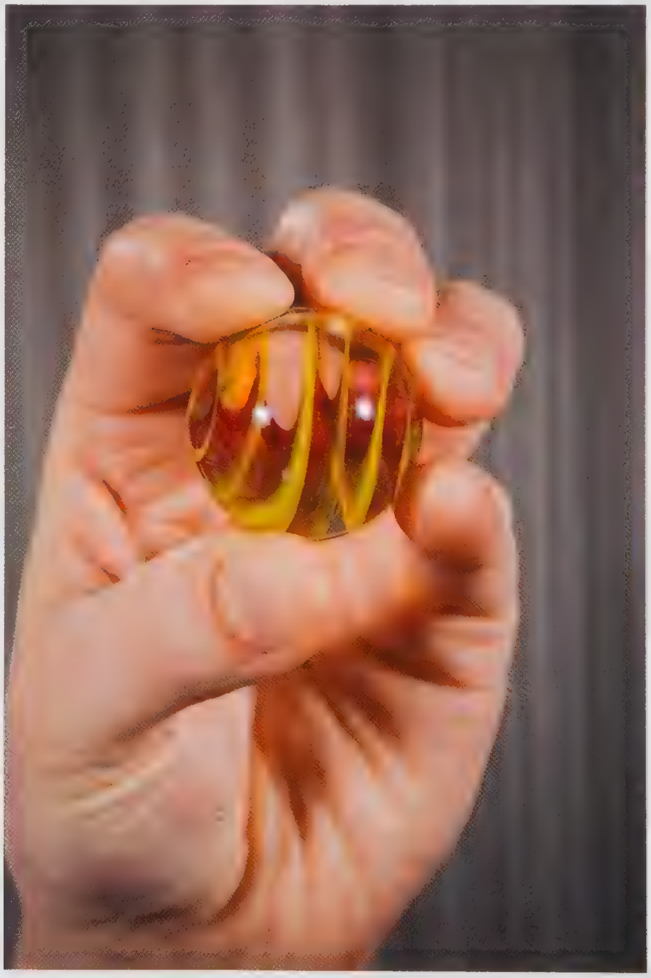
The four medial MCP joints possess two degrees of freedom, flexion and extension, and abduction and adduction. The mobility at these joints increases from the radial to ulnar sides of the hand, with an active ROM (AROM) from 90 degrees of flexion to 10 degrees of extension. Passively, variable amounts of extension are available. Functional flexion at the MCP joint is approximately 60 degrees.[17] The range in abduction and adduction is approximately 20 degrees in each direction. The range in the frontal plane is limited by articular surface geometry, and the range in flexion is limited by joint geometry and capsule, and the range in extension is limited by the volar plates.

The MCP joint of the thumb also possesses two degrees of freedom. The ROM is more limited here than in fingers 2 through 5. Almost no hyperextension is available in normal hands, and only approximately 50 degrees of flexion can be obtained. Extension at this joint is further limited by the presence of two sesamoid bones, stabilized by collateral and intersesamoid ligaments. The primary function of MCP mobility of the thumb is providing additional range for opposition and prehension activities.

Interphalangeal Joints

The IP joints of the fingers and thumb are similar in function. Each is a hinge joint with one degree of freedom. ROM at the IP joints, as with the other joints in the hand, increases from

A



B

FIGURE 26-10 **(A** and **B)** Hollowing of the hand allows it to conform to different size and shape objects.

the radial to the ulnar side of the hand. This is easily observed when making a fist. The ROM at the proximal interphalangeal (PIP) is from 0 degrees of extension to 100 degrees of flexion at the radial side of the hand and nearly 135 degrees of flexion at the ulnar side. Little hyperextension is available because of the volar plates. The distal interphalangeal (DIP) joint demonstrates less ROM, from 10 degrees of extension to 80 degrees of flexion. Functional flexion at the PIP joints is approximately 60 degrees, and functional flexion at the DIP joints is 40 degrees.[17]

Extensor Mechanism

The extensor mechanism of the fingers is composed of the extensor hood (i.e., extensor expansion or dorsal aponeurosis) and the extensor digitorum (ED), palmar interossei, dorsal interossei, and lumbrical muscles. Each finger contains a similar mechanism that is necessary for successful extension of the finger. As the ED courses distally, it flattens into an aponeurotic hood over the metacarpal, and just distal to the MCP joint, the ED is joined by tendon fibers from the interossei muscles. The interossei arise from the lateral borders of the metacarpals (see Fig. 26-9). This aponeurosis formed by the ED and interossei continues distally, where, proximal to the PIP, the hood splits into three branches. All three branches receive fibers from the interossei, and the medial branch also receives fibers from the lumbricals. A central tendon continues distally and crosses the PIP to insert at the base of the middle phalanx. Two lateral bands on either side continue distally, cross the PIP joint, and reunite into a single tendon that terminates at the distal phalanx. Several local ligaments attach to the extensor hood and prevent bowstringing during movement. The oblique retinacular ligaments are important in simultaneous PIP and DIP extension.

A complete description of the mechanics of the extensor hood is beyond the scope of this text, but a few generalizations can be made. At the MCP joint, contraction of the ED produces extension while activation of the lumbricals and interossei produces flexion. The torque produced by the ED exceeds that of others, and extension results. At the PIP joint, the ED, interossei, and lumbricals together produce extension (**Fig. 26-11**). Isolated contraction of the ED causes the finger to claw or to produce MCP hyperextension with IP flexion[10] because of the passive pull of the long finger flexors at the IP joints. Extension of the PIP joint also produces DIP extension (and vice versa), and when the PIP is held in flexion, the DIP is incapable of isolated extension. This mechanism is fine-tuned to produce fine movements and strong grip. Any imbalance in the lateral slips disrupts this mechanism and significantly alters hand function.

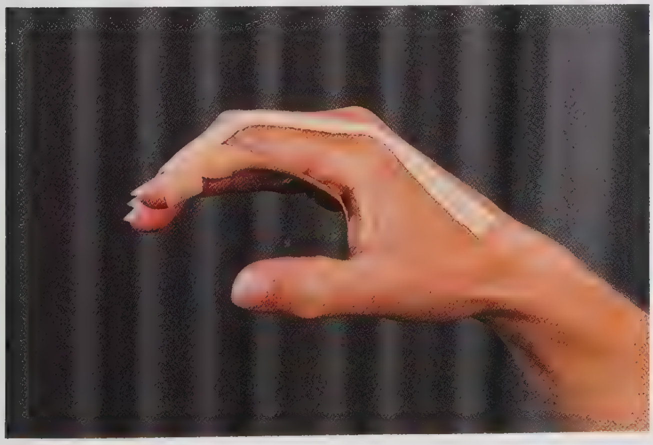


FIGURE 26-11 Patient with a lumbrical strain who improved with kinesiotaping.

Prehension

The hand is well suited for the major task of grasping, gripping, and manipulating objects. Prehension is the global term for the usual tasks of grasping, holding, and manipulating objects. Many terms are commonly used to describe hand functions. Most functions can be grouped into the categories of grip and pinch. These can be further subdivided into categories such as power grip, precision grip, hook grip, key pinch, and precision pinch. The power grip is used for developing firm control, while the precision grip is used when accuracy and precision are needed. The precision grip allows the hand to conform to different size and shape objects. Examples of power grip include hook, spherical, cylinder, and fist grasps. These grips utilize primarily the medial side of the hand. Examples of pinch types include the key, and tip-to-tip and pulp-to-pulp pinches, which use more of the lateral side of the hand.

Grip activity has been broken down into four stages. In the first step, the hand opens by simultaneous action of the long extensor and hand intrinsic muscles. The fingers then close about the object, requiring activity of the intrinsic and extrinsic flexor and opposition muscles. The third step is an increase in force in these same muscles to a level appropriate for the task. Lastly, the hand again opens to release the object.[17] While the flexors are grasping the object, the wrist extensor muscles must fire simultaneously to prevent the long flexors from producing wrist flexion.

The innervation of the hand is related to the two types of grip. The ulnar nerve controls the motor and sensory distribution of the medial digits, and these digits are used more for the power grip. The median nerve controls the lateral digits, which are used more for the precision grip. The thumb musculature, used in both types of grip, is innervated by both nerves.[17]

The power grip is used when force generation is the primary objective (**Fig. 26-12A**). Carrying a suitcase, climbing on a jungle gym, making a fist, and grasping a baseball to throw are all examples of power grip. In this situation, the ulnar digits stabilize the object, holding it against the palm, with or without the assistance of the thumb. The fingers are fully flexed while the wrist is extended and ulnarly deviated.

The precision pinch is used when fine control is necessary. This grip is used when holding a writing instrument, putting a key in the door, holding playing cards or a piece of paper between two fingers (Fig. 26-12B and C). The precision pinch includes primarily the MCP joints and the radial side of the hand. The index and middle fingers work with the thumb to create a tripod. In contrast with the power grip, the object in a precision pinch may never come in contact with the palm.

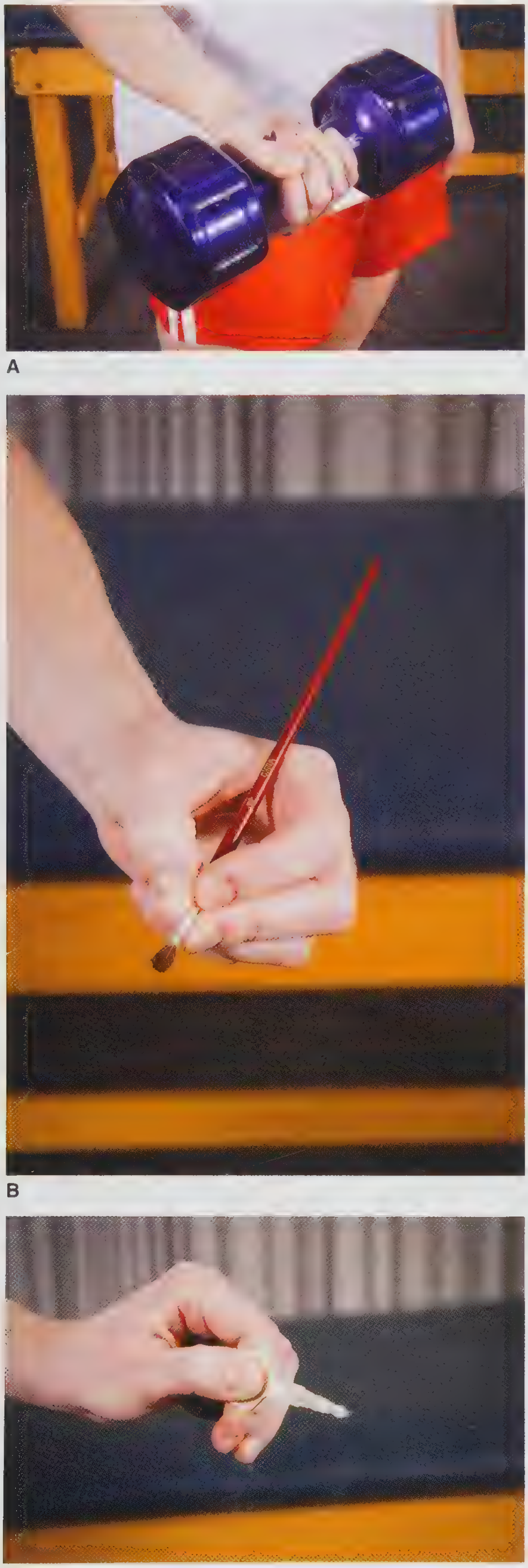


FIGURE 26-12 **(A)** Power grip. **(B)** Precision grip. **(C)** Key grip.

EXAMINATION AND EVALUATION

Examination and evaluation of the elbow, wrist, and hand must include a comprehensive assessment of the upper quarter. The upper extremity relationships between the cervical spine and distal joints require a full examination to ensure identification of the problem source. Many of the examination techniques depend on the situation. The presence of comorbidities such as diabetes or rheumatoid arthritis (RA) necessitates different examination techniques from those used for the patient without such additional issues. The following sections address the key aspects of elbow, wrist, and hand examinations.

History and Observation

The history and subjective information focuses the remainder of the examination. In addition to the medical history and evaluation of the current problem, subjective information about the signs and symptoms after the injury is valuable. Information is gathered about the activity limitations (e.g., inability to manipulate buttons, zippers, and other small objects, inability to carry out hygiene activities, difficulty writing or typing, problems opening jars) and participation restrictions (e.g., unable to work because of inability to type, unable to care for child because of pain and weakness in elbow) associated with the current complaint. Information to differentiate primary elbow, wrist, and hand problems from those referred from the cervical spine must be ascertained.

The resting position of the hand also should be observed, including these deformities:

- Swan-neck deformity
- Boutonnière deformity
- Ulnar drift (commonly observed in patients with RA)
- Clubbing of DIPs
- Heberden or Bouchard nodes
- Claw fingers
- Dupuytren contracture
- Mallet or trigger finger

Mobility Examination

Mobility examination of the elbow, wrist, and hand includes osteokinematic and arthrokinematic testing as well as tests of muscle extensibility. It is particularly important to find the sources of mobility loss in the hand, because this impairment is associated with significant activity limitations, participation restrictions, and disability. Examination procedures should distinguish between contractile and noncontractile tissues and between intrinsic and extrinsic muscle limitations. In most cases, both osteokinematic and arthrokinematic tests of mobility should be performed, as well as tests of muscle flexibility.

Muscle Performance Examination

Muscles functioning at the elbow, wrist, and hand should be tested in a logical order on the basis of the subjective information provided, history, and the results of the examination.

Many of the hand muscles are quite small, and therapists must consider their relative strength when applying traditional manual muscle testing criteria. Stabilization, particularly when trying to isolate small intrinsic muscles of the hand, ensures that the muscle of interest is being tested. Kendall[4] has described the testing procedures for the relevant muscles in the region. Grip and pinch (tip pinch and key pinch) force measurements are commonly used and have high reliability. However, large changes (i.e., improvements) in these measures are necessary before they can be reliably detected with standard measuring devices.[21]

Other Tests

Many special tests assess the integrity of tissues throughout the upper quarter. These tests examine ligament stability, soft-tissue mobility, neurologic status, and functional tasks. Magee[17] has provided a complete listing and description of special tests. Some of the more common tests used are listed in **Display 26-1**.

DISPLAY 26-1

Special Tests at the Elbow, Wrist, and Hand

Elbow

- Valgus stress test (0 and 30 degrees)
- Varus stress test (0 and 30 degrees)
- Tinel sign
- Pinch grip
- Tennis elbow tests
  - Resisted wrist extension
  - Passive wrist flexion
  - Resisted third finger extension (biases ECRB)
- Golfer elbow
  - Resisted wrist flexion
  - Passive wrist extension

Wrist and Hand

- Carpal tunnel tests
  - Phalen test
  - Reverse Phalen test
  - Tinel sign
  - Three jaw chuck test
- Allen test
- Finkelstein test
- Brunnel-Littler test
- Retinacular test
- Froment sign
- Ligamentous instability testing for the fingers
- Thumb ulnar collateral ligament testing
- Lunotriquetral ballottement test
- Scaphoid stress test
- Hand function tests
- Grip strength test
- Reflexes and sensation
- Upper limb tension tests

THERAPEUTIC EXERCISE INTERVENTIONS FOR COMMON IMPAIRMENTS OF BODY FUNCTIONS

Mobility of Joint Functions: Impaired Range of Motion

Impaired mobility in the distal upper extremity can be very disabling. Fine motor skills are necessary for the simplest of daily activities. Mobility activities must restore full ROM throughout the distal segments to maintain independence in many household tasks. Impaired mobility in this region is treated with a combination of therapeutic modalities, exercise, and splinting.

Hypomobility

Hypomobility in this region can occur for a number of reasons. Injuries that necessitate a period of immobilization can produce profound mobility loss. Surgery, neurologic injuries, burns, and falls can significantly impair mobility. Because of the mobility required for functional use of the upper limb, loss of motion in this region can be quite disabling. Lack of mobility in the distal upper extremity can result in faulty movement patterns, resulting in overuse and pain in the proximal upper extremity, such as the shoulder.

Intervention for mobility loss requires a thorough evaluation to determine the structures responsible for or contributing to the motion loss. The joint capsule, short musculotendinous structures, immobile fascial tissues, or restricted nervous tissues are a few examples of tissues that may be at fault. Evaluation techniques aimed at differentiating contractile from noncontractile tissues, followed by specific tension testing, can pinpoint the source of limitation. Only then can appropriate intervention be initiated.

Mobility impairment at the ***elbow*** includes loss of flexion and extension. Loss of elbow extension occurs frequently after fractures or dislocations at the elbow, or with prolonged use of a shoulder sling. The elbow is also at risk of the development of heterotopic ossification following injury or trauma.[22] Loss of motion occurs rapidly at the elbow, and therefore immobilization is kept to the minimum acceptable time. Degenerative joint disease has a lower impact on the upper extremity joints than the lower, and loss of motion because of arthritic changes at the elbow therefore is less much common than at the knee. Loss of motion at the elbow is often compensated by trunk, shoulder, and wrist motion, all of which may place additional loads on these structures.

Mobility loss at the ***forearm*** includes loss of pronation and supination. The capsular pattern shows equal loss of pronation and supination. Loss of motion at the forearm is common after immobilization for wrist and hand fractures. Loss of pronation and supination results in difficulties with turning knobs, opening jars, receiving change, and turning a key. These motions are frequently transferred to the shoulder, with the person performing external and internal rotation to compensate. Restoration of motion is important to prevent secondary injury to the shoulder.

Loss of motion at the ***wrist*** is common after falls or fractures injuring the wrist. Fractures of the distal radius or ulna require immobilization and potentially surgical stabilization. Scaphoid fractures are prone to avascular necrosis due to the local blood supply, and therefore require surgical fixation and/or immobilization. This immobilization leads to loss of mobility at all joints of the forearm, wrist, and hand. RA also affects the wrist joint causing deformity, pain, and loss of hand function.

Loss of motion in the ***hand*** is frequently caused by rheumatoid arthritic changes. Loss of motion in the hand may also result from osteoarthritis (OA), and this process tends to affect the PIP and DIP joints but not the MCP joints (see **Self-Management 26-1**). The thumb CMC is significantly affected by OA and RA. Injuries such as fractures, dislocations, and burns produce limitations in mobility after treatment. Dupuytren contraction, or contraction of the palmar fascia, usually affects the fourth or fifth fingers, where the skin is adherent to the underlying fascia. This progressive fibrosis of the palmar fascia has no known cause and affects men older than 40 years of age more than women.[17] These impairments can lead to activity limitations (e.g., inability to grasp a pen) and therefore participation restrictions (e.g., unable to work because of inability to grasp objects).

SELF-MANAGEMENT 26-1
Proximal and Distal Interphalangeal Joint Flexion

Purpose: To increase the mobility in the joints and tendons of your fingers

Starting Position: Start with all the joints of your fingers as straight as possible.

Movement Technique: Keeping your knuckle joints (MCP) straight, bend the middle and fingertip joints (PIP and DIP) as far as possible. Return to the starting position.

Dosage:

Repetitions: ______________________

Frequency: ______________________

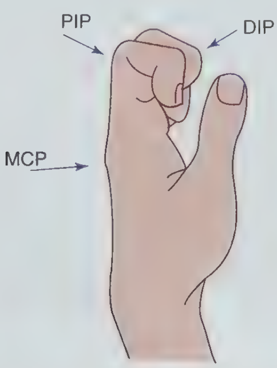


FIGURE 26-13 Elbow joint mobilization. Distal traction at humeroulnar joint to increase elbow flexion and extension range of motion.

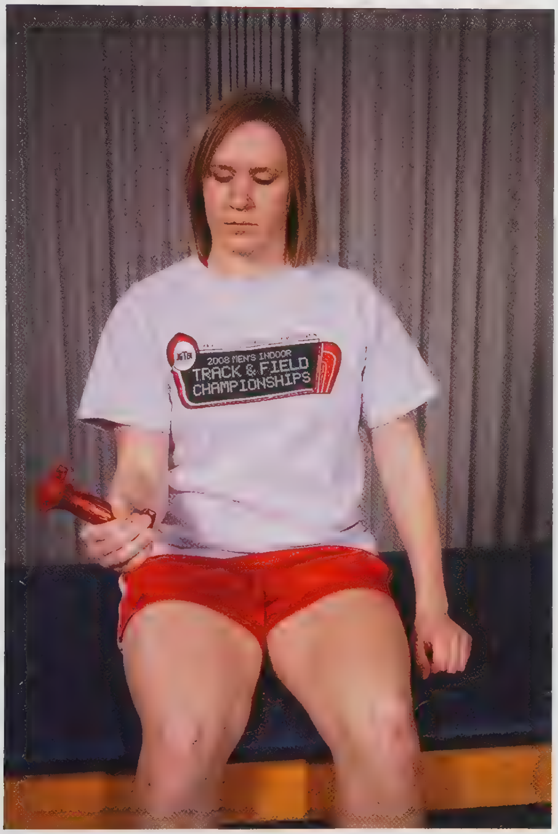
Activities to increase mobility begin with an intervention to warm the tissue (i.e., active exercise, superficial, or deep heat), followed by stretching the musculotendinous tissue, or mobilizing the joint depending upon the source of the restriction. For example, limited motion because of capsular restriction at the elbow may be treated with humeroulnar distraction techniques and some anterior and posterior glides (see Chapter 7; **Fig. 26-13**). After mobilization techniques, passive prolonged stretching in the direction of limitation may be performed along with concurrent application of heat or cold. Active mobility in the new range should follow (**Fig. 26-14 A** and **B**). For example, active pronation and supination may be followed by active hand to mouth exercises or active forward reaching. When immobility is caused by a short or stiff muscle, traditional stretching techniques may be employed. At the same time, postural correction and strengthening of the antagonist (which is often weak because of its lengthened position) must occur. Immobile fascial connective tissues are mobilized by manual techniques such as massage and manual deep pressure application. As with stretching, this intervention should be followed with active use of the limb (see **Self-Management 26-2** and **Building Block 26-1**).

Treatment for immobility of the hand of a patient with RA depends on the acuteness of the situation and the degree of deformity. Immobilization may be the treatment of choice in some phases of this disease process (see the "Stiff Hand and Restricted Motion" section). Neural gliding techniques are employed when neural tension test reveals immobility of neural tissue to be the source of the patient's symptoms.

Hypermobility

Hypermobility is an uncommon problem at the elbow and forearm. The humeroulnar joint is a very congruent joint; as such, hypomobility is a much more common complaint. Elbow hyperextension ROM is one criterion for a diagnosis of systemic hypermobility. However, hypermobility at this joint is rarely symptomatic because of the limited weight bearing occurring in

A



B

FIGURE 26-14 **(A)** Contract-relax stretching of the forearm into supination, followed by **(B)** active use of the forearm into elbow flexion with forearm supination.

the upper extremities. Individuals participating in upper extremity weight-bearing sports such as gymnastics or wrestling may have difficulty associated with elbow hyperextension during sports.

Similarly, hypermobility is uncommon at the wrist and hand. Hypermobility should not be confused with instability. Instabilities occur in the wrist and the hand. Lunate dislocation with perilunate instability and scapholunate dissociation (SLD) are common, and instability in the fingers is evident in the hand of the patient with RA. However, physiologic hypermobility rarely exists without pathology or injury, and if hypermobility is present, it rarely produces symptoms.

SELF-MANAGEMENT 26-2

Metacarpophalangeal and Proximal Interphalangeal Joint Flexion with Distal Interphalangeal Joint Extension

Purpose: To increase the mobility of your finger joints and tendons

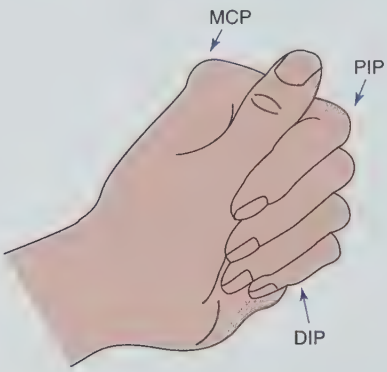
Position: Start with all joints of your fingers as straight as possible.

Movement Technique: Bend your knuckle (MCP) and middle (PIP) joints while keeping the fingertip joints (DIP) straight. Return to the starting position.

Dosage:

Repetitions: ____________________

Frequency: ____________________



BUILDING BLOCK 26-1

A 56-year-old forklift driver has pain with active pronation and supination following a radial head fracture which is now healed. Outline a typical treatment session for this patient in the early phase.

Impaired Muscle Power Functions

Several injuries or pathologies can impair a patient's ability to produce torque in the distal upper extremity. Fractures, dislocations, contusions, sprains, tendon lacerations, burns, nerve entrapments, and crush injuries are some of the conditions that can limit a person's torque-producing ability. The relationship between the force impairment and activity limitations or participation restrictions should justify and guide treatment. The clinician should progress specific muscular strengthening exercises to activities that reproduce the function of the upper extremity. This includes *self-care activities* such as dressing, grooming, and bathing and *work activities* such as pushing, pulling, grasping, pinching, typing, and other dexterous movements.

A B

FIGURE 26-15 Resisted wrist extension. **(A)** Gripping free weights; **(B)** Use of a cuff weight without grip.

Any strengthening exercises for the elbow, wrist, and hand must consider the kinetic chain relationship across these joints. The joints are interconnected and functionally related, and the muscular anatomy often crosses several joints. Strengthening exercises for the elbow often load the wrist and finger muscles as the individual holds a weight or other resistive equipment in the hand. Strengthening exercises requiring a grip differ from those using resistance around the wrist (e.g., a cuff weight). For example, strengthening exercises for lateral epicondylitis focus on strengthening the wrist extensor muscles in their roles as active wrist extensors (concentrically and eccentrically) and as stabilizers against finger flexor activity such as gripping or shaking hands. Any wrist extension exercise that concurrently requires gripping may overload these muscles (**Fig. 26-15**). This relationship is one reason why prescribing shoulder exercises while holding a 16-oz can in the hand can produce lateral epicondylitis in previously asymptomatic individuals.

Neurologic Causes

Neurologic pathology or injury is a common source of impaired muscle function in the distal upper extremity. Cervical degenerative joint disease, degenerative disk disease, foraminal stenosis, and cervical spine injuries can cause symptoms distally in the respective nerve root distributions. After exiting the cervical spine, the nerves may be entrapped in a number of locations throughout the neck, thorax, and arm. Entrapment may produce distal neurovascular symptoms such as thoracic outlet syndrome. In this situation, the neurovascular bundle is compressed at one or more sites (e.g., cervical rib, scalene muscles) producing a variety of intermittent to constant symptoms. The ulnar nerve is also subject to traction injuries at the medial elbow in the thrower. Similarly, the mobility of any nerve within its nerve sheath may become restricted (**Fig. 26-16**; see Table 26-6).

Injury, compression, traction, or ischemia of these nerves, proximally or distally, results in various symptoms, such as loss of torque production in the muscles served by the damaged nerve. Treatment for this inability to produce torque depends on the specific situation. For example, when distal weakness is caused by cervical spine disk herniation, traction, postural retraining, and cervical spine exercises are initiated, followed by progressive resistive exercises for distal musculature after the proximal symptoms have improved. Nerve entrapments at the elbow, wrist, or hand are initially treated by release techniques to mobilize the nerve. In contrast, traction injuries to the ulnar nerve at the elbow are initially treated with stabilization techniques followed by strengthening exercises. Perform these exercises in positions or postures that minimize the traction or compressive forces on the nerve. Progression to more provocative and functional patterns should follow (see **Building Block 26-2**).

FIGURE 26-16 Neural gliding techniques with an emphasis on median nerve.

BUILDING BLOCK 26-2

A 16-year-old softball pitcher experiences weakness in the muscles innervated by the ulnar nerve due to valgus stress traction injury. She has been taken off pitching until symptoms resolve and needs to rehabilitate key musculature. What are the key muscle groups to consider for rehabilitation? What types of exercises might be recommended?

Muscular Causes

Muscle injuries in this region range from muscular overuse injuries to tendinopathies at the elbow (i.e., medial and lateral epicondylitis) and wrist (i.e., de Quervain tenosynovitis) to tendon lacerations in the hand. Interventions to improve torque production after muscular injury depend on the location and severity of injury, the role of that muscle in functional activities, and the stages of healing. The first muscle loading following a muscle injury may be in the form of stretching, AROM, or isometric exercise. As these loading techniques are tolerated, progression ensues.

After the appropriate level of load is determined, progress isometric to dynamic exercises the involved musculature at the elbow, forearm, wrist, and/or hand. Exercises may be performed in an open chain, using light weights, bands, or other functional objects (**Fig. 26-17**). Closed chain activity such as leaning against a wall or on a countertop to provide resistance is also appropriate. In the hand, manual resistance, specific muscle activation exercises or simple gripping exercises using sponges, putty, or other small resistive objects are often used (**Fig. 26-18**). Resistance to extension can be provided manually or by using small resistive bands or rubber bands. In addition to restoring torque-producing abilities, the fine motor function of the muscles must be retrained. Several dexterity tasks are available for training these skills (see **Self-Management 26-3**).

FIGURE 26-17 Resisted wrist flexion combined with grip strengthening using a resistive band.

FIGURE 26-18 Grip strengthening using putty.

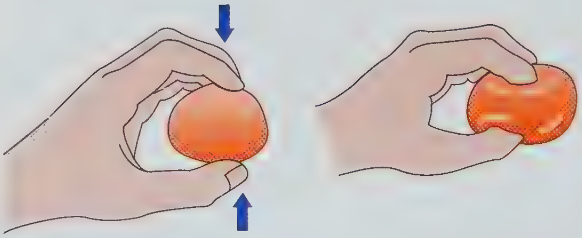
SELF-MANAGEMENT 26-3
Finger Pinch with Putty

Purpose:	To increase the strength of the muscles used to pinch
Starting Position:	Form the putty into the shape of a ball. Hold it between your fingertips.
Movement Technique:	Pinch the putty between your fingertips and your thumb until your fingers press through the putty. Reshape the putty and repeat.

Dosage:

Repetitions: ____________________

Frequency: ____________________



Deconditioning, Disuse, and Overuse

Proximal muscle deconditioning can lead to distal muscle overuse injuries. For example, as the rotator cuff fatigues during a repetitive lifting task, more of the lifting may be performed by the elbow flexors and wrist extensors, predisposing the individual to lateral epicondylitis. This occurs with repetitive work or leisure activities and reinforces the importance of a thorough upper quarter examination. Effective repetitive wrist and hand activity requires proximal stabilization. When the proximal muscles fatigue, posture is compromised, and a greater load is placed on the distal muscles. As one group of distal muscles fatigues, the load is shifted to alternate muscle groups, overworking these muscles. Ensure sufficient muscle endurance for the required task throughout the kinetic chain (**Evidence and Research 26-2**).

EVIDENCE and RESEARCH 26-2

Researchers performed electromyography of the wrist musculature before and after inducing delayed onset muscle soreness in the upper trapezius muscle. Following the onset of trapezius muscle pain, the ECRB showed decreased activity, while the FCU showed a decrease in the relative rest time. Results suggest that shoulder pain impacts coordination of distal musculature during computer work.[23]

Endurance Impairment

Muscular endurance impairment is often seen at the wrist and hand in individuals who perform repetitive work with their hands. Imbalance between the endurance of wrist flexors and extensors, along with a number of other factors (i.e., posture, tool design, volume of activity, temperature, vibration, etc.), contribute to forearm, wrist, and hand pain. Overwork of the wrist and finger flexors during repetitive gripping or typing can contribute to overuse problems of the forearm, wrist, and hand. The use of smartphones has led to new problems in the hand (see **Evidence and Research 26-3**). Forms of epicondylalgia at the elbow may be considered forms of endurance impairment as well. Epicondylitis may develop as an acute injury because of a muscular strain, or it may result from fatigue of the overworked musculature. In this situation, impaired muscle endurance is contributing to the situation.

EVIDENCE and RESEARCH 26-3

Texting and the use of smartphones has led to tendon and nerve problems in the wrist and hand. Smartphone overuse has led to decreased hand function, increased median nerve size, thumb pain, and decreased pinch strength,[24] while repetitive gaming has resulted in tendon rupture.[25] Ultrasound shows that the flexor pollicis longus (FPL) tendon is thicker in frequent smartphone users as compared to low use individuals.[26] Ergonomic analysis of smartphone use suggests that the tendon load varies by the activity, and that smaller buttons place a greater load on the thumb musculature.[27]

Particular attention should be given to the posture assumed during performance of these exercises. Wrist extensor strengthening exercises should focus on the position of interest; if the individual functions at work with the wrist in a specific posture, that posture should be assessed and corrected if necessary. Subsequent exercises should focus on strengthening the muscle at the length it will be during functional activity. In contrast, training the wrist extensor muscles in the case of lateral epicondylitis will likely use a dynamic range of strengthening, given the wide ROM for most activities producing lateral epicondylitis (e.g., tennis, painting, hammering; see **Self-Management 26-4** and **Building Block 26-3**).

Pain and Inflammation Impairment

Pain and inflammation occur throughout the distal upper extremity for a variety of reasons. Injury or surgery can result in pain and inflammation at the specific site, while central

SELF-MANAGEMENT 26-4

Wrist Extension Exercise with Resistive Band

Purpose: To increase the strength of your forearm, wrist, and hand muscles

Starting Position: Use a resistive band of appropriate tension. Place the band across the back of the hand of your painful wrist with the palm down, forearm supported. Hold the band ends with your opposite hand and pull down creating tension in the band. Pull just hard enough to feel tension in your involved wrist that you can hold for 10 seconds; then release the tension and let your wrist relax.

Movement Technique: Level 1: Hold resistance for a count of 10. Rest by removing the band tension.

Level 2: Raise and lower the involved wrist through a comfortable range.

Level 3: Grasp the band in your involved hand and repeat, incorporating grip into the exercise.

Dosage:

Repetitions: ______________________

Frequency: ______________________

BUILDING BLOCK 26-3

An artist specializing in pottery complains of fatigue in her wrist and finger flexors after a day of working at the pottery wheel. She reports that this is due to putting in long hours preparing for a show. She has no neurologic symptoms nor signs of systemic disease. Design an initial therapeutic exercise program for her. Her show is completed, but she would still like to work at her wheel to keep up her inventory. What advice do you have regarding her work at the wheel?

or local nerve compression usually produces pain locally and pain radiating from the site of compression. Inflammatory conditions such as RA or OA produce pain and inflammation in the affected joints, and tendinopathies in their respective tendons.

Inflammation is easily detected in this region because of the superficial nature of the structures. The MCP, PIP, and DIP joints in the hand are easily observed for swelling and redness and palpated for warmth and tenderness. Crepitus in tendons such as the abductor pollicis longus (APL) and extensor pollicis brevis (EPB) tendons in a person with de Quervain syndrome is readily palpable, as is the local tenderness associated with medial and lateral epicondylitis.

Intervention for inflammation is based on the acuteness of the inflammation (see Chapter11). Gentle active, active assisted, or passive motion to maintain mobility during the acute phase may be indicated. In some situations, immobilization with splints may be necessary, with occasional removal for gentle mobility activities. After the acute phase has passed, more aggressive activities may be initiated.

Gentle grade I and II joint oscillations may be used to decrease pain in some situations. This approach along with ice and other adjunctive agents can decrease pain enough to allow resumption of a therapeutic exercise program.

Muscle Endurance Functions: Impaired Posture and Movement

The most common posture and movement impairments in this region are work- and hobby-related cumulative injuries. Lateral and medial epicondylitis at the elbow and carpal tunnel syndrome (CTS) and de Quervain tenosynovitis at the wrist result from impairments in posture and movement. Grasping and pinching always cause a flexion moment at the wrist that must be offset by extensor muscle activity, loading the common extensor origin at the elbow.

Hand grip strength is a function of the object's size and the posture of the wrist. For a given size of object, an optimal wrist position for maximum grip strength exists.[28] When examining an individual with a work- or hobby-related disorder, consider the size of the tool and its impact on elbow, wrist, and hand posture. These tools can be hobby-related (e.g., golf club, racquet, gardening tools, knitting needles) or work-related (e.g., hammers, screwdrivers, shovels, welding tools, sewing tools). When grip is involved, the posture of the upper quarter relative to that tool must be examined. Posture during non-grip activities such as keyboard operating also is important. The guidelines for posture while sitting at a computer work terminal can be found in **Patient-Related Instruction 26-1**.

Movement factors may contribute to injuries in this region. Fatigue during repetitive activity produces changes in movement patterns and subsequent overuse injuries. As muscles begin to fatigue, the individual has more difficulty controlling force production, and substitution occurs. Substitution may occur with a synergistic muscle or a muscle group more proximal or distal in the kinetic chain. In either case, the primary muscle and the substituting group are vulnerable to overuse injuries. Allowing adequate rest time, using proper tool size, reinforcing good posture, and controlling cycle time, recovery time, and exertion frequency can decrease repetitive loads (**Evidence and Research 26-4**).

Patient-Related Instruction 26-1

Computer Workstation Posture

The following information can help you to evaluate your computer workstation. If you have specific medical problems, consult your clinician for any special needs you may have.

Computer

Correct keyboard position

- Elbows bent at 90 degrees
- Wrists straight or slightly bent up
- Keyboard downwardly sloped
- Try placing the keyboard on a commercially available keyboard tray with a wrist rest.

Correct monitor position

- About 16 to 22 in away (about an arm's length)
- Top of the screen even with top of forehead
- Use a stand or adjustable monitor arm to regulate height.

Mouse

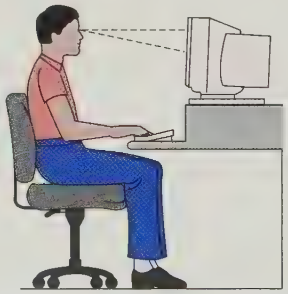
Correct mouse position

- Elbows bent at 90 degrees
- Wrist straight or slightly bent up
- Shoulders relaxed and arm at your side
- Elbow supported on armrest if available

Your Work

- Your document and screen should be at similar heights.
- Use a document holder.
- Sit directly in front of the keyboard, monitor, and document holder.

Sitting posture



EVIDENCE and RESEARCH 26-4

Increased use of smartphones and other digital media has led to new concerns about neck, shoulder, and arm pain. Electromyographic activity of six hand muscles of 56 young adults was obtained while texting from a mobile phone. A higher proportion of those in the asymptomatic group used back and forearm support with a more neutral head position than those in the symptomatic group. Looking at specifics of texting, those using a physical keypad used more thumb, finger flexor, and wrist extensor activity than those using a touchscreen using a device of similar dimensions.[29] More wrist extensor muscles were used with one hand texting compared with both, and there was greater finger flexor and wrist extensor activity as the screen size increased.[30] Holding the phone higher or lower impacts neck and elbow posture and symptoms[31] and varies with one- versus a two-handed texting technique.[32]

THERAPEUTIC EXERCISE INTERVENTIONS FOR COMMON DIAGNOSES

Osteoarthritis and Rheumatoid Arthritis

OA and RA commonly affect the wrist and hand.[33,34] The hands are the most frequent site of OA in the elderly, and can have a significant impact on function and disability in this population.[33] The prevalence of radiographic hand OA ranges from 29% to 76%. The wide variation is due to genetic and environmental differences.[35] Hand OA can have different presentations depending upon individual factors with predictors such as older age, genetics, female sex, menopausal, manual labor with pneumatic vibratory tools and metal, high impact physical activity, and repetitive use of the hand.[33] In patients with RA, hand and wrist dysfunction are common, with 75% of patients with a 15- to 20-year history of RA having erosive wrist disease.[36]

Hand osteoarthritis affects the second and third DIP, the first IP, and the first CMC joint the most frequently. The PIP has the lowest OA prevalence. Symmetry of OA between rows of joints was the most common pattern of interrelationship found.[37] Hand OA is associated with pain and loss of function, particularly when both the thumb and fingers are involved.[38,39] Pinch and grip strength and hand function measures are decreased with hand OA, while the high grip strength appears to be a predictor of the development of OA in the proximal hand joints but not the DIP joints.[40]

Rheumatoid arthritis is a chronic, systemic inflammatory disease affecting multiple joints, with its greatest impact on the synovial membranes. The wrists and hands are typically involved, and strength and mobility impairments can significantly impact the patient's quality of life.[41] At the *wrist*, the distal radioulnar joint is affected causing the ulna to dorsally subluxate on the radius at the distal radioulnar joint. The patient with RA often has a wrist deformity of flexion, radial deviation, and volar subluxation of the carpal bones.[20] Ankylosis may eventually ensue, severely restricting mobility at the wrist. This motion loss is particularly disabling for the individual with RA, because adjacent joints are also affected and unable to compensate for wrist immobility.

At the *hand*, RA causes MCP joint ulnar deviation and volar subluxation of the proximal phalanges. The synovial changes associated with RA weaken connective tissues surrounding the joints, leading to joint subluxation and/or dislocation. For example, swan-neck deformity, or hyperextension of the PIP and flexion of the DIP, results from flexor and extensor imbalance and PIP joint laxity.[20] A boutonnière ("buttonhole") deformity arises when the extensor mechanism fails over the PIP joint causing hyperextension of the DIP and flexion of the PIP with failure of the extensor mechanism. At the thumb, a "zig-zag" deformity can cause significant functional impairments for people with RA (**Fig. 26-19**). Additionally, mucous cysts and nodules impact the function of tendons, causing "trigger fingers" in tendons with sheaths.

Intervention for patients with RA affecting the wrist and hands typically consists of therapeutic exercise to maintain joint mobility and musculotendinous strength and integrity, night splinting, as well as patient education in joint protection.[42,43] A program that includes education in joint protection along with a strengthening program has been shown to produce outcomes that are clinically meaningful and cost-effective.[44] Programs consisting of strengthening exercises have shown improvements in strength and hand function at 6 weeks, that was further improved by 12 weeks.[45] The dosage of therapeutic exercise needs to be individualized based upon the stage and severity of the disease. Research has shown that intense exercise is tolerated in some patients with RA. Mobility, hand pain, and functional ability improved in patients undergoing an intense rehabilitation program compared with a conservative program.[46] However, for those with significant loss of hand function, surgical intervention can improve the quality of life (**Fig. 26-20** and **Evidence and Research 26-5**).

FIGURE 26-19 Arthritis can affect multiple joints of the wrist and hand.

FIGURE 26-20 Rheumatoid arthritis of the hands before and after surgery to correct deformities.

EVIDENCE and RESEARCH 26-5

A number of studies have found improvements in hand function and quality of life in patients with RA who complete a supervised hand rehabilitation program. A systematic review found that grip strength in various grip types was improved and transferred to daily functioning following hand therapy.[47] A 6-week program of isometric and isotonic hand exercise resulted in decreased pain and disease activity and improved hand function, dexterity, and quality of life in women with RA.[48] Group education about the disease process and self-management training also improves outcomes.[44]

FIGURE 26-21 A night splint is used to rest and maintain the position of the wrist and hand.

Splints or orthoses used for RA include resting hand splints, wrist supports, and finger splints.[49] A variety of splints are available and can be customized for use during functional activities or at night or other times of rest. Splinting should be accompanied by an appropriate therapeutic exercise program to ensure optimal mobility, strength, and function of the hand (**Fig. 26-21**).

Cumulative Trauma Disorders

Most musculoskeletal injuries that occur in the workplace are not caused by accidents or acute injuries that sprain ligaments; they result from wear and tear stresses on the musculoskeletal system. Wear and tear injuries are frequently referred to as cumulative trauma disorders (CTDs). The most common CTD is CTS which will be discussed in further detail in a subsequent section. Lateral epicondylitis, deQuervain's tenosynovitis, and other wrist and hand tendinopathies as well as neck, shoulder, and low back problems have been classified by the National Institute for Occupational Health and Safety[50] (**Display 26-2**).

CTDs are by definition work-related phenomena, although these disorders may also occur with certain hobbies and other nonwork-related activities. The World Health Organization has defined CTDs as being multifactorial in nature, indicating that a number of risk factors contribute to these disorders, including physical risk factors, environment, work organization, and psychosocial, sociocultural, and individual risk factors. Because of the multifactorial nature of CTDs, there is some controversy about the role these risk factors play in the development of CTDs.

Physical risk factors include repetition, awkward postures, prolonged activities, forceful exertions, and fatigue (**Display 26-3**).[41] Specific modifiable factors include work tasks with high vibration, working in flexion or extension for prolonged periods of time, tasks demanding heavy resistance, lack of variability in tasks, insufficient break time, and work that is highly repetitive.[26,51–53] The magnitude, duration, and repetition need to be considered for each of these risk factors. Environmental risk factors, such as vibration and cold, may also be present, further complicating the picture. The worker exposed to these factors and not given adequate recovery time may develop a CTD. The worker is unable to recover from the microinjuries or microtrauma that occurs at the tissue level over time. CTDs typically have a slow onset, with only minimal symptoms noticed initially. Many people ignore the early symptoms and do not seek medical attention until the symptoms prevent them from participating in work or in recreational or home activities.

Work may also aggravate or exacerbate an existing health or musculoskeletal problem. For example, forceful gripping at work may aggravate a previous sport injury at the elbow, such as lateral epicondylitis. The diagnosis of lateral epicondylitis is frequently used to describe a CTD injury at the elbow involving the lateral extensor mechanism.

Acting alone or in combination, awkward postures, excessive forces, and frequent repetitions may cause mechanical and physiologic stress on the soft tissues. When a person is positioned in an awkward posture, the body is unable to function at an optimal level. For example, wrist postures may shorten or elongate some muscle groups altering force production (**Evidence and Research 26-6**). When in a lengthened position, the wrist muscles may be unable to exert the required force for the task. Adopting a flexed wrist posture during typing and other hand activities is associated with wrist CTDs potentially due to the sustained work of the wrist extensors.[54,55] The individual may be functioning at a greater percentage of their maximum capabilities. Fatigue is more likely to occur when functioning at a higher percentage

DISPLAY 26-2

Factors Contributing to the Increase in Cumulative Trauma Disorders

- Work pace
- Same task, little variability
- Concentrated forces on smaller physiologic elements
- Decreased time for rest
- Increase in service and high-tech jobs
- Aging workforce
- Reduction in staff turnover
- Increased awareness of the problem

DISPLAY 26-3

Common Characteristics Associated with Cumulative Trauma Disorders

- Work-related: intensity, duration, repetition or cycle time, posture, vibration, force, contact stress, tool geometry
- Mechanical and physiologic processes
- Exacerbation of an existing health problem (e.g., RA, OA)
- Recovery requiring weeks, months, or years
- Multifactorial: work + recreational activity + hobbies
- Fatigue
- Symptoms often poorly localized, nonspecific, and episodic

EVIDENCE and RESEARCH 26-6

Research into the electromyographic (EMG) activity of wrist flexor and finger extensor musculature in both neutral and shortened positions showed that muscle shortening caused by changing the wrist posture changed the relationship between the time and frequency of EMG activity in both muscle groups.[54]

of the maximum voluntary contraction. Fatigue, coupled with excessive repetitive motions, may exceed the tendon sheath's capacity to lubricate the tendon, causing increased friction and eventual wear and tear of the tendon.

Vibration is a significant stressor contributing to a variety of wrist and hand musculoskeletal disorders. Termed *hand-arm vibration syndrome*, this primarily work-related musculoskeletal disorder is comprised of vascular, neurologic, and musculoskeletal components seen in people regularly exposed to high frequency vibratory tools (i.e., spinning/rotating tools, saws, grinders, and jackhammers).[56,57]

Workplace design and ergonomics must be carefully evaluated when a patient is diagnosed with a CTD. Ergonomics is the study of fitting the job to the individual. A job analysis or ergonomic analysis should be completed to assess the risk factors present in the individual's work environment. Certain occupational risk factors such as repetitive gripping or forceful pushing with the wrist in an ulnar-deviated position may prevent the person from successfully returning to that job without symptoms recurring. An example is an individual grasping a straight-handled tool such as a knife. This tool and activity places the wrist in an ulnar-deviated position. By angling the tool handle instead of the wrist, the wrist's position is improved. By ensuring appropriate preventive maintenance (e.g., sharpening the knife on a timely basis), the stress on the tool operator is decreased.

Nerve Injuries

A variety of nerve injuries occur throughout the elbow, wrist, and hand because of the anatomic structures in the upper extremity and the functional demands in the region. A thorough knowledge of the local anatomy provides a foundation for understanding the impairments found with these nerve injuries.

Carpal Tunnel Syndrome

CTS at the wrist is the most common peripheral compression neuropathy, affecting a greater proportion of women than men.[20,58,59] The prevalence of CTS in a population of adults has been estimated between 3.6% in those who never worked and 12.2% among former workers with an 8% lifetime risk of development.[59,60] The Bureau of Labor Statistics found a prevalence of current work-related CTS of 2.1% among current or recent workers in its 2010 survey.[36] The three occupational groups with the highest rate of days lost from work due to CTS include production, office and administrative support and installation, and maintenance and repair.[24] CTS in the working population is associated with significant costs at many levels (individual, employer, third-party payer, etc.). The average cross-sectional area of the carpal tunnel is 1.7 cm^2 with the wrist in neutral. CTS is caused by a decrease in the size of the carpal tunnel or an increase in the size of its contents, which compresses the median nerve (**Evidence and Research 26-7**). A single insult (e.g., Colles fracture), systemic conditions or disease (e.g., pregnancy, diabetes, RA), anomalous anatomy, and cumulative trauma within the carpal tunnel (e.g., flexor tenosynovitis) can compress the median nerve. Physical factors associated with CTS include repetitive motion, force, mechanical stresses, posture, vibration, and temperature.

EVIDENCE and RESEARCH 26-7

Pressure in the carpal tunnel varies with wrist position. Carpal tunnel pressure increases with non-neutral wrist positions, forearm and finger positions, and finger pressure.[61] Passive flexion and extension of the wrist has been shown to increase carpal tunnel pressure significantly. The mean wrist position associated with the lowest carpal tunnel pressure is approximately 2 degrees of flexion and 3 degrees of ulnar deviation. Wrist extension increases carpal tunnel pressure more than wrist flexion.[62]When typing, avoid positions of wrist extension greater that 30 degrees and radial deviation greater than 15 degrees. Digital fingertip pressure also increases carpal tunnel pressure beyond that of wrist position.[61]

CTS can manifest with sensory or motor impairments of the median nerve. Diagnosis is based on the presence of one or more common symptoms and on the results of provocative tests. Electrodiagnostic studies can be valuable in confirming the diagnosis and detecting other neuropathies. Associated impairments can include nocturnal pain and numbness, clumsiness when holding small objects or performing prehension grips, paresthesias in the median nerve distribution, and occasionally pain that radiates proximally. Symptoms of shoulder pain or upper arm pain are not uncommon.[26] Diagnosis is based on the history, a positive Tinel test result, direct compression tests, Phalen sign, manual muscle testing, sensation testing, upper limb tension tests, and extrinsic muscle length tests. The most commonly assessed outcomes include sensory functions, muscle functions, sensations of pain in the median nerve distribution, sleep functions, structure of the median nerve, structures of the area of the skin (ICF Body Structures and Functions impairments); self-care, domestic life, hand and arm use, fine hand use (ICF Activities limitations); and, participation in work and employment (ICF Participation restrictions).[63]

Conservative treatment for CTS is multifaceted and may include a variety of interventions. Review of conservative management has shown limited or no benefit to the use of nonsteroidal anti-inflammatory medications (NSAIDs). Oral corticosteroids show greater benefit than NSAIDs, but are associated with greater side effects.[59,64,65] Local cortisone injections have shown significant but short-term (<6 months) relief.[66,67] Night (and occasionally day) wrist splints positioned at 0 to 15 degrees of extension have been advocated (**Fig. 26-22**)[68–70] (**Evidence and Research 26-8**). Full-time splinting may be better than nighttime splinting only, but compliance may be difficult.[68] Splinting in neutral may be better than extension due to decreased tension on the median nerve in the neutral position.[69]

FIGURE 26-22 A wrist splint is used to rest the forearm and wrist musculature.

EVIDENCE and RESEARCH 26-8

A Cochrane review of the effectiveness of splints for CTS concluded that there is limited evidence that a splint worn at night is more effective than no treatment in the short term. While a number of studies reported significant improvement in outcomes following use of a night splint, the quality of these studies prevented firm conclusions on their efficacy.[71]

Exercise intervention for CTS has been shown to have limited effectiveness[51,52] (**Evidence and Research 26-9**). Therapeutic exercises focus on maintaining mobility and function without producing an exacerbation. Although not curative, therapeutic exercise may be beneficial for maintaining the integrity of associated soft tissues. Stretches for the extrinsic and intrinsic muscles are prescribed for several times each day (**Fig. 26-23**).[72] If working, a patient should perform them before work, on breaks, and after work. They should be performed slowly and gently; the patient should feel only a gentle stretching sensation. Differential tendon gliding exercises are performed to lubricate and increase gliding of the FPL, FDS, and flexor digitorumprofundus (FDP) tendons, all of which travel through the carpal tunnel. These are best performed with the hand elevated to concurrently control local edema. Carpal bone mobilization techniques may also be helpful in decreasing CTS symptoms.[73]

Median nerve gliding exercises and the upper limb tension test with median nerve bias can be used as treatment techniques, although research has not found consistent improvement in CTS with the addition of nerve gliding exercises.[58,75,76] The upper limb tension test with median nerve bias requires a position of shoulder girdle depression, shoulder abduction to approximately 110 degrees, forearm supination, wrist and finger extension, and shoulder lateral rotation.[1] After assuming this stretch position while standing, the patient should perform repetitions of elbow flexion and extension or wrist flexion and extension. Strengthening is generally not prescribed for patients with CTS who also have flexor tenosynovitis. If the precipitating factors have been eliminated and weakness creates a functional limitation, resistive exercises are closely monitored. The focus should be on balancing mobility and strength about the wrist.

EVIDENCE and RESEARCH 26-9

A Cochrane systematic review of exercise, neurodynamic mobilization, and carpal bone mobilization found limited evidence for the use of these interventions in people with CTS. The quality of the research in this area was very low, preventing any positive conclusions about the efficacy of these interventions.[74]

Patient education is a key intervention in the treatment and prevention of CTS. Patients are instructed to maintain a neutral upper extremity joint position during seated or standing work. This position is accomplished with the wrist in neutral, elbow flexed to approximately 90 degrees, shoulders relaxed in adduction, scapula slightly depressed and adducted, and the cervical spine positioned with the earlobe in line with the glenohumeral joint. The patient is also instructed to avoid a sustained pinch and grip, especially with the wrist in flexion, and to avoid repetitive overuse of the wrist and fingers. Patients should avoid direct pressure over the carpal tunnel by using a wrist rest or padded table edge or use a downwardly sloped keyboard. This type of keyboard has been shown to decrease the wrist extension angle and decrease muscle activity[77] (see Patient-Related Instruction 26-1).

Ergonomic intervention includes use of ergonomic tools that are padded with appropriately sized grips and handles. Data processing station revision should allow an adjustable chair height and keyboard height and tilt. Antivibration gloves are helpful for preoperative and postoperative carpal tunnel release to pad and protect the carpal tunnel and flexor tendons (**Fig. 26-24**).[75,78]

Patients treated acutely for CTS related to flexor tenosynovitis often respond well to conservative treatment without recurrence of symptoms if finger and wrist position and activities are monitored.[75] Conservative treatment is recommended for patients with transient symptoms and negative nerve study results. Patients who fail conservative treatment (usually a 3-month trial) often require carpal tunnel release surgery.[79] Studies have shown that the carpal tunnel increases in size with the release of the volar carpal ligament. Symptoms often improve immediately after surgery in mild to moderate cases. Because of the progressive nature of CTS, surgical outcomes appear to be improved by earlier surgical intervention (within 3 years of diagnosis). Carpal tunnel release offers good symptom relief for most patients.[80,81]

Cubital Tunnel Syndrome

Cubital tunnel syndrome is the second most common entrapment neuropathy in the upper extremity.[60] This syndrome is characterized by ulnar nerve pathology at the elbow in the absence of trauma. The cubital tunnel is formed by the medial epicondyle, olecranon, medial collateral ligament of the elbow, and a fibrous band called the arcade of Struthers.[82] Several muscles in the wrist and hand are innervated by the ulnar nerve, and the ulnar nerve provides sensation to the dorsal and volar ulnar side of the hand, the fifth finger, and the ulnar half of the fourth finger.

Ulnar nerve entrapment may produce nerve injury through ischemia or mechanical deformation of the nerve. These forces can occur from trauma to the elbow, external compression, repetitive elbow motion, osteophytes due to elbow osteoarthritis

FIGURE 26-23 Tendon gliding for flexor digitorum superficialis (FDS) and profundus (FDP). **(A)** Start; **(B)** glides FDS and FDP; **(C)** biases FDS; **(D)** biases FDP; **(E)** maximal FDS and FDP.

FIGURE 26-24 Antivibration gloves.

or prolonged elbow flexion. With elbow motion, normal nerve excursion has been reported to be as great as 10 mm. Traction on the nerve may occur with repetitive activities such as throwing. The nerve may also undergo increases in traction forces when its excursion is limited by posttraumatic adhesions.[38] As the elbow moves from extension to flexion, intraneural pressure in the cubital tunnel increases significantly (**Evidence and Research 26-10**). Pressure as high as 209 mm Hg has been recorded in a patient with cubital tunnel syndrome with elbow flexion and FCU contraction.[39]

EVIDENCE and RESEARCH 26-10

Studies of cubital tunnel pressure have found progressively increasing cubital pressure as the elbow moves into flexion, and the pressure increase has correlated with patient symptoms.[83–85] Additionally, ulnar nerve strain is increased when the shoulder is in internal rotation compared with a neutral position.[86]

Symptoms of cubital tunnel syndrome can include aching in the medial forearm and ulnar side of the hand. The aching can radiate proximally or distally. Paresthesias or anesthesias in the ulnar nerve distribution often accompany the pain.[39] Prolonged or repeated endrange elbow flexion tends to exacerbate symptoms. Functional activities eliciting symptoms include sleeping with the elbow flexed at night, combing the hair, driving, or holding the telephone. Leaning on the medial elbow can directly compress the ulnar nerve. Early in the syndrome, patients typically control the paresthesias by repositioning the elbow in a more extended position. As the syndrome progresses, activity limitations caused by motor changes cause activity limitations such as difficulty in turning keys, a weak grip and pinch, and dropping objects held in the ulnar side of the hand.

Focused physical examination techniques include Tinel testing over the ulnar nerve, provocative elbow flexion testing (including direct compression over the cubital tunnel), upper limb tension testing with ulnar nerve bias, observation of muscle bulk and clawing in the fourth and fifth digits, muscle testing, Froment sign, and sensory testing. The differential diagnoses include C8–T1 nerve root pathology, thoracic outlet syndrome, and compression of the ulnar nerve at Guyon canal.

Conservative management of cubital tunnel syndrome consists of eliminating all sources of external and dynamic ulnar nerve compression at the elbow, anti-inflammatory medication, elbow splinting in 40 to 60 degrees at night, elbow pads, and stretching exercises.[87] Stretching exercises focus on extrinsic flexor and extensor muscles along with ulnar nerve–innervated intrinsic muscle stretches. Nerve gliding techniques may be appropriate for patients with intermittent symptoms. The ulnar nerve's normal longitudinal excursion can be limited by adherence to adjacent structures. Nerve gliding can be achieved by assuming a modified ulnar nerve bias tension test position while standing.[88] This position requires shoulder depression and abduction, wrist extension, and forearm supination, followed by elbow extension.[1] Several repetitions of elbow or wrist flexion and extension can be performed. Due to rapid onset of ischemia with prolonged stretching, nerve mobilization performed intermittently is usually better tolerated than a prolonged stretch (**Fig. 26-25**).

Key adjunctive interventions are focused on patient education. Posture correction and proximal stretching or strengthening to maintain posture is indicated when the patient has faulty posture. Short pectoralis minor and weak scapular stabilizer muscles are often observed in individuals working at computers or on assembly lines. Although ADLs can be modified to allow rest of the involved arm, it is more challenging to modify work conditions. Use of the uninvolved arm is encouraged to wash and comb hair, eat, or perform any activity requiring prolonged or repeated elbow flexion. Use of a telephone headset is helpful in cases of frequent or prolonged telephone use. If conservative treatment of cubital tunnel syndrome does not reduce or resolve symptoms in 3 months, surgical treatment may be considered. In the absence of clinically identifiable sensory loss or muscle weakness, conservative treatment may be continued indefinitely in the form of a home exercise program. Ulnar nerve transposition surgery involves mobilizing the ulnar nerve at the ulnar groove and anteriorly transposing it subcutaneously, intramuscularly, or submuscularly to the flexor pronator muscle group.[89] This procedure is commonly performed as part of a reconstruction of the UCL.

FIGURE 26-25 Nerve gliding stretch with elbow extension, forearm supination, and wrist extension.

Radial Tunnel Syndrome

Radial nerve entrapment at the elbow, also called radial tunnel syndrome, is entrapment of the posterior interosseous nerve in one of five locations within the radial tunnel[90]:

- The entrance to the tunnel where fibrous bands encircle the nerve
- The leash of Henry, where the radial recurrent vessels supply the brachioradialis and the extensor carpi radialis longus (ECRL) muscles
- The fascia and medial portion of the ECRB tendon
- The arcade of Frohse
- Distally between the tendinous origins of the supinator muscle[91]

Radial nerve entrapment occurs much less frequently than median and ulnar nerve compressions. The annual incidence is estimated at 0.03%.[90] Radial nerve compression may be caused by direct trauma or anatomic structures compressing the nerve. Nerve compression commonly results from repetitive pronation and supination or wrist flexion and extension activities. Occasionally, a single strenuous effort initiates the problem, and subsequent repetitive motion perpetuates it.

The patient with radial tunnel syndrome often has symptoms similar to those produced by lateral epicondylitis and the two can coexist, complicating diagnosis and treatment.[92] Frequently, these persons have undergone unsuccessful treatment for lateral epicondylitis and use of tennis elbow straps may increase symptoms due to compression. The most common symptom is that of aching in the extensor supinator muscle mass that is distal to the lateral epicondyle, a nonspecific symptom that makes differential diagnosis difficult. Tenderness is approximately 2 to 3 in (5 to 7 cm) distal to the lateral epicondyle, with occasional pain radiating distally. No overt sensory deficits are found, because the posterior interosseous nerve contains only motor fibers. Imaging studies and electromyography and nerve conduction studies are typically normal.[90] The upper limb tension test with radial nerve bias may provide additional information. A brachial plexus or C7 nerve root injury should be excluded in the differential diagnosis.

Intervention for radial tunnel syndrome is initially conservative, followed by surgical decompression if conservative measures are not successful. Conservative measures include activity modification, anti-inflammatory medication, therapeutic exercise, and wrist cock-up splinting for 3 to 6 months. The goal of stretching is to restore full extrinsic wrist extensor and flexor muscle length and tendon excursion. If extensor stretches are painful, initial stretches can be performed with the elbow flexed and forearm supinated, followed by fisted wrist flexion. The exercise is progressed until full elbow extension and forearm pronation are achieved with fisted wrist flexion without forcing through pain. Radial nerve gliding techniques may be helpful to encourage adequate nerve gliding from the cervical spine to the wrist and hand level. Soft-tissue massage to the forearm flexors and extensors may help to relax involved muscles and improve the extensibility and circulation in the area. However, there are no randomized clinical trials examining conservative interventions for radial tunnel syndrome.

Upper extremity activities should be performed with the forearm in neutral to prevent prolonged stretching or overuse of the supinator muscle. This activity modification is particularly important in lifting tasks. Job rotation or diversification can prevent prolonged use of the extensor supinator muscle group.

Functional outcomes after conservative management of radial tunnel syndrome are difficult to determine because of the challenge in identifying the correct diagnosis, the relative rarity of the syndrome, and the frequent surgical intervention in clearly diagnosed cases. The clinician should be alert to radial tunnel syndrome as a differential diagnosis in cases of recalcitrant lateral epicondylitis. When radial tunnel is properly diagnosed, surgery is often the treatment of choice and produces good outcomes.[93] Patients commonly are seen postoperatively for scar and pain management, stretching, and strengthening programs.

Musculotendinous Disorders

Lateral Epicondylar Tendinopathy

Tendinopathy of the common wrist extensor musculature is the most frequent problem seen in the lateral elbow. The incidence of this syndrome in recreational and professional tennis players is 39% to 50%.[94] The prevalence of lateral epicondylar tendinopathy (LET) in the general population has been found to be approximately 1.3%.[95] Any individuals using hand tools for work or hobbies are susceptible to developing symptoms. The combination of continuous grip along with repeated wrist and elbow activity precipitates symptoms. Repetitively handling tools weighing >1 kg, repetitive movements, low job control, and low social support have also been shown to increase the risk of lateral epicondylitis.[96,97] Additionally, smoking has been found to be a risk factor for lateral epicondylitis.[95]

Wrist extension is accomplished by the combined actions of the ECRL, ECRB, and extensor carpi ulnaris. These muscles all originate on the lateral epicondyle and supracondylar ridge of the humerus. The lateral epicondyle is also the origin of the ED and extensor digiti minimi. Of the extensor muscles involved in LET, the ECRB is generally the greatest contributor to symptoms.[98] This is most likely due to its insertion along the central column of the hand, which is formed by the lunate, capitate and the third metacarpal. This creates the "keystone" of the longitudinal arch, rendering the ECRB as a frequent stabilizer. The wrist is stabilized by the extensors working in synergy with the flexors. Biomechanical models have shown that grasping and pinching tasks always produce a flexion moment at the wrist that must be countered by the wrist extensors. Many tasks requiring use of hand tools or writing instruments require wrist extensor activity. Because optimal hand function occurs when the hand is in a complete fist and the wrist is extended 15 to 20 degrees, the grip size of the implement and the resting posture of the wrist can have a great impact on producing and alleviating symptoms. These factors are important aspects of patient education.

Individuals with LET describe pain with any activity that requires gripping and lifting, such as shaking hands, lifting a carton of milk, or turning doorknobs. Use of hand tools, writing, and lifting bags also produce symptoms. Tenderness to palpation over the lateral epicondyle is common, and resisted wrist, middle finger, or index finger extension is painful. Despite these consistent findings in patients with LET, a number of factors will influence the intervention choices and the prognosis. Coomes et al.[98] have proposed an algorithm for the management of subgroups of patients with LET. Those in the low-risk subgroup may begin with a "wait and see" approach with general advice and education. If they do not improve with this regimen, they move into the moderate-risk subgroup. Here patients undergo a multimodal physical therapy program including relative rest/activity modification/advice, occasional bracing or taping, pain control, manual therapy, and therapeutic exercise. If no better following appropriate physical therapy, then diagnostic imaging to confirm LET is performed, and additional adjunctive treatment, work/activity modification, and surgical/medical referrals are considered.[98,99]

Multimodal intervention includes isometric, concentric, and eccentric exercise, combined with manual therapy.[99] Strengthening should focus on the role of the wrist extensors in upper extremity function. The wrist extensors function to stabilize the wrist against the wrist and finger flexors as well as functionally extending the wrist. Because the wrist extensors work during wrist extension and gripping, the clinician must approach use of handheld weights cautiously. The initial strengthening program may include gripping and wrist extension as separate exercises, gradually progressing to concurrent wrist extension and gripping (**Fig. 26-26**). Depending on the symptoms, the program may begin with isometric muscle contractions and progress to dynamic concentric and eccentric exercises. Wrist exercises may begin in a flexed elbow position to decrease tension on the common extensor tendon at the elbow.

There is a growing body of literature supporting the use of eccentric exercise in the treatment of tendinopathy.[100–103] It is theorized that chronic tendinopathy-related pain may be due to neovascularization that occurs in this disorder. The eccentric exercise is suggested to hinder the angiogenesis found with chronic tendinopathy. A growing body of research is examining the effectiveness of different exercise regimes on outcomes in LET. In general, it is difficult to conclude that one type of muscle contraction is superior to others due to differences in dosage parameters (**Evidence and Research 26-11**). Differences in outcomes are not only related to exercise dosage, but also to complicating factors such as the extent of tendon damage, severity and duration of symptoms (possibly associated with central sensitization), associated neck or other arm pain, motor control impairments, work-related factors, and psychosocial impairments.[98]

Adjunctive interventions include therapeutic modalities such as ice, cross-friction massage, prolotherapy, patient education, and bracing. Bracing may include a counterforce brace such as a tennis elbow strap or a wrist splint (**Fig. 26-27**). A counterforce brace decreases loads on the extensor origin by creating a new origin of the muscle that bypasses the inflamed portion of the tendon. A wrist splint can limit wrist extensor

FIGURE 26-26 Wrist extension exercises using a band. **(A)** Without grip. **(B)** With grip.

EVIDENCE and RESEARCH 26-11

Recent literature reviews suggest that strength training is effective for treating LET. Peterson et al.[104] studied 120 subjects with LET and found that those treated with eccentric exercise decreased pain and improved muscle strength more effectively than those treated with concentric exercise. Olaussen et al.[105] randomized 177 (157 completed) subjects into three different groups (physiotherapy with two corticosteroid injections, physiotherapy with two placebo injections, or wait-and-see). The corticosteroid plus physiotherapy group had a 10.6× greater odds of success than the placebo plus physiotherapy group at 6 weeks, a benefit that was lost by 12 weeks. By 52 weeks, there was no clear benefit to any group. Cullinane et al.[106] found the addition of eccentric exercise to a multimodal program for LET to be beneficial. However, eccentric exercise was not compared against any other type of exercise.

FIGURE 26-27 Tennis elbow strap.

activity necessary by providing an external stabilization to the wrist. Patient education regarding home and work ergonomics should be provided. Lifting with the forearm supinated and the elbow flexed decreases wrist extensor muscle activity. Tasks should be modified to limit repetitive elbow and wrist motion when possible.

When conservative management of lateral epicondylitis fails, surgical management, typically consisting of debridement of scar tissue, may be considered. Good documentation and appropriate follow-up care are necessary to ensure that all conservative measures have been appropriately exhausted before surgery is considered.

Medial Epicondylitis

Medial epicondylitis is encountered less frequently than lateral epicondylitis and accounts for 10% to 20% of all epicondylitis cases.[39] Its prevalence in the general population has been estimated at 0.4%.[95] The muscles involved are the flexor pronator group, including the FCR, palmaris longus, PT, and FCU. Repetitive wrist flexion at work or in recreational activities such as golf or fly fishing subject the common wrist flexors to overuse. Repetitive movements, high hand grip forces, and working with vibrating tools have been associated with medial epicondylitis.[52,97] Smoking, obesity, repetitive movements, and forceful activities are also significantly associated with medial epicondylitis.[95] Approximately 20% of cases are associated with concurrent ulnar nerve symptoms.[107] Affected persons usually describe pain at the medial epicondyle with resisted wrist flexion and forearm pronation. Passive stretch into extension and supination also may reproduce symptoms.

Management of medial epicondylitis is conservative, with a focus on controlled activity matched with appropriate rest, stretching and strengthening exercises, and interventions to reduce pain and inflammation.[108] Therapeutic exercises include

FIGURE 26-28 Wrist flexor stretch.

stretching for the flexor and pronator muscles, as long as stretching does not reproduce elbow symptoms (**Fig. 26-28**). As symptoms resolve, a progressive strengthening program with an emphasis on the demands specific to the individual patient is implemented. Like LET, similar symptoms at the medial elbow can be successfully treated with isometric, concentric, and/or eccentric exercise.[109] Braces are not as commonly used in the case of medial epicondylitis as compared to LET. When conservative management fails, surgical resection of the diseased portion of the tendon may be undertaken.[107]

de Quervain Syndrome

de Quervain syndrome, also called stenosing tenosynovitis, is an inflammation of the tendons of the first dorsal wrist compartment. The muscles in this compartment are the EPB and APL; they share a tendinous sheath. The most common cause is overuse of the hand and wrist, particularly in movements requiring radial deviation while the thumb is stabilized in a grip.[110] An example is a hairdresser using scissors to cut hair. Women are affected about 3 to 10 times more often than men.

Persons with de Quervain syndrome notice pain on the radial aspect of the wrist in the region of the radial styloid. Flexing the thumb across the palm is quite painful, especially when combined with ulnar deviation. In addition, resisted extension and abduction may be painful as well. Palpable tenderness and bogginess may be noticed over the tendons of the first compartment. Radial and ulnar deviation may produce clicking or pain. The Finkelstein test is the most commonly used test to diagnose de Quervain syndrome. Measurements may reveal that pinch and grip are weak and painful.

A Delphi panel recommended instructions, splinting, NSAIDs, corticosteroid injections, and surgery as primary interventions.[111] Adjunctive interventions included exercise therapy and kinesiotaping. Therapeutic exercise intervention for de Quervain syndrome includes stretching for the EPB and APL and the extrinsic wrist flexor and extensor muscles. Strengthening should be initiated after full pain-free ROM has been achieved. Strengthening includes the thumb and wrist musculature and full gripping exercises. To prevent further overuse to these tendons during the initiation of a rehabilitation program, immobilization using a forearm base thumb spica splint may be necessary. The splint should be worn during symptomatic times or periods of high activity. The splint is removed to perform exercises throughout the day.

Other adjunctive measures include advice and patient education about pain, function, and activity modification.[111] Work, hobby, or sport modifications to decrease the frequency and forces involved in wrist and thumb motion may be necessary to allow the rehabilitation program to succeed. Therapeutic modalities to reduce inflammation such as ice and iontophoresis may be helpful. The physician may place the patient on an anti-inflammatory medication, inject the area with steroid or analgesic medication, or surgically release the first dorsal compartment. Patient education to avoid or limit situations contributing to the symptoms is essential to prevent recurrence.

Trigger Finger

Trigger finger is a result of thickening of the flexor tendon sheath. Thickening causes catching of the tendon as the finger actively flexes.[17] The flexor tendons of the fingers have an intricate anatomy that includes a synovial sheath extending from the mid-metacarpal area to the DIP joints. Overlying the sheath is a series of annular and cruciform fibrous bands or pulleys. These pulleys hold the flexor tendons close to the metacarpals and phalangeal bones, thereby improving the efficiency of motion. Thickening of the sheath at the A-1 pulley (i.e., fibrous band that overlays the synovial sheath at the MCP joint level) and enlargement of the flexor tendons are the basis for the symptoms found with this condition. This thickening may be caused by repetitive trauma or by direct pressure over the MCP joint in the palm, as when grasping.

Impairments associated with trigger finger include pain and tenderness in the finger from the volar MCP to the PIP level and intermittent triggering or "snapping" of the finger. The triggering usually occurs with flexion, and it may require passive assistance to fully extend the finger.

Intervention for trigger finger is usually conservative and involves active IP flexion and tendon gliding exercises on an hourly basis. Splinting is common, and the hand-based splint or digital splint holds the MCP joint at full extension while leaving all other joints free. The splint is worn at all times for 1 to 3 weeks. Thereafter, it is worn for periods of high activity. The splint prevents triggering at the A-1 pulley and rest to minimize inflammation. The physician may inject into the synovial sheath at the level of the A-1 pulley to decrease local inflammation. Corticosteroids are commonly injected, besides NSAIDs and hyaluronic acid injection options.[112]

If conservative management is unsuccessful, surgery may be performed to release the A-1 pulley. Postoperative therapeutic intervention includes the same active exercise program and potential splinting as conservative management. Progressive grip strengthening may be required to return the patient to full functional use of the hand for work and ADLs. Education and work modification to avoid or limit repetitive grasping and releasing activities of the hand also are necessary.

Tendon Laceration

Tendon lacerations and repair require a complex series of treatments that must account for wound healing, tendon healing, and surgical techniques. Tendon repair treatment is complicated by the need for tendon excursion to prevent adhesions while allowing stability and protection to the healing tendon. Controlled motion helps prevent tendon adhesion, which limits motion and therefore limits function. Too much motion may compromise the repair. The clinician must provide a system of controlled motion, based on physician preference, surgical technique, mechanism of injury, and patient adherence

The extensor tendons are divided into eight zones that determine treatment protocol used. Because of the extensiveness of each protocol, we review only the highlights for each zone (**Fig. 26-29A**).[113] In zones I and II, laceration causes a mallet finger. A mallet finger splint is fit to the patient's DIP joint in 0 to 15 degrees of hyperextension from postoperative day 1 through 6 weeks. The PIP joint is left free to allow movement at the PIP level and proximally. The DIP joint should not be allowed to flex during this time. AROM exercises at the PIP joint are initiated at 4 to 6 weeks with flexion to 25 degrees. Strengthening is started at 6 to 8 weeks with monitoring for an extensor lag. If a lag is present, the patient returns to wearing the splint and AROM.

For zones III and IV, a digital gutter splint is fabricated to include the DIP and PIP joints (MCP is left free) at 2 weeks after surgery. If the lateral bands were not repaired, mobilization of the DIP may begin at 10 to 14 days. If the lateral bands were repaired, the DIP should be immobilized for 4 weeks. The PIP joint may be immobilized for up to 6 weeks. At 6 to 8 weeks, AROM is begun, with progressive flexion and extension exercises. Treatment must be modified if an extensor lag develops and will be individualized based upon consultation with the hand surgeon. Gentle strengthening is begun after 8 weeks.

For zone V (distal to tendineae junctionae), a hand-based splint is custom fabricated at 3 days to 1 week. This hand-based splint holds the MCP in 70 to 80 degrees of flexion and the digit in full extension. This position prevents contracture of the lateral bands at the MCP. AROM, passive ROM (PROM), and strengthening are continued as for zones III and IV.

For zones V (proximal to tendonae junctionae), VI, VII, and VIII, a volar forearm splint is fabricated at 3 to 5 days postoperatively. This splint extends from just proximal to the PIP joint, crosses the MCP joint, and continues two-thirds of the way up the forearm, with the wrist positioned in 30 degrees of extension. This allows controlled movement of the extensor tendons through PIP and DIP joint movement, which prevents tendon adhesions. AROM, PROM, and strengthening exercises are continued as for the more distal zones.

Flexor tendon repairs also rely on zones to determine the appropriate protocol. There are five flexor tendon zones (see Fig. 26-29B). Current treatment protocols focus on controlled motion to prevent scar adhesions that limit functional movement. They also rely on the use of a dorsal blocking splint to prevent disruption of the surgical repair. This dorsal blocking splint is custom fabricated with the wrist in 20 degrees of flexion, the MCPs in 50 degrees of flexion, and the PIP and DIPs in full extension (**Fig. 26-30**).[43]

The program for zones I, II, and III consists of passive flexion and extension motion at the PIP and DIP joints and composite passive flexion and extension at the MCP, PIP, and DIP joints within the confines of the splint. This program is started on postoperative day 1 or 2 and continued through week 5.[43] AROM is started at 3½ weeks, PROM into extension is begun at 6 weeks, and strengthening is started at 8 weeks. Full functional use is allowed at 10 to 12 weeks postoperatively. The program for zones I, II, and III uses the dorsal blocking splint

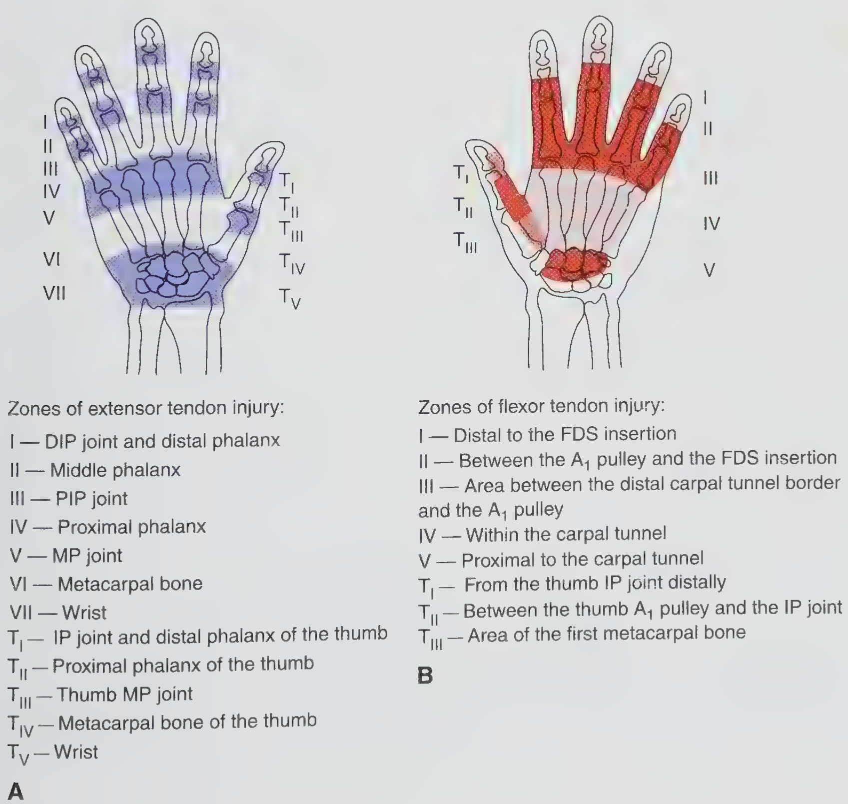


FIGURE 26-29 **(A)** Extensor tendon zones of the hand. **(B)** Flexor tendon zones of the hand.

FIGURE 26-30 A dorsal blocking splint.

with rubber band traction. The addition of a palmar pulley allows for greater FDP tendon excursion. The rubber band traction holds the digit into near full composite flexion, and the patient is instructed to extend the finger against the force of the rubber band to the dorsal blocking splint. The patient is instructed to do this 20 to 30 times per hour. This protocol is initiated 2 to 6 days postoperatively. AROM is started 5 weeks postoperatively, with PROM into extension started 7 to 8 weeks postoperatively. Strengthening is performed after 8 weeks.[43] The outcomes for flexor tendon repairs with early active mobilization are good.[114–117] **Table 26-7** provides guidelines following flexor tendon repair. However, current clinical practice patterns vary widely and often differ from those reported in the literature[117] (see Table 26-7).

TABLE 26-7

Flexor Tendon Repair Postoperative Protocol with Early Passive Motion

STAGE	PRECAUTIONS	GOALS	INTERVENTION
Early: weeks 1–3	No active flexion No wrist motion Active extension only to DBS Splint at all times	Protect healing structures Decreased edema and pain Minimize tendon adhesion Full protected IP joint extension Decreased PIP joint contracture Maintain ROM of uninvolved joints HEP independence	*Dorsal Blocking Splint*: Wrist flexion 20–30 degrees MP flexion 60–70 degrees IPs 0 degree Dynamic traction of fingers into flexion Palmar pulley at DPC to attain increased IP flexion Night block to hold IPs in extension *Exercise*: 1. Active extension to DBS with passive flexion 2. Protected PROM 3. Edema control 4. Scar massage 5. Sensory education
Intermediate: weeks 3 or 4–6	Guarded AROM No composite digit and wrist extension No passive composite extension Protect repaired pulleys	1. Protect healing structures 2. Decrease edema and pain 3. Restore tendon glide 4. Decrease scar adherence 5. Restore PROM of restricted joints 6. Maintain ROM of uninvolved joints 7. Gradually increase active/passive extension to full range	1. Gentle AROM 2. Isometric exercise 3. Active assisted flexion 4. Progress to tendon gliding exercise *Blocking exercise*: (if tendon restricted) FDS at 4 wk. FDP at 6 wk. *Splinting* with wrist in neutral to increased extension 5. Edema control 6. Scar management 7. Progress to light prehensile activity
Late: weeks 6–12	Prevent tendon rupture Prevent tenosynovitis of repaired tendons	1. Maximize full tendon glide and musculotendinous length 2. Maximize grip and pinch strength 3. Resume work and avocational activity	*Splinting*: 1. Phase out of protective splint 2. To decrease contractures 3. To increase excursion of long flexors or extensors *Exercise*: 1. Blocking, if needed 2. Isolated FDS glide 3. Muscle tendon unit stretching 4. Sustained gripping 5. Progress to strengthening Gradually resume full ADLs, return to work and avocational activities

DBS, dorsal blocking splint; IP, interphalangeal joint; PIP, proximal interphalangeal joint; ROM, range of motion; HEP, Home exercise program; DPC, dorsal palmar crease; PROM, passive range of motion; AROM, active range of motion; FDS, flexor digitorum superficialis; FDP, flexor digitorum profundus; ADLs, activities of daily living.

For zones IV and V, both protocols are overall as previously delineated, but they progress faster. AROM is initiated at 3 weeks within the dorsal blocking splint. AROM out of the splint occurs at 4 weeks. PROM into extension and strengthening is initiated at 6 weeks. A four-strand suture technique allows controlled active movement beginning on postoperative day 2. A wrist-hinged dorsal blocking splint is used to allow a tenodesis movement in which the digits are held at the end range by active digit contraction. PROM may be used to achieve full composite flexion. This splint and active motion is continued until week 8, with full active and passive exercise and strengthening started at that time.[43]

Bone and Joint Injuries

Injuries to the bones and joints of the elbow, wrist, and hand can cause significant impairments, activity limitations, and participation restrictions. Fractures of the hand are the most common fractures in the body.[118] Fracture management requires an understanding of the fracture's stability, healing process and potential, and need for surgery to establish stability and healing potential.[119] It is essential that these injuries are properly evaluated and appropriate interventions applied.

Medial Elbow Instability

Medial elbow instability is seen in children and adults, and is found most often in individuals involved in throwing. High forces on the medial elbow structures during the cocking and acceleration phases of throwing can result in attenuation and rupture of the static ligamentous structures. During the acceleration phase of throwing, elbow extension speeds can reach 2,300 degrees per second.[120] In the adult, acute rupture of the UCL can occur. More often, continued valgus loading and loss of dynamic muscular support places loads on the UCL, leading to gradual instability. Progressive instability can lead to rupture or tension of the ulnar nerve. In some cases, this progressive instability and load on the ulnar nerve leads to surgical reconstruction of the UCL. Approximately 25% of major league pitchers and 15% of minor league pitchers have a history of UCL reconstruction.[121] The majority of these athletes successfully return to their previous level of sport.[122,123] **Table 26-8** provides

TABLE 26-8

Rehabilitation Guidelines Following UCL Reconstruction

PHASE	PRECAUTIONS	GOALS	INTERVENTIONS
Early: weeks 4–6	Brace: Week 1: immobilization fixed at 90 degrees Week 2: hinged brace from 30 to 100 degrees Week 3: hinged brace from 15 to 100 degrees Week 4: hinged brace from 10 to 120 degrees	1. Protect healing tissues 2. Decrease pain and inflammation 3. Prevent muscular atrophy 4. Initiate elbow ROM	1. Gentle A/AAROM for elbow and wrist 2. Gentle mobility to achieve ROM goals 3. Submaximal isometric for shoulder IR, abduction, elbow flexion and wrist flexion/extension at week 2 4. Gripping exercise 5. Cervical spine and shoulder ROM
Intermediate: weeks 6–12	Week 5: hinged brace from 0 to 130 degrees Week 6: discontinue brace except in risky environments Avoid all valgus positions and minimize valgus stress to elbow during rehabilitation	1. Increased ROM to nearly full ROM by week 10 2. Prevent re-injury 3. Increased total arm strength	1. Gentle A/AAROM for elbow and wrist 2. Light dynamic resistance for shoulder IR, abduction, elbow flexion and wrist flexion/extension 3. Scapular strengthening and stabilization 4. Core, hip, and lower extremity strengthening 5. Continued upper quarter mobility
Late: weeks 12–20	No pain with strengthening exercises Postexercise pain should be minimal and resolve within 24 hr	1. Maximize shoulder strength in key muscle groups and functional activities 2. Increased distal muscle function and strength	1. Shoulder and elbow strengthening in functional movements and activities, controlling valgus force at elbow 2. Progressive scapular strengthening 3. Rhythmic stabilization for elbow and shoulder with progressively less protected positions 4. Core, hip, and lower extremity strengthening 5. Address any remaining impairments
Return to activity: weeks 20–36	No pain with strengthening or functional progression; postexercise pain should resolve within 24 hr	1. Good dynamic neuromuscular control in functional activities 2. Biomechanically sound functional activities to minimize medial elbow stress 3. Return to pain-free activity	1. Multi-joint, multi-plane strengthening program 2. Shoulder and elbow strength and stabilization drills, specific to work or sport 3. Plyometric program using ball or other tools specific to the work or sport tasks 4. Functional progression, including interval throwing program in thrower, or other sport- or work-specific activities

UCL, ulnar collateral ligament; ROM, range of motion; A/AAROM, active/active assisted range of motion; IR, internal rotation.

guidelines for rehabilitation following UCL reconstruction. However, rehabilitation to the level of competitive sports such as baseball requires additional consideration of the demands of these sports.[123,124]

In the child or adolescent, medial elbow instability is commonly known as "little league elbow." The growth plate and associated ligamentous and tendinous structures are at risk until the fusion at the growth plate is complete, which occurs roughly at age 14 to 15 years.[125] In the child, the valgus stress on the medial side of the elbow is countered with a compressive force on the lateral side at the radiocapitellar joint. This can lead to compression and shearing of the radial head on the capitellum. Osteochondrosis of the capitellum can occur with loose body formation (**Evidence and Research 26-12**).

EVIDENCE and RESEARCH 26-12

A number of factors predisposing young baseball players to elbow injuries have been found including: age older than 11 years, height, pitching position, number of days of training, grip strength, arm fatigue, and shoulder external rotation range of motion.[126–128] Matsuura et al.[129] found that of the 449 youth baseball players (ages 7 to 11 years) studied, 30% reported an episode of elbow pain during the season. Of these, 72% had abnormal elbow examinations and 81% had radiographic abnormalities.

Treatment of the child or adult with valgus instability depends on the pathologic stage. Controlled rest is essential, along with strengthening exercises for the involved musculature. Dynamic support of the medial elbow to minimize loads on the static structures is a critical component of the treatment program. This approach includes strengthening the trunk, shoulder, elbow, forearm, and wrist muscles (**Fig. 26-31**). Proximal weakness can transfer loads distally, and a rotator cuff problem can produce instability problems at the elbow. In addition to strengthening, consideration of throwing form and the throwing schedule (e.g., number of throws, games, innings) is important to prevent a recurrence of the problem.

FIGURE 26-31 Therapeutic exercise on a ball, weightbearing on the upper extremity to strengthen in a closed chain.

Elbow Dislocations

Elbow dislocations are second in incidence only to dislocations of the shoulder in the adult population with an annual incidence of 5.2/100,000.[130] The elbow is the most frequently dislocated joint in children younger than 10 years of age.[131] Elbow dislocations are classified by the direction of movement of the radius and ulna on the humerus, and most are posterior. Elbow dislocations are also classified as "simple" where only a dislocation occurs and closed reduction is successful, and "complex" where the dislocation may be associated with a fracture, and surgery may be necessary. A fall on an outstretched hand or hyperextension are the most common mechanisms of injury. Dislocation also can injure the UCL, the lateral collateral ligament, the anterior capsule, and common flexor and extensor muscle origins or fracture the medial epicondyle. The ulnar, median, or radial nerves may be injured. After dislocation, the elbow is reduced (and stabilized if necessary) and may be immobilized for 1 to 3 weeks due to concerns of long-term instability. Stabilization can be in a hinged external fixator or cross-pinning with supplemental cast immobilization. Both interventions have yielded similar ROM outcomes, while external fixation has been associated with higher complications.[132,133] Other research shows that patients with simple dislocations randomized to early mobilization returned to work earlier and had improved early ROM compared with a group immobilized for 3 weeks.[134] Patients in the early mobilization group used a sling for comfort the first week and performed AROM within comfort limits starting at day 2. No passive stretching was performed for the first 3 weeks.

Impairments after dislocation include loss of motion, pain, inability to produce torque, potential instability, and occasionally neurovascular problems. Restoration of full motion may be difficult and should be a priority in the treatment program. Many patients retain a residual loss of extension of 10 to 15 degrees, and full recovery of motion and strength takes 3 to 6 months for most patients.[135]

Intervention after dislocation includes AROM and active assisted range of motion (AAROM) initiated 2 to 7 days after the dislocation and PROM 3 weeks after the dislocation. Motion should be performed in a variety of shoulder positions with some describing an overhead position to improve congruency and stability in the early healing phase.[130] Dynamic splinting may be necessary to restore motion. Prefabricated splints are available to restore flexion or extension. A static night splint can maintain current range if a dynamic splint cannot be tolerated all night. Caution is necessary to avoid overly aggressive PROM, because it may contribute to heterotopic bone formation. Individuals with head injuries or those with a combined fracture dislocation with prolonged immobilization face the greatest risk of heterotopic bone formation, particularly in the brachialis muscle.

Isometric muscle contractions are initiated early and progressed to dynamic contractions as tolerated (**Fig. 26-32**). Open and closed chain exercises and proprioceptive neuromuscular facilitation techniques are useful for restoration of function. If instability is present, a hinged elbow support with extension blocks may allow functional use of the elbow within a limited range. Exercises are performed throughout the day, in or out of the brace. If the patient has hypomobility, joint mobilization techniques can help restore full elbow and forearm mobility (see Chapter 7). Patients undergoing surgery for chronic elbow instability need to initiate rehabilitation immediately after surgery and continue for at least 6 months to obtain the best outcome.[136]

A B

FIGURE 26-32 Rhythmic stabilization for muscles supporting elbow joint. **(A)** Resisted elbow extension. **(B)** Resisted elbow flexion.

Carpal Instability

The bony and ligamentous anatomy of the wrist is intricately balanced to allow for concurrent flexibility and stability. Williams et al.[9] observed that the carpal bones are spring loaded like a jack-in-the-box and kept under control by ligament restraints. The palmar ligaments are very substantial compared with the dorsal wrist ligaments. An area between the capitate and lunate where no ligamentous support is maintained is an area of potential weakness. A fall on an outstretched hand can result in damage to the scapholunate ligament and produce instability. This instability may result in dislocation of the lunate where its dorsal surface faces dorsally, called *dorsal intercalated segment instability*. Injury resulting in a volarly facing distal lunate is called *volar intercalated segment instability*.

Many types and descriptions of static and dynamic carpal patterns exist. *Static instability* patterns demonstrate radiographic changes such as abnormal gapping between carpal bones. A static instability generally indicates a significant injury such as a complete ligament tear. Dynamic instability patterns are detected during the physical examination or with special imaging techniques. *Dynamic instability* patterns generally indicate increased laxity or partial ligament tears.

Scapholunate dissociation (SLD) is the most common form of carpal instability and occurs when ligaments from the proximal pole of the scaphoid are torn. This injury can occur from a fall on an extended, ulnarly deviated wrist; degeneration resulting from RA; a direct blow to the wrist; or in association with a distal radius fracture, carpal fracture, or carpal dislocation. Scapholunate instability is the most frequent cause of carpal instability and accounts for a large proportion of impairments, activity limitations, and time lost from work.[137] The severe form of instability is termed the SLAC (scapholunate advanced collapse) wrist and may be the result of the undetected or untreated injury. Isolated injury to the scapholunate interosseous ligament may be difficult to detect with standard clinical examination or radiographs, and may be the first step in progressive decline to degenerative changes (**Fig. 26-33 A** and **B**)[137] (**Evidence and Research 26-13**).

Impairments associated with a SLD include point tenderness over the involved ligament, swelling of the dorsal wrist, pain or limited AROM and PROM of the wrist, a painful click or clunk with radial deviation, grip weakness, and decreased wrist and hand function because of pain. In addition to routine examination procedures such as documentation of pain with rest and functional activities, ROM, and strength of the forearm, wrist, and hand musculature, the clinician should assess grip and pinch

FIGURE 26-33 **(A)** Scapholunate advanced collapse (SLAC) wrist before surgery. **(B)** SLAC wrist after proximal row carpectomy.

EVIDENCE and RESEARCH 26-13

A recent study calls into question the assumptions about SLD and its prognosis.[138] In a study of 124 patients, the majority were unable to recall any specific wrist injury. While the majority had pathologic measurements on radiographs on their symptomatic side, on the asymptomatic side, 52% of the gap measurements and 70% of the angle measurements were pathologic. While 80% had abnormal radiographs bilaterally for at least one of the variables, only 11% had a clinical instability pattern typical of SLD and 50% had degenerative changes. Thus, the recommendations for interventions based upon radiographs and the assumptions about progression to arthritis should be reexamined.

strength. Grip strength is performed with a dynamometer at the standard setting, with five settings used to demonstrate a bell-shaped curve and rapid alternating grip strength. Lateral and three-point pinch strength is also assessed.

Severe instabilities are treated with surgical reduction and ligament reconstruction. Fusions may also be performed for a number of carpal instability patterns. After surgery or for mild cases of instability, the patient is referred for rehabilitative management.[137,139]

Therapeutic exercises for carpal instability include grip and pinch strengthening exercises. Putty exercises and isolated muscle strengthening exercises are incorporated to restore strength and dynamic function throughout the region. With a lunate dislocation and ligament injury, a painful grip may indicate instability leading to lunate destruction. In this situation, grip strengthening should be avoided. Any mobility deficits are treated with AROM, PROM, and AAROM.

Intervention for carpal instability also includes protective splinting of the wrist. The thumb MCP is included in cases of scaphoid involvement, such as SLD. If the ligament disruption is on the ulnar side of the wrist, a wrist cock-up or ulnar gutter splint suffices. Therapeutic modalities may be used for pain and inflammation, and patient education is a critical component of successful management.

Ulnar Collateral Ligament Injuries of the Thumb

The MCP joint of the thumb functions primarily in flexion and extension because of the condyloid shape of the joint surface. Small degrees of abduction, adduction, and rotation also occur. Tautness in the UCL limits abduction and extension and adds stability to the joint in a functional position. However, this functional position also places the UCL at risk of injury. The most common injuries to the thumb MCP involve the UCL.

Skier's thumb, or an acute sprain (macrotrauma) to the UCL of the MCP joint, is the result of abduction or hyperextension forces. This injury occurs frequently in skiing when a fall catches the thumb in the strap of the ski pole, pulling the thumb into abduction. Complete ruptures lead to instability and significant disability. Gamekeeper's thumb is an overuse injury resulting from repetitive microtrauma in the form of valgus stress to the MCP joint, similar to the repetitive valgus stress at the elbow seen in throwers.[140,141]

A thorough examination, with valgus stress performed in extension (collateral ligament and volar plate) and flexion (collateral ligament only), should be done to differentiate partial from complete tears due to differences in treatment based upon severity. Impairments associated with gamekeeper's thumb include tenderness along the ulnar aspect of the MCP joint, localized edema, and instability of the joint. Clinically, joint instability manifests as difficulty gripping items, particularly with a spherical or cylindrical grip.

Rhee et al.[140] have outlined an algorithm to guide treatment of UCL injuries. For those injuries with significant laxity or displaced or rotated fractures, operative repair offers the best outcome. For injuries with equivocal exams, advanced imaging is recommended followed by operative treatment of complete ruptures and conservative management of incomplete ruptures.

Treatment of partial tears requires immobilization in a thumb spica cast for 4 weeks depending upon the degree of injury, followed by a thumb spica splint (**Fig. 26-34**). The splint is removed throughout the day to allow exercise of the wrist and hand, and ensuring appropriate mobility of the IP joint.[142] Athletes are allowed to compete if their sport allows use of a splint. At 4 weeks, formal therapy is initiated, with strengthening at 6 to 8 weeks and return to full activity at 12 weeks.

Acute grade III injuries with instability require surgical stabilization. For patients with chronic UCL instability, surgical reconstruction is advised.[143] Both of these procedures demonstrate excellent outcomes. Therapeutic exercise after immobilization after surgical and nonsurgical treatment include pain-free thumb MCP flexion and extension and gradually adding pain-free rotation and opposition. After 4 to 6 weeks, grip and pinch strengthening exercises are initiated with putty or gripper equipment (see **Self-Management 26-5**). Lateral (key) pinch is initiated, but the patient should be instructed to limit or avoid tip pinch stress until 6 to 8 weeks. Exercises should be progressed to activities pertinent to the patient's lifestyle as quickly as possible within the constraints of healing.

SELF-MANAGEMENT 26-5
Thumb Press

Purpose: To increase the strength of your thumb muscles

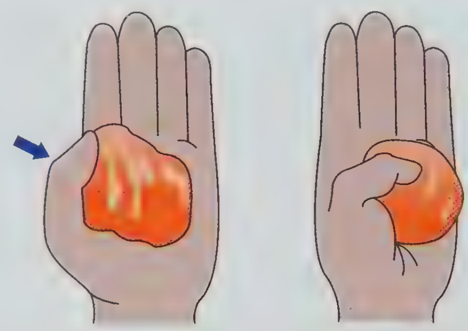
Starting Position: Form the putty into a barrel shape, and place it in the palm of your hand, resting against your thumb.

Movement Technique: Press your thumb into the putty with as much force as is comfortable until your thumb has pressed through the putty into your hand. Reshape the putty and repeat.

Dosage:

Repetitions: ______________________

Frequency: ______________________



Olecranon Fractures

Olecranon fractures are generally the result of a direct blow or a fall. A fall on an outstretched hand with the elbow in flexion, followed by a strong contraction of the triceps, can cause an olecranon fracture. A nondisplaced fracture is immobilized in 45 to 90 degrees of flexion for a short time. A displaced fracture may be treated with open reduction and internal fixation (ORIF) using tension band wiring or plate and screw fixation. A small comminuted fracture may be excised with reattachment of the triceps tendon. Excision of loose bodies is required during surgery to prevent a loss of mobility from these fragments. The impairments seen after fracture or surgery are pain, limited ROM, and loss of the ability to produce torque. Because of the close proximity of the ulnar nerve to the olecranon, it is vulnerable to injury. Close examination is necessary to assess the status of the nerve.

FIGURE 26-34 Thumb spica splint.

Intervention after fracture begins with AROM in a forearm neutral position. AROM and AAROM may be initiated as early as 2 days after fracture. These individuals usually are immobilized, and the immobilization is removed for ROM activities. The length of immobilization is decreased for the elderly, and ROM exercise is initiated sooner.[144] AROM is progressed to PROM and stretching.

The biceps muscle often shortens because of the flexed elbow position during immobilization or protection periods. Suggested forms of exercise to restore muscle length include elbow and shoulder extension, walking with a normal arm swing, and contract-relax stretching.

The adaptive shortening may result in weakness, and strength should be addressed concurrently. Suggested strengthening exercises include isometric contractions throughout the available range for all major muscle groups, resistive band exercises for shoulder musculature, resisted elbow flexion in a variety of forearm positions, resisted elbow extension, and resisted wrist and forearm exercises. A stationary bicycle with combined arm movements or a cross-trainer allowing repetitive elbow flexion

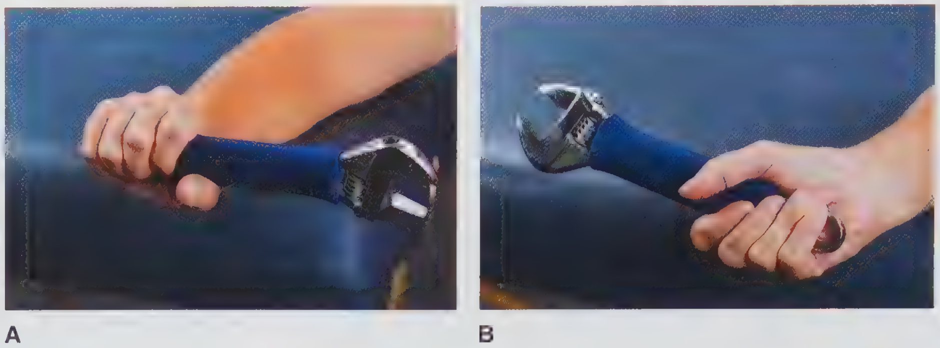


FIGURE 26-35 Range of motion of the forearm using a household object such as a wrench or hammer. **(A)** Supination. **(B)** Pronation.

and extension is helpful to restore motion and strength. If forearm rotation strength is limited, a light hammer can be used to train pronation and supination (**Fig. 26-35**).

Adjunctive interventions include elevation, ice, and active shoulder, wrist, and finger exercises to control edema. Scar massage should be initiated early after surgical stabilization. Generally, the scar is mature enough to tolerate massage 10 to 14 days postoperatively. The triceps may become adherent to the scar and should be treated with cross-friction massage and triceps-resistive exercises. Joint mobilization with distraction may be initiated in later stages if loss of motion is a problem. The prognosis after an olecranon fracture is good, but loss of terminal extension is a common residual impairment.

Radial Head Fracture

Radial head fractures occur most often as a result of falls on an outstretched hand with the forearm in supination. These fractures also occur in combination with dislocation. The individual with a radial head fracture has pain over the radial head in the lateral elbow, and forearm rotation is painful. A nondisplaced fracture can be treated with sling immobilization for 1 to 2 days, whereas a displaced fracture may be treated with ORIF. For severe fractures, the radial head may be excised. Any pathology at the distal radioulnar joint can complicate this form of treatment. The patient may be immobilized with the forearm in neutral but allowing elbow ROM (i.e., sugar tong or Muenster splint) for 2 to 3 weeks.

The most common impairment after a radial head fracture is a loss of 10 to 20 degrees of elbow extension. Crepitus or clicking at the radial head may occur with supination and pronation.

Treatment of a nondisplaced radial head fracture includes initiation of elbow and forearm AROM 1 week after injury. Successful treatment demands early ROM. The progression is similar to that for olecranon fractures. After ORIF of displaced fractures, motion may begin immediately postoperatively, barring any secondary injuries. Strengthening and functional use of the limb should be progressed as for other upper extremity injuries.

Colles Fracture

The distal radius is fractured more frequently than any other bone in the body.[20] The Colles fracture is a dorsally angulated fracture of the distal radius with or without concurrent ulnar fracture. This fracture occurs most often from falling on an outstretched hand. The volarly angulated distal radius fracture is known as a Smith fracture. The Colles fracture is initially treated with closed reduction and cast immobilization in an above-elbow cast to prevent pronation and supination or with ORIF. The cast allows motion at the MCPs of digits 2 to 5 and movement at the IP joint of the thumb. If healing is progressing well, a short forearm cast may be applied after 2 weeks.

The major impairments after cast removal are pain, decreased mobility and strength, and swelling. Control of edema is critical to prevent a stiff hand. Elevation, ice, edema massage, and compression garments can be used to reduce edema. Education about controlling edema must be emphasized to prevent further complications.

Restoration of mobility is essential for full functioning of the hand. The priority in the early phase of mobility exercises should be to regain wrist flexion, extension, and supination, because these are usually the most limited motions and important for a functional outcome (see **Self-Management 26-6**). Exercises should include AROM and self-PROM techniques using the opposite extremity. If mobility remains limited, joint mobilization may facilitate gains

SELF-MANAGEMENT 26-6
Finger and Wrist Flexor Stretching

Purpose: To increase the mobility of the soft tissues in your wrist and hand

Starting Position: With your palm facing up and wrist at the edge of a table

Movement Technique: Using your other hand, gently press your wrist and fingers down toward the floor. Hold 15 to 30 seconds, relax, and repeat.

Dosage:

Repetitions: ______________________

Frequency: ______________________

FIGURE 26-36 Wrist extension exercise after Colles fracture. Wrist stabilization is necessary to prevent substitution by finger extensor muscles.

in ROM (see Chapter7). When dealing with complicated Colles fractures, splinting may be necessary to maintain gains in ROM achieved while at rest or at night or to assist in increasing mobility. Static splinting provides support and maintains mobility between exercise sessions. This intervention may be supplied by prefabricated wrist supports or custom-made splints. Dynamic splinting may also be of value in cases of limited mobility. These splints include a constant or variable tension across the wrist, forearm, or both areas to facilitate increasing motion in the direction desired. Many commercial devices are available, or a custom splint may be fabricated.

Strengthening exercises may be initiated with isometric contractions, grip strengthening, and resisted elbow exercises. Watch for substitution, and utilize proximal stabilization to ensure motion at the joint(s) of interest (**Fig. 26-36**). As mobility improves, dynamic exercise for the wrist and hand may be initiated (**Fig. 26-37**). The clinician must consider the patient's pre-injury status to establish relevant goals.

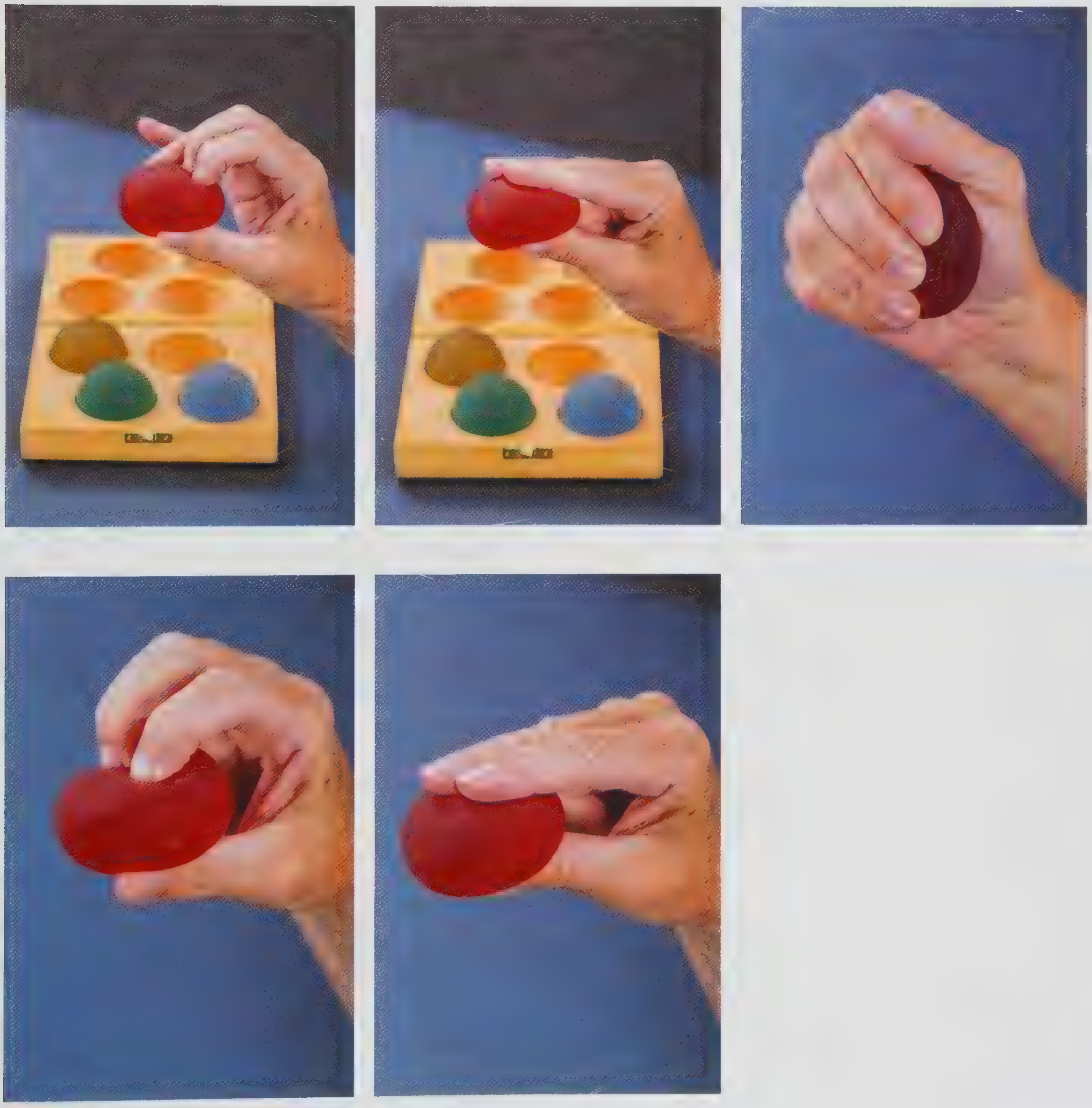


FIGURE 26-37 Grip strengthening exercises requiring concurrent wrist stabilization. Resistance is easily altered by changing the color resistance ball.

Scaphoid Fracture

The scaphoid is often fractured as a result of a fall on an outstretched hand but frequently goes unrecognized. Individuals often pass these fractures off as sprains because of the lack of obvious deformity. The scaphoid is highly susceptible to injury because of its shape and its position. Its narrow midline makes it more vulnerable to stress, and its position crosses the two rows of carpal bones, predisposing it to more frequent injury.

The individual with a scaphoid fracture relates a history of a fall on or other trauma to an extended wrist, with subsequent pain and loss of motion. Pain is particularly apparent with any overpressure in extension, such as in pushing a heavy door open. Athletes are unable to bench press because of the pressure into wrist extension. Palpable tenderness over the anatomic snuffbox and painful extension warrant medical evaluation.

Medical intervention for scaphoid fractures is immobilization for 8 to 12 weeks. Because the poor vascular supply predisposes the scaphoid to nonunion, these fractures are treated conservatively. If the fracture is severe or displaced, ORIF with a Herbert screw may be used. Because of the importance of the scaphoid in providing stability to the wrist, healing of this fracture is important. A bone stimulator may be used to facilitate bone healing. The thumb is immobilized along with the wrist because of its involvement in thumb mobility.

The rehabilitation after immobilization is similar to that for a Colles fracture. Edema control and restoration of mobility, strength, and function relative to the individual's needs are the primary goals. Self-stretching exercises, mobilization, and strengthening exercises are indicated (**Fig. 26-38**). Specific thumb AROM and PROM exercises should also be included. Specific grip, pinch, and thumb opposition strengthening exercises also are important after a scaphoid fracture. Putty or other household products (e.g., racquetball, Nerf ball, clothespin, rubber bands) may be used. Include the patient in discovering objects at home or work that may be used to accomplish the established goals (**Fig. 26-39**).

FIGURE 26-38 A variety of dexterity exercises can improve hand function.

FIGURE 26-39 Resisted pinching using a clothespin.

Metacarpal Fracture

Metacarpal fractures account for 30% to 50% of all hand fractures.[118,145] Metacarpal fractures can occur from a fall onto an outstretched hand with initial ground contact along the metacarpals, from industrial accidents (e.g., punch press machines), or from fist fights. When the fifth metacarpal is the only involved bone, it is commonly referred to as a boxer's fracture. Metacarpal fractures can occur at the base, shaft, neck, or head. Tension in the long finger flexors can cause angulation, shortening, and/or rotation of metacarpal fractures. Importantly, these tendons must be considered during the healing process to avoid adhesions and loss of tendon mobility during the fracture healing process.[119]

Impairments associated with fracture in the acute stage include pain, swelling, loss of motion and strength, and deformity. The MCP joints of fingers 2 through 5 are essentially ball and socket joints with a slack joint capsule in extension and taut collateral ligaments in flexion. The dorsal and palmar interossei muscles arise from the metacarpal bones and insert into the extensor mechanism. These muscle groups need special attention during evaluation, because their length and strength may be affected after injury or immobilization for metacarpal fractures.

Medical intervention depends on the severity of the fracture. If the fracture is nondisplaced, it is usually casted for 2 to 3 weeks. A custom static splint that crosses the wrist and includes only the affected MCP joints up to the level of the PIP joint may be worn for 2 to 3 weeks. Radial or ulnar gutter splints allow immobilization of only the affected metacarpals and permit passive ROM while in the splint. If the MCP joint is flexed during immobilization, the position can prevent collateral ligament contracture. If the fracture is displaced or unstable, surgical fixation with pins, Kirschner wires, or a plate is indicated.

The start of rehabilitation depends on the medical intervention. If the fracture is surgically stabilized, treatment begins as early as 1 to 3 days after surgery. Early intervention avoids associated impairments of dorsal hand edema, extensor tendon adhesions, MCP collateral ligament adhesions, and intrinsic muscle contractures. Exercises in the first phase emphasize gentle AROM of the wrist and all fingers and blocked MCP flexion and extension exercise (see **Self-Management 26-7**). This specific exercise prevents collateral ligament adhesions and encourages extensor tendon gliding with minimal stress placed on the fracture site. Aggressive interosseous and lumbrical stretching along with thumb-index web space stretching also should be initiated in this phase. Intrinsic muscle stretching can only be accomplished by maintaining the MCP in neutral or hyperextension while flexing at both IP joints (**Fig. 26-40**).

At 2 weeks, scar mobilization may begin, and at 4 to 6 weeks after surgery, passive MCP flexion may be initiated. At 6 to 8 weeks after surgery, intervention may focus on aggressive MCP flexion (i.e., joint mobilizations), wrist strengthening, and grip and pinch strengthening, including the intrinsic muscles (e.g., putty exercises for finger abduction and adduction).

The patient treated with immobilization may begin after cast removal at 2 to 3 weeks after the injury. Gentle AROM of the wrist and MCP joints is initiated at this time. PROM is initiated after 4 to 6 weeks. All other noninvolved joints and fingers should be completing AROM exercises from the beginning of immobilization to prevent functional loss. The program is progressed similar to that for surgical management.

FIGURE 26-40 Stretching exercises at the proximal and DIP joints.

SELF-MANAGEMENT 26-7
Metacarpophalangeal Joint Extension with Proximal and Distal Interphalangeal Joint Flexion

Purpose: To increase the mobility in your finger extensor tendon

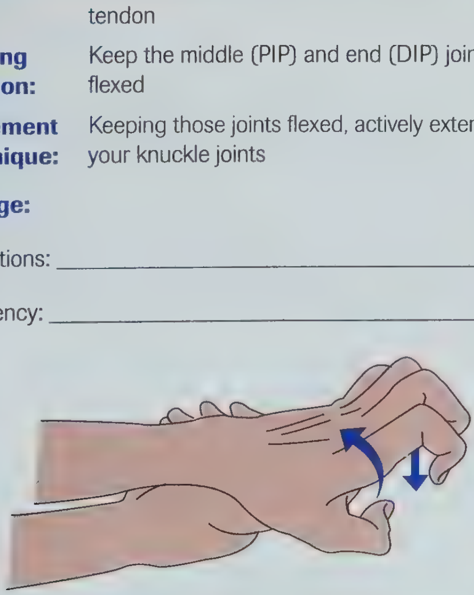
Starting Position: Keep the middle (PIP) and end (DIP) joints flexed

Movement Technique: Keeping those joints flexed, actively extend at your knuckle joints

Dosage:

Repetitions: ____________________

Frequency: ____________________



Adjunctive agents include education, elevation, ice, and compression garments to control edema. Dynamic splinting may be used to promote passive stretching of the MCP joints for 20-minute sessions performed six to eight times per day. Massage is used to manage scar formation in the operative cases.

Phalangeal Fracture

Phalangeal fractures usually occur as a result of trauma. Approximately 45% to 50% of all hand fractures involve the distal phalanx, 15% to 20% the proximal phalanx, and 8% to 12% the middle phalanx.[118] Unlike metacarpal fractures, phalangeal fractures are more often unstable due to the lack of soft-tissue support and the additional tension in the long finger flexors.[119] Additionally, immobilized phalangeal fractures result in loss of motion at a higher rate than metacarpal fractures, in both the injured and adjacent fingers.[119]

Impairments observed in the acute stage include localized swelling, pain, and tenderness over the fractures; hypomobility at IP joints and possibly MCP joint; and abnormal alignment of the IP joint. Patients may also experience lateral instability. Associated impairments after immobilization usually include restricted PIP joint flexion and extension (from volar plate contracture), DIP flexion and extension, and flexor tendon adhesions.

As with metacarpal fractures, the intervention depends on the severity of the fracture. If nondisplaced, the immobilization is accomplished by a custom splint or foam-covered metal splint. The period of immobilization varies according to the location of the fracture. If located at proximal or distal ends, only 3 to

4 weeks are required because of the good vascularity in cancellous bone. Midshaft middle phalangeal fractures require 10 to 14 weeks or longer because of the poor blood supply in the bony cortex. Displaced fractures require internal fixation with Kirschner wires or pinning. Extreme care is taken to avoid rotation, and often a buddy splint or buddy taping technique is used to help minimize this complication.

Intervention after nonsurgical postimmobilization care of phalangeal fractures is usually initiated at 3 to 6 weeks after injury or when immobilization is no longer necessary. Exercises of active and passive motion for all MCP, PIP, and DIP joints should be initiated along with tendon gliding exercises. For PIP joint restrictions of 20 degrees or more, dynamic PIP extension splinting may be required. Several commercial prefabricated splints are available, or custom splints can be fabricated. Static progressive splinting can be used at night. The finger splint is fabricated in full extension, and tension-adjustable straps are used to allow gradual finger extension toward the splint.

After surgical internal fixation, intervention may begin as early as 2 days after surgery. Gentle AROM of the MCP, PIP, and DIP joints, with emphasis on full PIP joint motion, is initiated. Tendon gliding, scar management, and edema control also should be encouraged. At 4 to 8 weeks after surgery, dynamic PIP extension splinting may be initiated, along with buddy taping during exercises or ADLs. Again, these general guidelines will vary depending upon the phalanx fractured, as well as the fixation, healing, and associated considerations.

Therapeutic exercise interventions include AROM, joint mobilization techniques, and continuous passive motion devices. Exercise is best tolerated if initiated at proximal and less painful joints. Supine shoulder flexion or simple posture correction with the patient's back against a wall promotes upper extremity blood flow and improved proximal joint alignment. Active exercise of the wrist and hand should be performed elevated and directed to individual joints and motions. Blocked finger flexion exercises encourage more complete joint motion and specific tendon gliding (see **Self-Management 26-8**). Holding a towel or soft ball while gripping can improve motor function by the assistance of palmar sensory stimulation (**Fig. 26-41**). Patients are encouraged to keep the wrist in slight extension during gripping exercises to ensure maximal efficiency of the flexor tendons.

SELF-MANAGEMENT 26-8
Blocked Finger Extension

Purpose: To increase the mobility of your finger joints and tendons.

Starting Position: Level 1: Hold the knuckle joint of your finger straight.

Level 2: Hold the knuckle and middle joints of your finger straight.

Movement Technique: Level 1: Bend your middle joint, keeping your fingertip joint straight.

Level 2: Bend only your fingertip joint.

Dosage:

Repetitions: ______________________

Frequency: ______________________

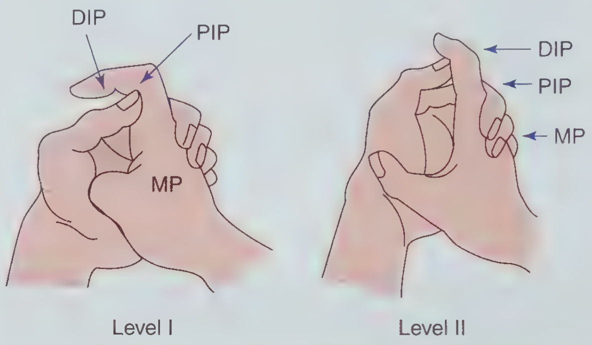


FIGURE 26-41 Grasping exercise using a towel.

Stiff Hand and Restricted Motion

The diagnosis of the "stiff hand" is often used to describe joint limitation from a variety of causes. The primary diagnosis can include lacerations, burns, fractures, soft-tissue crush injuries, and nerve and vascular trauma. The common cause is tissue trauma resulting in an inflammatory response. The resulting edema, fibrosis, and collagen alteration limit tissue gliding (i.e., tendons) and extensibility (i.e., skin, ligament, and joint capsule). Restricted motion is categorized as intra- or extraarticular by the tissue causing the limitation. Joint stiffness that follows simple immobilization is attributable to fixation of the joint ligaments to bone in areas normally meant to be free from such fixation, as well as shortening of the ligament by new collagen synthesis.

Knowledge of the normal anatomy and kinesiology of the wrist and hand help to understand, predict, and effectively treat limited mobility. At the MCP joints, the capsule is very elastic dorsally to allow for full MCP joint flexion. The extensor expansion glides over the dorsal capsule. With dorsal hand swelling, the MCP joints often lose joint flexion. This is initially caused by limited extensibility of the dorsal skin and progressively by adhesions of the collateral ligaments in their position of joint extension. The PIP and DIP joints are similar to the MCP joints with two exceptions. First, the collateral ligaments at the IP joints do not become slack in flexion; they remain taut throughout joint range, preventing lateral motion of the IP joints. Second, unlike the MCP joint, the loose-packed position for the IP joints is flexion. The volar plate becomes slack with IP joint flexion and taut in extension, preventing hyperextension, as seen at the MCP joint. After prolonged local swelling, the IP joints tend to lose joint extension, and the volar plate can become adhered in its slack position, preventing the necessary lengthening for full IP joint extension.

Structures outside the joint such as muscle, tendon, or skin adhesions can also limit joint motion. After prolonged immobilization in wrist and finger flexion, the flexor muscles become shortened. After tendon repair or fractures adjacent to tendons, tendon gliding is often limited by scar tissue or fracture calluses. For complete finger flexion, 7 cm of excursion is needed in the FDP tendons.[3] After a dorsal hand burn, metacarpal fracture, or prolonged dorsal hand edema resulting in decreased skin mobility, adjacent joint motions may be lost. Approximately 4 cm of dorsal skin laxity is needed for full MCP joint flexion and complete fisting.

Patients with articular and extraarticular tissue restriction describe activity limitations such as an inability to hold a fork or grip a steering wheel and difficulty getting their hands into their pockets. Examination must distinguish between articular and extraarticular sources of limited motion. A thorough evaluation, performed with an understanding of the local anatomy and kinesiology, can result in effective intervention.

Interventions for articular limitations include heat before joint mobilization, strengthening, and splinting. Splinting can include dynamic splints (worn for 20 to 30 minutes six to eight times each day or 2 to 3 hours for one or two times each day) or static splints (worn at night). A flexion glove can apply nonspecific tension to the dorsal tissue of the fingers, with an elastic strap used to increase forces at the IP joints (**Fig. 26-42**).

Extraarticular restrictions rely heavily on tendon gliding activities such as differential tendon gliding and blocked IP flexion. As with articular restrictions, static or dynamic splinting plays a role in improving mobility. When intrinsic muscles are shortened or the tendons adhere to surrounding tissues, stretching, gliding, and splinting are the treatments of choice. Along with exercise and splinting, edema can be controlled with compression gloves, compression pumps, elevation, and wraps. Scar massage is important in treating surgical or burn cases.

FIGURE 26-42 A flexion glove can improve the range of motion into flexion.

KEY POINTS

- The ulnar nerve may become entrapped in the cubital tunnel, the median nerve compressed in the carpal tunnel, and the radial nerve entrapped in any of several locations at the lateral elbow.
- The UCL is the primary static stabilizer and the FCU muscle the primary dynamic stabilizer of the medial elbow.
- The carpal tunnel is located on the volar aspect of the wrist and contains nine tendons (4 FDS, 4 FDP and FPL) and the median nerve.
- Grip is generally divided into power grip, used when force generation is the primary objective, and prehension grip, used when precision is the main goal.
- Activities to increase mobility include traditional stretching exercises, joint mobilization, and tendon and nerve gliding exercises.
- CTDs are usually the result of a combination of factors such as work pace, decreased rest intervals, and little variability in the task.
- Conservative management of CTS is often successful if hand and wrist postures and hand activities are monitored.
- Radial tunnel syndrome is often misdiagnosed as lateral epicondylitis.
- Cases of lateral and medial epicondylitis often result from repetitive wrist and hand activities at work, at home, or during recreation.
- Medial elbow instability occurs in children and adults who participate in throwing sports. Progressive instability in the child can lead to osteochondrosis of the capitellum and loose body formation.
- Sprain of the thumb's UCL (skier's or gamekeeper's thumb) can result in degenerative joint disease of the CMC joint if instability continues.
- The anatomy of the scaphoid predisposes it to nonunion after a fracture. Any individual with wrist pain and wrist extension loss after a fall on an outstretched hand should be evaluated for fracture of the scaphoid.
- Interventions for individuals with a stiff hand include mobility activities, splinting, and strengthening exercises.

CRITICAL THINKING QUESTIONS

1. Consider Case Study No. 8 in Unit 7. Design a workstation for this individual given his physical examination and subjective history. How would your treatment differ if the patient's occupation was
   a. A carpenter
   b. A house painter
   c. A portrait painter
   d. A violinist
   e. A pianist
2. Consider potential reasons why this patient's symptoms did not resolve after his workstation update several months ago.
3. Discuss the relationship between this patient's head and neck examination and his distal complaints.

SELECTED INTERVENTION 26-1

Upper Quadrant

See Case Study No. 8

Although this patient requires comprehensive intervention, one specific exercise addressing motor control is described.

ACTIVITY: Simulated typing with surface electromyography (SEMG).

PURPOSE: Develop motor control strategy to use appropriate levels of wrist extensor activation, wrist flexor relaxation, production of microrests, and complete baseline recovery between timed bouts of data entry.

RISK FACTORS: Watch for cervical posture as part of repetitive strain; injury to extensor group may be secondary to cervical dysfunction.

SUBSYSTEM EMPHASIZED: Neural

STAGE OF MOTOR CONTROL: Skill

MODE: Isometric wrist extensor and flexors, concentric and eccentric finger flexors and extensors.

POSTURE: Sitting at a simulated workstation in optimal ergonomic posture, with SEMG appropriately placed on right and left forearm flexor and extensor groups.[41]

MOVEMENT: While simulated typing is performed on a keyboard using a palm and wrist rest and optimal ergonomic posture, SEMG monitors forearm flexor and extensor activity bilaterally. The right forearm attempts to follow the template developed by the left forearm. Random stopping is called out to determine the spontaneous speed and level of recovery to baseline. Timed rest breaks are scheduled to determine planned speed and level of recovery to baseline.

SPECIAL CONSIDERATIONS: Closely monitor cervical position and paracervical muscle tension.

DOSAGE

Special Considerations

Anatomic: Lateral epicondyle, musculotendinous and tenoperiosteal junction of wrist and finger extensor group.
Physiologic: Subacute strain.
Learning capability: May be difficult as patient works up to 60 hours a week at visual display terminal. Probably has strong patterns of overuse of wrist and finger extensors.

Repetitions/sets: Five minutes of typing form one repetition. Perform up to five sets.

Rest period: Random 5-second rest breaks are called out during each repetition; 15-second breaks are taken after each 5-minute bout of exercise.

Frequency: If SEMG is rented, practice should be twice daily for 2 to 4 weeks. If only used in clinic, recommend three times a week for 3 to 6 weeks. For cost-effectiveness, unit rental is preferred.

Sequence: Perform after stretching exercises are performed, but not after muscle performance exercises so as not to overly fatigue muscles.

Speed: Functional speed.

Environment: Initially in quiet home environment, then progress to work environment.

Feedback: Initially, continuous audio feedback from the SEMG unit. Threshold is set so as not to exceed left side wrist and finger extensor activity. Visual feedback is used to see the speed and level of recovery to baseline during microrests and rest breaks. The patient is reassessed once each week, and the decision to progressively fade feedback is based on performance. Progressive fading of feedback occurs during exercise sessions to eliminating either audio or visual feedback every third set, to every other set, and so forth. A second party relaying the results between sets provides verbal knowledge of the results.

Functional Movement Pattern to Reinforce Goal of Exercise: In addition to using an improved motor strategy during data entry, the patient is encouraged to use elbow flexors instead of forearm extensors during lifting tasks (e.g., lift in forearm supination vs. pronation) to reduce the strain to the wrist/finger extensors.

Rationale for Exercise Choice: This exercise was chosen as a skill-level activity to reduce the overuse of the wrist and finger extensors during a highly repetitive functional activity. Through the use of SEMG feedback with a proper faded feedback schedule,[42] the patient can develop an intrinsic reference for muscle activation and error detection to improve motor control strategies to reduce recruitment effort and improve the speed and level of relaxation to baseline.

SELECTED INTERVENTION 26-2

Total Body

See Case Study No. 10

Although this patient requires comprehensive intervention, one specific exercise prescribed in the intermediate stage of recovery is described.

ACTIVITY: Step-ups; swing phase, with counterrotation.

PURPOSE: Incorporate proper total-body movements in a functional context.

RISK FACTORS: None

SUBSYSTEM EMPHASIZED: Neural.

STAGE OF MOTOR CONTROL: Controlled mobility.

POSTURE: Standing in front of a 6-in step in front of a mirror.

MOVEMENT: Lift the right leg onto the step with simultaneous right thoracic rotation and left forward arm swing.

SPECIAL CONSIDERATIONS: Be sure the patient does not hike his right hip during the hip flexion phase and does not drop his right shoulder (right thoracic lateral flexion) or adduct his right scapula instead of right thoracic rotation during the upper body counterswing maneuver.

DOSAGE

Special Considerations

Anatomic: Right hamstring and adductor, right subscapularis, right glenohumeral joint.

SELECTED INTERVENTION 26-2 (*continued*)

Physiologic: Chronic moderate strain and tendinitis, questionable instability of right glenohumeral joint.
Learning Capability: Very ingrained movement pattern from a long history of high-mileage running; may require high repetitions and significant feedback in early stages of learning.
Repetitions/sets: Initially to form fatigue as evidenced by hip hike, shoulder drop, and scapula adduction; work up to three sets of 20 to 30 repetitions.
Frequency: Six to 7 days each week.
Duration: Expect at least 2 weeks before evidence of motor control changes and 6 to 8 weeks before skill level is achieved.
Sequence: Perform after specific exercises for psoas muscle performance, thoracic rotation mobility, and abdominal muscle performance exercises have been performed. Follow with step-up: stance phase.
Speed: Slow progressed to functional speed.
Environment: Home in front of a mirror.
Feedback: Initially in clinic with mirror providing visual feedback and clinician providing verbal feedback. Taper to continued use of mirror, but with knowledge of results of verbal feedback after every three to four repetitions. Withdraw mirror and verbally provide knowledge of results every three to four repetitions. Progress toward skill.
Functional Movement Pattern to Reinforce Goal of Exercise: Ascending stairs, gait.
Rationale for Exercise Choice: The total-body movement pattern of right hip hike and right shoulder drop during swing phase of gait may be perpetuating the upper and lower extremity conditions. Without adequate hip flexion, the gluteus maximus is less efficient at assisting the stance phase of gait or step-up; the persistent right shoulder drop and scapula adduction and downward rotation can perpetuate posture and movement impairments consistent with glenohumeral impingement and hypermobility. As a result, this pattern of movement must be altered to fully recover from the upper and lower body conditions.

LAB ACTIVITIES

For each of the following case scenarios, evaluate your patient and design and execute an exercise program. Teach your patient a home exercise program.

1. A 56-year-old woman sustained an ulnar shaft fracture when she slipped and fell on the ice 6 weeks ago. She was casted for 3 weeks above the elbow and then recasted with a below-elbow cast. Her cast was removed 3 days ago. Evaluation reveals loss of AROM and PROM for elbow extension, pronation, and supination, wrist flexion and extension, and radial and ulnar deviation. Strength testing was not performed. She had no edema. Joint play assessment was not performed, but atrophy was visible.
2. A 12-year-old boy complains of medial elbow pain. He is active in Little League and pitched 14 innings over the weekend. He complains of pain along the medial collateral ligament, pain with passive elbow extension, flexion, pronation, and supination (with a guarded end-feel). A mild effusion is observed, and there is increased laxity with valgus stressing. Radiographic findings are negative.
3. A 44-year-old patient presents with lateral elbow pain after shoveling wet, heavy snow. He complains of pain with activities such as picking up his briefcase, turning the doorknob, and grasping objects. He also has difficulty using the mouse on his computer. Examination reveals a loss of AROM and PROM of wrist flexion (and finger flexion increases symptoms), decreased strength with wrist extension and supination, and pain with palpation at the lateral epicondyle. There is no effusion, but slight warmth is noticed.
4. Three weeks ago, a 22-year-old collegiate gymnast dislocated her elbow (the olecranon displaced posteriorly) from a fall on an outstretched hand when she missed grasping the high bar and fell to the floor. She was in a sling for 2 weeks and has been out of the sling for 1 week, but she is carrying her arm in a guarded position. Examination reveals a loss of elbow extension (actively and passively with a springy end-feel), full anteroposterior flexion, and a loss of pronation and supination anteroposteriorly. Joint play assessment reveals decreased humeroulnar joint distraction.
5. A 70-year-old woman fell on the ice and sustained a Colles fracture 8 weeks ago. She underwent a closed reduction and was immobilized in a series of casts. She also has insulin-dependent diabetes mellitus and has decreased sensation over the distal forearm, wrist, and hand. Examination reveals a loss of all active and passive wrist motion, decreased joint play in the inferior radioulnar joint, visible atrophy, and a loss of strength with resisted movements in neutral.
6. A 32-year-old man sustained a scaphoid fracture 10 weeks ago when he fell on an outstretched hand while skiing downhill. He was casted for 8 weeks, and periodic radiographs revealed nonunion of his scaphoid. He underwent surgical stabilization of the fracture using a bone graft from his iliac spine. He has been immobilized for 12 weeks since surgery. He is referred to physical therapy to begin ROM out of the splint four times each day. Examination reveals a loss of all wrist motions, decreased thumb flexion and extension, and decreased opposition.
7. A 40-year-old meat cutter sustained a laceration of his finger extensors (proximal to his MCP joints) while working. He underwent surgical fixation and was allowed to actively contract only the finger flexors. He has been removed from his splint and is allowed to begin active finger extension. Examination reveals decreased active finger extension (at the MCP joints) from weakness but full passive finger extension. Mobility of the MCP joints is decreased.
8. A 50-year-old man sustained a crush injury to his hand when his shirt sleeve got caught in a printing press and pulled his hand in. He sustained multiple metacarpal and carpal fractures, some of which were surgically stabilized through pinning. He has been casted for 8 weeks and presents to physical therapy today. Examination reveals a massive loss of motion of all wrist and fingers joints, atrophy in the thenar and hypothenar eminence, and decreased joint mobility in the carpal and MCP joints and all finger joints.

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Case Studies

LORI THEIN BRODY • CARRIE M. HALL • ELIZABETH A. V. BLOOM

UNIT

7

CASE STUDY NO. 1

Cody is a 17-year-old high school student who complains of right (R) hip pain. He describes onset of hip pain after playing soccer that began with summer training. Pain has gradually worsened over the season to the point that he is unable to practice or play without pain lasting several days. The pain is located at the lateral hip and groin region. One it is aggravated, pain is present in sitting as well. He is able to walk with minimal pain, but cutting and kicking seem to aggravate it the most.

EXAMINATION

Pain: 4/10 in sitting, constant in nature: 2/10 with weight-bearing, 6/10 with passive hip flexion/IR/adduction.

Gait: Excessive pelvic rotation versus hip flexion with swing, + Trendelenburg pattern with excessive hip IR during stance.

Active Range of Motion: 90 degrees hip flexion before onset of lumbar flexion, excessive pelvic rotation with hip ER in prone, limited hip IR to 20 degrees. Hip abduction limited to 15 degrees before onset of lateral pelvic tilt, hip adduction 20 degrees.

Passive Range of Motion: Hip flexion 95 degrees with pain end range, hip ER 20 degrees, hip IR 20 degrees prone, 5 degrees at 90 degrees hip flexion, hip abduction 20 degrees, hip adduction WNL

Accessory Motion: Limited posterior glide R femoral head

Special Tests: + hip impingement, limited hip IR and hip flexion/cluster sign for cam impingement

Palpation: Tenderness middle third of groin region and over greater trochanter

Strength Testing: Gluteus medius 3–/5; adductor 3+/5; gluteus maximus 3+/5; Iliopsoas 3–/5; Hip lateral rotators 3–/5; hip internal rotators 3+/5; quadriceps 4/5; hamstrings 4–/5

Pelvic Alignment: Intrapelvic torsion with R innominate (inlet) extension, IR, adduction; L innominate (inlet) flexion, ER, abduction

Balance: Failed load transfer onto R limb with slight pelvic drop, femur MR, and foot pronation

Additional Tests: Imaging reveals sizable cam impingement

Functional Outcome Score: Lower Extremity Functional Scale (LEFS): (range 0 to 80) 45—moderate activity limitation (MCID = 9) (Accessed February 2015, from http://www.mccreadyfoundation.org/documents/LEFS.pdf)

EVALUATION: Painful hip in positions of impingement or in high loads or ROM demands in WB

Impairment

- Limited and painful hip ROM
- Decreased strength to iliopsoas, gluteus medius, hip lateral rotators
- Intrapelvic torsion favoring femoral movement patterns into IR, adduction, and extension
- Hip adduction, IR patterns during stance phase of gait
- Decreased static and dynamic standing balance

Activity Limitation

- Painful motions of the pelvis over the femur when changing directions
- Poor muscle performance for optimal gait and running mechanics
- Acetabular and femoral incongruence causing pain in WB and sitting activity
- Faulty biomechanics in gait

Participation Restriction

- Unable to cut in soccer or sit in class
- Unable to run or kick in soccer

DIAGNOSIS: Cam deformity with clinical findings of limited and painful hip flexion, adduction, IR

PROGNOSIS

Short-Term Goals (7 to 10 days)

1. Walk 3 miles with optimal mechanics and without hip pain
2. Sit for 60 minutes without hip pain
3. Improve LEFS score to 61 (mild limitation)

Long-Term Goals (3 to 4 weeks)

1. Kick soccer ball during drills for 10 minutes without hip pain
2. Run and cut at full speed during game without hip pain
3. Improve LEFS score to 76 (no limitation)

CASE STUDY NO. 2

Sarah is a 69-year-old, retired college professor with a medical diagnosis of osteoarthritis in both knees. She is widowed and living alone in a third-floor apartment with elevator access. Yesterday, Sarah underwent elective surgery for bilateral (B) total-knee arthroplasties. Her medical history includes emphysema, myocardial infarct 2 years ago, moderate obesity, and hypertension. She lives independently. Prior to surgery, she had a maximum walking tolerance of one-half block when using a cane for support.

EXAMINATION

Arousal/Cognition: Alert and oriented; follows complex commands; motivated to get out of bed

Cardiovascular: Pale with complaints of nausea; short of breath with exertion; diaphoretic in sitting; vital signs: pulse 96 supine, 108 sitting; blood pressure 144/66 mm Hg supine, 126/64 mm Hg sitting

Wounds: Dressed with gauze and clear tape, moderately soaked with bloody drainage; periwound regions warm to touch, hypererythemic, and swollen

Pain: 3/10 at rest, 8/10 with movement

Active Range of Motion: R knee extension/flexion 20 to 47 degrees (pain elicited); L knee extension/flexion 15 to 52 degrees (pain elicited)

Endurance: Maximum sitting tolerance 15 minutes; maximum standing tolerance 20 seconds

Strength Testing: Iliopsoas (B) 2+/5; gluteus maximus (B) 4/5; gluteus medius (B) 2+/5; quadriceps (R) 2/5, (L) 3–/5; hamstrings (R) 2+/5, (L) 3–/5

Resisted Testing: Shoulder girdle extension and depression, elbow extension all strong and pain free

Posture: Semiflexed both knees, with L > R valgus knee deformity

Gait: Wide base of support, stiff knees, flexed trunk, maximum upper extremity support on walker

EVALUATION: Acute, postoperative pain, inflammation, muscle weakness, and decreased active motion of both knees

Impairment

- Bilateral decreased knee active range of motion
- Bilateral weak quadriceps and hamstrings
- Postoperative pain and inflammatory response
- Markedly limited activity tolerance

Activity Limitation

- Required moderate assistance for bed mobility and basic sit to stand transfer
- Unable to sit >15 minutes
- Unable to stand >20 seconds
- Unable to walk

Participation Restriction

- Unable to resume independent basic and instrumental activities of daily living
- Unable to walk household distances
- Unable to resume teaching and writing interests
- Unable to access family, church, and clubs for social interaction

DIAGNOSIS: Postopera.tive day 1 after bilateral total knee arthroplasties

PROGNOSIS

Short-Term Goals (7 to 10 days)

1. Independent bed mobility and basic transfer with walker
2. Independent ambulation 30 m with walker
3. Active knee range of motion >10 to 70 degrees to enable up/downstairs
4. Out of bed and up in chair >5 hours per day

Long-Term Goals (12 weeks)

1. Ambulation >100 m, rest breaks as needed, allowing for baseline compromised cardiopulmonary status
2. Return to independent driving for community access
3. Return to preoperative vocational routine

CASE STUDY NO. 3

Cathy is a 61-year-old journalist with a number of complaints, including trunk weakness, leg weakness, and generalized fatigue. She has a history of osteoporosis, osteoarthritis, and a recent 2-week bout with diarrhea caused by her medication. Previously, Cathy worked a 40- to 50-hour work week. In the past 6 months, the pain and fatigue have limited her work to no more than 30 hours per week in a good week. Pain is primarily in her low back, hips, and knees. She has been managed by a Pain Clinic, resulting in a change to her medications and she was referred to a physical therapist. She has no history of regular exercise nor any home exercise equipment. Her maximum walking tolerance is reportedly one block, limited by shortness of breath, general fatigue, and hip discomfort.

EXAMINATION

Posture/Alignment: Long kyphosis with posterior displacement of the upper trunk and a forward head. Lumbar spine is flattened. Posterior pelvic tilt. B hips extended and internally rotated. B knees in recurvatum; tibial external rotation; scapulae abducted and elevated

Muscle Length: Hamstrings—passive straight-leg raise to 50 degrees (B)

Strength Testing: Trunk curl 3−/5; leg lowering 2−/5; iliopsoas (R) 3/5 degrees, (L) 3−/5; gluteus medius (R) 3/5, (L) 2+/5; gluteus maximus (B) 3+/5; quadriceps (R) 4/5, (L) 4−/5; hamstrings (R) 4−/5, (L) 3+/5; rhomboids (B) 3+/5; lower trapezius (B) 3/5

Active and Passive Range of Motion:

Thoracolumbar spine: Forward bend thoracic > lumbar flexion with lumbar spine remaining in neutral; back bend with excessive extension at thoracolumbar junction; patient reports stiffness with all movements.

Hip: Internal rotation (R) 0 to 20 degrees, (L) 0 to 15 degrees, external rotation (R) 0 to 35 degrees, (L) 0 to 33 degrees, flexion (bent knee) 0 to 85 degrees, extension 0 to 5 degrees

Shoulder: Flexion in scapular plane 0 to 140 degrees when lifting bilaterally, with early upward rotation of scapulae and lacking thoracic extension and complaining of mid-back pain at end range. Single arm flexion results in an additional 10 degrees of elevation.

Functional Outcome Score: Standardized 12-minute walk test completed with subjective complaints of shortness of breath and lower extremity muscle fatigue; distance, 900 m; standing rest required at 10 minutes, peak heart rate of 132, blood pressure of 153/88 mm Hg

WOMAC: 46%

EVALUATION: Generalized deconditioning with gradual onset of faulty alignment because of changes in joint mobility and muscle strength and length, compounded by recent illness

Impairment

- Muscle weakness pelvic girdle
- Faulty spinal, pelvic, and lower extremity alignment
- Muscle shortening of hamstrings, rectus abdominis, and pectoralis major and minor bilaterally
- Decreased cardiorespiratory endurance
- Decreased lower extremity muscle endurance
- Restrictions at thoracolumbar spine intervertebral and thoracic spine costovertebral joints
- Faulty shoulder girdle movement patterns
- Impaired muscle performance of axioscapular upward rotators
- Hip joint restrictions

Activity Limitation

- Unable to walk >10 minutes without shortness of breath and fatigue
- Stairs require rail support
- Difficulty getting up from low chairs
- Rest breaks required during AM and PM self-care routine

Participation Restriction

- Unable to tolerate exertion of more than 30 hours per week of work
- Unable to complete basic and instrumental activities of daily living in a timely manner
- Avoidance of social activities because of fatigue and pain

DIAGNOSIS: Generalized deconditioning superimposed on baseline medical diagnoses of osteoporosis, osteoarthritis, and chronic pain involving primarily low back and lower quarter.

PROGNOSIS

Short-Term Goals (2 weeks)

1. Demonstration of energy conservation and pacing techniques to maximize activity tolerance at work and home

Long-Term Goals (4 to 6 months)

1. Increase in musculoskeletal and cardiovascular endurance to allow resumption of full duties at work and home

CASE STUDY NO. 4

Jack is a 58-year-old retired banker who presented with complaints of right (R) shoulder pain that was most noticeable when reaching overhead or behind. His pain occasionally wakes him at night. Jack's medical history is significant for a nonspecific R shoulder injury sustained playing tennis 2 years ago. This went untreated, and the symptoms resolved. Jack has been refurbishing his 35-feet wooden sailboat and noticed the onset of shoulder pain after sanding the deck. He is R-hand dominant. He is currently limited in recreational activities, but not limited in his ability to perform work duties.

EXAMINATION

Posture/Alignment: Forward head with upper cervical extension, head tilt (R), cervical-thoracic junction flexion, and flattened thoracolumbar spine; scapulae elevated, abducted, and downwardly rotated R > L; R humerus anteriorly and superiorly displaced in the glenohumeral joint

Active Range of Motion: R shoulder flexion 0 to 90 degrees, extension 0 to 30 degrees, abduction 0 to 100 degrees, external rotation 0 to 25 degrees, internal rotation 0 to 50 degrees; pain elicited end range all directions; neck rotation limited by 50% to the right (pain R shoulder end range) and 25% to the left (pain R shoulder end range), neck flexion limited by 50% (pain R shoulder end range), neck extension limited by 50% (pain R shoulder end range)

Passive Range of Motion: R shoulder flexion 0 to 110 degrees, extension 0 to 33 degrees, abduction 0 to 110 degrees, external rotation 0 to 25 degrees, internal rotation 0 to 55 degrees; end range pain elicited in all directions; neck ROM similar to active range with pain elicited in R shoulder at end range in all directions

Neural Tension Testing: + ULTT for median and radial nerves (R)

Accessory Motion Testing:

Glenohumeral: Diffusely hypomobile, especially posterior and inferior glides

Scapulothoracic: Hypomobile medial glide and upward rotation; hypermobile lateral/cephalic glides

Upper thoracic: Hypomobile segmental anterior/posterior glides T2–T8

Strength Testing: Upper trapezius/levator scapula (R) 5/5, (L) 5/5; middle trapezius (R) 3/5, (L) 3/5; lower trapezius (R) 3/5, (L) 3/5; rhomboids (R) 3/5, (L) 4/5; serratus anterior (R) 2+/5, (L) 5/5; GH LR (R) 3–/5, (L) 4/5; GH MR (R) 3–/5, (L) 4/5; Bicep (R) 3–/5, (L) 4+/5; Tricep (B) 4/5; thumb abduction (R) 3–/5, (L) 4/5

Resisted Testing (neutral position): Weak and painless R shoulder flexion, extension, internal rotation, abduction and adduction; external rotation

Quality of Movement: Glenohumeral flexion/abduction achieved through 30 degrees of glenohumeral motion, followed by 1:1 scapulohumeral rhythm to roughly 90 degrees; remaining motion achieved through shoulder girdle elevation

Additional Tests: Imaging reveals HNP at C5/C6 encroaching on R nerve root

Functional Outcome Score: Quick Dash (Gummesson C, Ward MM, Atroshi I. The shortened disabilities of the arm, shoulder and hand questionnaire (Quick DASH): validity and reliability based on responses within the full-length DASH. BMC Musculoskelet Disord 2006;7(44):1–7): range 0 to 100; Quick Dash: 59 (moderate activity limitation); Quick Dash Work Module: 15 (no activity limitation); Quick Dash Sports Module: 65 (severe activity limitation) Minimal Clinical Important Difference (MCID) 8% (Accessed February 3, 2015, from http://www.physio-pedia.com/DASH_Outcome_Measure#cite_note-Gummesson-3)

EVALUATION: Decreased osteokinematic and arthrokinematic motion of R shoulder girdle and cervical-thoracic spine, resulting in faulty movement patterns and pain with end range shoulder function; neural tension and weakness pattern suggestive of C5/C6 level disc pathology

Impairment
- Decreased physiologic and accessory motion
- Faulty scapulothoracic, glenohumeral, and cervical-thoracic spine alignment
- Faulty shoulder girdle movement patterns
- Pain with end range shoulder girdle motion, especially forward flexion
- Limited neck mobility
- + ULTT

Activity Limitation
- Unable to reach overhead or behind back, lift, or pull overhead
- Disturbed sleep

Participation Restriction
- Difficulty retrieving wallet from back pocket
- Difficulty unlocking car passenger door from driver's seat
- Unable to complete moderate- or heavy-duty boat refurbishing tasks

(*continued*)

CASE STUDY NO. 4 (*continued*)

DIAGNOSIS: Subacute R shoulder adhesive capsulitis secondary to cervical disc pathology

PROGNOSIS

Short-Term Goals (3 weeks)

1. Decrease night pain by 50%
2. Light weight lifting and reaching activities up to shoulder height without pain
3. Improve Quick Dash Sport Module to 36 (moderate activity limitation)

Long-Term Goals (3 to 4 months)

1. No night pain
2. Ability to tolerate resisted motion at end range of shoulder motion; thus able to complete heavy-duty jobs on boat
3. Improve Quick Dash Sport Module to 15 (no activity limitation)

CASE STUDY NO. 5

Irene is an 85-year-old woman who fell at home, resulting in acute low back pain and right more than left (R > L) lower extremity radiculopathy and necessitating bed rest for more than 2 weeks. She is weak, deconditioned, unsteady on her feet, and fearful of falling. She now uses a walker for ambulation. Her back still gives her pain, although she no longer suffers lower extremity symptoms. Irene lives in her own apartment in an assisted-living environment. Before the fall, she independently handled her basic activities of daily living and was socially active with fellow residents.

EXAMINATION

Posture: Kyphotic/lordotic thoracolumbar alignment; anterior pelvic tilt; hips slightly flexed

Strength Testing: Leg lowering 2/5; gluteus maximus (R) 2+/5, (L) 3+/5; gluteus medius (R) 2/5, (L) 3/5; iliopsoas (R) 3/5, (L) 4–/5; quadriceps (R) 4/5, (L) 4+/5; hamstrings (R) 3–/5, (L) 3+/5

Muscle Length: Moderate shortening of quads > iliopsoas, R > L; (B) hamstrings unremarkable

Functional Movement Testing: Pain with standing or walking (4/10). Pain relief with sitting or sidelying. Standing forward bend at 20 degrees; standing backward bend trace with reproduction of symptoms

Gait: Positive Trendelenburg with stance R > L; wide base of support; flexed at hips with forward displaced trunk over pelvis; markedly diminished lumbopelvic rhythm

Balance: Standardized stand reach test of 6 inches; provoked balance response demonstrates delayed step response with hip > ankle strategies

Reflexes: Knee jerk (B) 2+; ankle jerk (R) 1+, (L) 2+

Sensory: Light touch intact, mildly decreased proprioception, R > L

Functional Outcome Score: Berg Balance Score (0 to 56) (Accessed January 17, 2017 from https://www.physio-pedia.com/images/b/bd/Berg_balance_scale_with_instructions.pdf)—36 (high fall risk); Oswestry Disability Index Score (0-100) (Accessed January 17, 2017 from http://www.physio-pedia.com/Oswestry_Disability_Index): 35 (severe activity limitation)

EVALUATION: Fixed kyphosis and lordosis malalignment, with corresponding muscle length and tension changes; painful with active or passive extension, affecting static and dynamic standing balance, and standing tolerance

Impairment

- Fixed kyphotic-lordotic alignment of thoracolumbar spine
- Muscle weakness, especially trunk and proximal lower extremity
- Shortened iliopsoas and quadriceps, R > L
- Decreased static and dynamic standing balance (Berg Balance Score 36)
- Fear of falling
- Pain with lumbar extension

Activity Limitation

- Assistance required to get out of bed or up from a chair
- Inability to stand >2 minutes
- Inability to walk >10 m
- Mobility avoidance

Participation Restriction

- Loss of independence performing basic activities of daily living
- Loss of independence with ambulation
- Unable to walk to dining room
- Reluctant to participate in usual social activities (bridge, films, out for dinner with family)

DIAGNOSIS: Signs and symptoms consistent with lumbar stenosis exacerbated by fall.

PROGNOSIS

Short-Term Goals (2 weeks)

1. Independent ambulation with walker, 25 m
2. Independent transfer out of bed
3. Independent stand for 10 minutes for morning self-care routine
4. Improve Berg Balance score to 45 (moderate fall risk)
5. Improve Oswestry score to 30 (moderate activity limitation)

Long-Term Goals (8 weeks)

1. Independent ambulation within building complex; no assistive device
2. Resume all previous social activities with friends and family
3. Improve Berg Balance Score to 56 (functional balance)
4. Improve Oswestry Score to 15 (mild activity limitation)

CASE STUDY NO. 6

Megan, a 12-year-old female tennis and volleyball player, presented 2 weeks after right (R) anterior cruciate ligament injury which occurred during volleyball. MRI showed no meniscal damage. At this point, she does not wish to have surgery and would rather wait to see if her knee is unstable before considering reconstruction. She does not wish to give up either her tennis or volleyball.

EXAMINATION

Gait: Toe-touch pattern with use of axillary crutches; knee held semiflexed

Active Range of Motion: Knee extension/flexion 15 to 90 degrees with subjective sensation of "tightness" at both extremes

Passive Range of Motion: Knee extension/flexion full extension to 100 degrees with end range flexion limited by muscle guarding

Palpation: Moderate suprapatellar swelling; posterior capsule distention; girth (3 cm proximal to superior patellar pole) R = 44 cm, L = 38 cm; 1+ joint effusion; joint lines nontender

Strength Testing: Resisted testing contraindicated; patient unable to perform a quadriceps set; able to perform straight leg raise in hip flexion, abduction, and extension

Accessory Motion: Normal patellar glides

Special Testing: Varus and valgus stress testing at 0 and 30 degrees flexion: negative; Lachman's 2+; Instrumented laxity testing: 4 mm greater anterior displacement on the R compared with the L

Functional Outcome Score: KOOS QoL = 5; KOOS Sports & Recreation = 0; KOOS ADL = 33

EVALUATION: R knee joint effusion, pain, decreased range of motion, and altered muscle recruitment patterns

Impairment

- Localized swelling in suprapatellar and posterior capsule regions
- Subacute pain rated at 4/10
- Impaired quadriceps recruitment
- Loss of R lower extremity coordination

Activity Limitation

- Unable to tolerate foot flat stance on R with a step through pattern
- Ambulates with flexed knee gait pattern
- Crutches required secondary to above gait problems
- Stair negotiation slow
- Unable to squat with knee control

Participation Restriction

- Unable to participate in usual sports

DIAGNOSIS: R knee dysfunction from primary structural injury

PROGNOSIS

Short-Term Goals (2 to 4 weeks)

1. Ambulate without assistive device
2. Return to modified school routine without assistive device

Long-Term Goals (6 to 12 months)

3. Return to volleyball and tennis
4. Adopt appropriate movement patterns to prevent further knee injury and avoid surgery

CASE STUDY NO. 7

Mary is a 36-year-old wife and mother of two young children. She has a 6-month history of chronic back, R hip, and R ankle pain, recently diagnosed with psoriatic arthritis. She is not working, although she is trained as a research laboratory technician. Mary reports she's having a hard time keeping up with her husband and children and increasing difficulty managing her home. Even minor activities such as lifting or carrying her children can result in profound pain, fatigue, or weakness just a few hours later. She once was very active and now is skeptical but hopeful that she can return to a regular exercise program. Ultimately, she would like to return to part-time work. She is scheduled for a follow-up with her rheumatologist to discuss treatment with biologic drugs. She has been referred to physical therapy to help with managing painful regions and getting back to a fitness program.

EXAMINATION

Posture and Observation: Medium build; stands in ankle plantar flexion, knee recurvatum (R > L), anterior pelvic tilt, lumbar lordosis, thoracic kyphosis. R iliac crest is elevated, R femur adduction and IR, R > L midfoot pronation. Resting muscle tension apparent in lumbar erector spinae. Upper chest breathing pattern.

Active Range of Motion: Thoracolumbar: flexion to floor with thoracic and hip motion relatively greater than lumbar motion, pain elicited at onset of forward bend and upon return to extension; faulty lumbopelvic rhythm. Extension, rotation, and sidebending all moderately decreased with guarding; squatting limited by 50% due to R hip and R ankle pain. Ankle ROM limited to 5 degrees (R), 8 degrees (L) DF. R hip mildly limited in abduction, ER, and flexion compared to L; L limited in adduction, IR, and extension compared to R.

Passive Range of Motion: Painful before onset tissue resistance with R hip flexion, abduction, ER (7/10) (hyperalgesia). Painful at end range of tissue resistance ankle DF (4/10).

Accessory Joint Mobility: Limitation with PA pressure thoracic spine T1–T10. Limitation transverse PA pressure L4–L5, S1 on R.

Muscle Length: Shortened hamstrings (L); shortened gastroc/soleus (R); shortened two joint hip flexors, adductors (R).

Strength Testing: Trunk curl 3–/5; leg lowering 2/5; gluteus maximus (B) 3+/5; gluteus medius (R) 3–/5, (L) 3/5; iliopsoas (B) 3+/5; quads 4–/5 B; hamstrings (R) 4+/5, (L) 4–/5; gastrocsoleus 10 heel raises before fatigue on R, 20 on L. L4, L5 LM on R abnormal muscle contraction with multifidus lift test (Hebert et al., 2013).*

Movement Testing: Active movement testing revealed lumbar extension/rotation patterns with limb motions. R hip adduction and IR patterns with closed chain testing. R > L ankle PF and pronation patterns with closed chain testing.

Surface Electromyography: Elevated resting muscle tension prevalent lumbar paraspinals; lacking flexion relaxation response at end range forward bending.

Palpation: Painful (7/10) to light pressure in lumbar paraspinal lateral hip and groin, and along posterior tibialis insertion (allodynia), joint position; intrapelvic torsion with sacral rotation to R and R innominate in extension, adduction, IR; L innominate flexion, abduction, ER.

Functional Outcome Score: Fear Avoidance Behavior Questionnaire—Physical Activity (FABQpa) (0 to 24) (Accessed February 3, 2015 http://www.physio-pedia.com/images/2/29/FABQ.pdf): 12 (moderate fear avoidance); Oswestry Disability Index Score: 40 (moderate activity limitation); LEFS Score: 42 (moderate activity limitation)

EVALUATION: Low back pain with movement impairment of extension/rotation syndrome; hip pain with movement impairment of hip adduction with IR; foot pronation syndrome. Soft tissue pain in posterior tibialis. All painful conditions aggravated with activity.

Impairment

- Low back, R hip, R ankle regional pain, aggravated with activity
- Movement impairment patterns present in the low back, hip, and ankle
- Abnormal static and dynamic muscle tension and recruitment patterns, B lumbar erector spinae elevated and R LM reduced
- Mild diffuse loss of active physiologic range of motion, affecting spine, hips, and ankles

Activity Limitation

- Unable to sit >10 minutes
- Unable to stand >15 minutes
- Unable to walk >1/2 mile
- Unable to lift >10 lb from floor height

Participation Restriction

- Unable to play on the floor with children
- Unable to tolerate sexual intercourse
- Unable to return to work as laboratory technician
- Unable to resume fitness activities

* Hebert JJ, Koppenhaver SL, Teyhen DS, et al. The evaluation of lumbar multifidus muscle function via palpation: reliability and validity of a new clinical test. Spine J 2015;15: 1196–1202.

(continued)

CASE STUDY NO. 7 (*continued*)

DIAGNOSIS: Regional chronic pain with comorbidity of psoriatic arthritis and elevated FABQ score with findings of weakness, fatigue, loss of motion, and abnormal motor recruitment.

PROGNOSIS

Short-Term Goals (6 to 8 weeks)

1. Ambulate 15 minutes twice per day without residual symptoms
2. Lift 20 lb from floor height
3. Carry 15 lb for 3 minutes
4. Squat to thigh parallel to ground x 10 repetitions without residual symptoms
5. Improve FABQ score to 9 (mild fear avoidance)
6. Improve LEFS score to 61 (mild activity limitation)
7. Improve Oswestry score to 15 (mild activity limitation)

Long-Term Goals (1 year)

1. Return to work part time
2. Continuous ambulation for 30 to 40 minutes without residual pain or fatigue
3. Resume variety of fitness activities including weight lifting, yoga, Pilates
4. Improve FABQ score to 4 (minimal to no fear avoidance)
5. Improve LEFS score to 76 (no activity limitation)
6. Improve Oswestry score to 4 (no activity limitation)

CASE STUDY NO. 8

George is a 35-year-old computer data entry specialist with a 9-month history of multiple complaints, including interscapular pain, head, jaw, and neck pain with associated headaches, and right (R) lateral forearm pain. No specific traumatic event preceded these symptoms, although they have progressively worsened over the last couple of months such that they now interfere with his ability to work. He does report clenching his jaw when under stressful deadlines and wears a night guard. His employer completed a workstation assessment several months ago and provided state-of-the-art office equipment, but this has provided no significant relief of George's symptoms. Typically, he can spend several uninterrupted hours on the computer without awareness of time passed. A typical work week is 60 hours. George is moderately obese and admits to a sedentary lifestyle. He is currently moderately limited in his ability to work related to UQ symptoms.

EXAMINATION

Posture/Alignment: Forward head, elevated shoulders L > R, excessive lumbar lordosis with anterior pelvic tilt. Scapulae excessively abducted and downwardly rotated L > R. Cubital fossa oriented medially bilaterally. Laterally rotated femurs with hyperextended knees in postural knock-knees

Active Range of Motion:

Cervical: Flexion 0 to 25 degrees; extension 0 to 60 degrees, pain elicited; rotation (R) 0 to 55 degrees, (L) 0 to 60 degrees; sidebend (R) 0 to 35 degrees, (L) 0 to 45 degrees

TMJ: Jaw opening to 45 mm with lasting deviation to the R

Shoulder: Forward flexion (R) 0 to 120 degrees, (L) 0 to 140 degrees; extension (R) 0 to 30 degrees, (L) 0 to 45 degrees; external rotation (R) 0 to 35 degrees, (L) 0 to 50 degrees

Hip: Hip external rotation (B) 0 to 45 degrees, internal rotation (B) 0 to 10 degrees

Muscle Length: Shortened latissimus dorsi; lengthened rhomboids and mid-lower trapezius; shortened pectoralis major

Strength Testing: Serratus anterior 3/5; rhomboid major 4/5; upper trapezius 5/5; middle and lower trapezius 1 to 2/5; infraspinatus/teres minor 4/5; anterior/middle deltoid 5/5; biceps (R) 4–/5, (L) 5/5; triceps (B) 5/5; flexor carpi radialis/ulnaris (R) 4/5, (L) 5/5; extensor carpi radialis longus brevis (R) 3+/5, pain elicited, (L) 5/5; pronator teres/supinator (R) 4–/5, (L) 5/5; trunk curl 3/5; leg lowering 2/5; iliopsoas (R) 3+/5, (L) 4/5

Accessory Motion Testing: Cervical—L > R hypomobile posterior/anterior and rotation segmental testing at C1/2 and C2/3; decreased R TMJ in all directions; shoulder girdle: decreased anterior/inferior glenohumeral glides; decreased scapulothoracic inferior glide and downward rotation; excessive scapulothoracic lateral glide and upward rotation

Palpation: Suboccipital region moderately tender; tender R masseter, pterygoids, and temporalis; diffusely tender interscapular L > R; tender R lateral epicondyle

Deep Tendon Reflexes: Biceps (R) 1+, (L) 2+; triceps 2+ and symmetric

Sensation: Diminished light touch R lateral forearm and thumb

Functional Outcome Score: Neck Disability Index Score (NDI) (0 to 50) (Accessed February 3, 2015, from http://academic.regis.edu/clinicaleducation/pdf%27s/NDI_with_scoring.pdf): 23 (moderate activity limitation); Quick Dash: 37 (moderate activity limitation); Quick Dash Work Module: 63 (moderate activity limitation)

EVALUATION: Chronic postural malalignment resulting in multifocal postural and movement dysfunction most evident in overstretched and weakened scapular stabilizers and upper cervical and TMJ segmental hypomobility; subsequent musculoskeletal pain and headaches; subacute overuse injury to R wrist extensor group

Impairment

- Upper cervical, asymmetric facet joint motion dysfunction
- Asymmetric TMJ joint motion with overall reduced opening
- Painful and shortened deep suboccipital extensors and R TMJ closing musculature
- Faulty shoulder girdle alignment

Activity Limitation

- Unable to sit >30 minutes
- Daily headaches, limiting concentration
- Difficulty with wide mouth opening
- Difficulty keying with R hand because of forearm pain

Participation Restriction

- Unable to complete job requirements
- Loss of job satisfaction
- Unable to open mouth wide to eat large size food such as a burger or apple

(continued)

CASE STUDY NO. 8 (*continued*)

Impairment

- Overstretched and weakened shoulder girdle adductors, upward rotators, and depressors
- Postural muscle weakness and fatigue
- Pain and inflammation R extensor carpi radialis longus

Activity Limitation

Participation Restriction

DIAGNOSIS: Chronic grade 1 muscle strain of middle and lower trapezius; upper cervical facet joint movement dysfunction and possible fixed deformity; R TMJ joint hypomobility; R extensor carpi radialis longus tendinitis

PROGNOSIS

Short-Term Goals (2 to 4 weeks)

1. Reduce headache frequency and intensity by 50%
2. Increase sitting tolerance to 60 minutes, incorporating postural adjustments and short breaks
3. Open mouth to 50 mm
4. Improve NDI score to 15 (mild activity limitation)
5. Improve Quick Dash Work score to 35 (mild activity limitation)

Long-Term Goals (6 months)

1. Reduce headache frequency and intensity by 75% to 100%
2. Return to baseline work level
3. Open mouth wide enough to eat apples and burgers
4. Improve NDI score to 3 (mild activity limitation)
5. Improve Quick Dash Work score to 10 (no activity limitation)

CASE STUDY NO. 9

Janet is a 47-year-old nurse with primary complaints of posterolateral right (R) thigh pain. The pain is worse with weight-bearing first thing in the morning, gets better with limited activity, but worsens by the end of the day—especially if she has been on her feet quite a bit during the day. Secondary complaints include intermittent, dull low back pain and occasional bouts of sharp pain in the arch of her R foot. She is a regular walker, walking in the country on the road facing traffic, approximately 3 miles per day, 5 days per week. She has had to stop this activity due to lateral R knee pain.

EXAMINATION

Posture and Alignment: Thoracic kyphosis, lumbar lordosis, posterior pelvic tilt with anterior displacement of pelvis over base of support; elevated iliac crest R > L; medially rotated femurs R > L; laterally rotated tibias R > L; foot pronation R > L; leg length measures: R leg $^3/_8$-inch longer than the L

Active Range of Motion: Hip internal rotation 0 to 55 degrees, external rotation 0 to 30 degrees; thoracolumbar flexion full and pain free with reversal of lumbar lordosis

Muscle Length: Shortened tensor fascia lata/iliotibial band (TFL/ITB) with end range stretch pain; shortened hamstrings (medial > lateral); shortened gastroc/soleus on the R

Strength Testing: Leg lowering 2/5; trunk curl 4/5; gluteus medius (R) 2+/5, (L) 3/5; gluteus maximus (R) 3/5, (L) 3+/5; TFL (R) 3+/5 (pain elicited), (L) 4/5; iliopsoas (R) 2+/5, (L) 3/5; quadriceps (R) 4–/5, (L) 4+/5; hamstrings (R) 4+/5, (L) 4+/5; posterior tibialis (B) 5/5 (R > L muscle fatigue)

Accessory Motion Testing: Hypermobile posterior/anterior glides T10–L2 with relative hypomobility of lower lumbar segments; hypomobile dorsal glide great toe R > L

Movement Testing: Single-leg stance (R) with pain and excessive medial rotation of femur; decreased pain when femur held in lateral rotation

Gait: Positive Trendelenburg (R), medial rotation of femur midstance (R), excessive foot pronation early and late stance R > L

Palpation: Tender along R ITB, particularly at distal lateral knee; slight tenderness to deep palpation of plantar fascia at calcaneus origin

Functional Outcome Score: KOOS Symptom Scale = 75; KOOS Pain = 61; KOOS QoL = 50

EVALUATION: Acute, easily irritable pain arising from R ITB resulting from compensatory TFL patterns associated with weakness and length–tension imbalance of TFL synergists; intermittent bouts of foot pain arising from plantar fascia, excessive pronation, and great toe hypomobility

Impairment

- Postural alignment fault of posterior pelvic tilt, medially rotated femur, and foot pronation; leg length difference
- Muscle weakness of TFL synergists, including gluteus medius, iliopsoas, and quadriceps
- Shortened iliotibial band
- Lengthened gluteus medius
- Faulty movement patterns during gait

Activity Limitation

- Unable to walk 20 minutes without onset of R leg pain

Participation Restriction

- Unable to perform all job requirements for full 8-hour shift
- Unable to walk for fitness
- Difficulty performing household tasks because of leg pain

DIAGNOSIS: ITB fasciitis and intermittent plantar fasciitis

PROGNOSIS

Short-Term Goals (4 to 6 weeks)

1. Perform light duty work 40 hours per week
2. Walk 1.5 miles per day, paced at 20 minutes per mile, without leg or foot pain
3. Perform housework without leg pain if paced at 30- to 40-minute work intervals

Long-Term Goals (12 to 16 weeks)

1. Resume full duty work at 40 hours per week
2. Walk 3 miles per day, paced at 20 minutes per mile, without leg or foot pain
3. Perform all housework without limitations
4. Improve KOOS score by 50%

CASE STUDY NO. 10

Pete is a 38-year-old man with complaints of right (R) shoulder and hip pain. He fell onto his R shoulder 6 months ago. He complains of clicking and instability, particularly during movements of hand behind back. He also has impingement pain at the middle to end range of arm elevation. He is an avid runner (30 to 40 miles per week) and has posterior, superior, and medial hip pain after about 2 miles of running. The hip pain resolves about 45 to 60 minutes after the run. His occupation requires prolonged sitting at a computer, and he has increased hip pain after 45 to 60 minutes of sitting. His shoulder also begins to ache after approximately the same time period. He was also planning on beginning swimming to train for a triathlon when he fell. He has not been able to make any progress on his swimming skills.

EXAMINATION

Alignment: Slight forward head and head tilt to left (L); R head of humerus slightly anterior displaced; R scapula in moderate depression, tilt, downward rotation, adduction; R iliac crest elevated relative to L; R femur adducted and in slight medial rotation relative to L; R tibia slightly laterally rotated; R foot in slight abduction and pronation. Total body posture is a classic swayback. Sitting alignment is with pelvis in posterior tilt and R trunk sidebending with R scapula depressed, downwardly rotated, and tilted

Gait: At load response, the trunk is in R sidebend with R scapula depressed, downwardly rotated, and adducted; throughout R stance phase, the pelvis demonstrates a compensated Trendelenburg on the R; throughout swing phase on the L, the pelvis moves in excessive R forward rotation (clockwise approximately 12 degrees); foot mechanics appear unremarkable with the exception of slight excessive supination at terminal stance

Lumbar and Cervical Scan Examinations: Negative for reproduction of symptoms or neurologic signs

Range of Motion:

R shoulder: Flexion 0 to 150 degrees, scaption 0 to 150 degrees, lateral rotation/medial rotation (with arm abducted 90 degrees) 90 to 40 degrees

R hip: Flexion/extension 95 to 10 degrees, abduction/adduction 30 to 5 degrees, lateral/medial rotation (prone) 50 to 20 degrees

Thoracic rotation: 25% limitation R rotation

Scapulohumeral Rhythm: During arm elevation, scapula is slow to upwardly rotate; most of the rotation occurs in the last phase of arm elevation; reduced overall scapulothoracic (ST) upward rotation on R relative to L; scapular winging on return from elevation

Muscle Length: Moderate shortness in R medial hamstrings, R tensor fascia lata/iliotibial band (TFL/ITB), excessive length of R iliopsoas, moderate shortness in R rhomboid, significant shortness in infraspinatus/teres minor (R), excessive length in R lower trapezius and serratus anterior

Strength Testing (short-range positional strength): Gluteus medius (R) 3+/5, (L) 4+/5; gluteus maximus (R) 4–/5, (L) 4+5; iliopsoas (R) 3/5, (L) 4/5; medial hamstrings (R) 4–/5 (pain elicited), (L) 5/5; adductors (R) 4–/5 (pain elicited), (L) 5/5; hip lateral rotators (R) 3+/5, (L) 4+/5; subscapularis (R) 3+/5, (L) 4+/5; infraspinatus/teres minor (R)/(L) 5/5; upper trapezius (R) 4–/5, (L) 5/5; middle trapezius (R) 3+/5, (L) 4/5; lower trapezius (R) 3+/5, (L) 4/5; serratus anterior (R) 3–/5, (L) 4/5; trunk curl 5/5; leg lowering 3/5

Joint Mobility: Moderate restriction in glenohumeral (GH) posterior and inferior glide (capsular end-feel, pain after resistance), moderate excessive mobility in GH anterior glide (capsular end-feel); moderate restriction in ST upward rotation (muscular end-feel), and acromioclavicular joint anterior glide (capsular end-feel); moderate restriction in hip posterior and inferior glide (capsular end-feel, pain after resistance)

Resisted Tests: Weak and painful R medial hamstrings, hip adductors, and supraspinatus and subscapularis

Special Tests: Positive apprehension and relocation signs for R shoulder, positive anterior impingement sign for R shoulder, positive slump test for R lower extremity (pain reproduced in posterior, superior, and medial hip)

Palpation: Tenderness over subscapularis and supraspinatus insertions; tenderness in the region of medial ischial tuberosity and inferior pubic ramus

Functional Tests: Pain and apprehension with reaching R hand behind back; painful arc with touching R hand to head; during hand behind back maneuver, R scapula fails to adduct, and humeral head translates excessively anteriorly when compared with L. Step-ups illustrate hip hike with hip flexion phase on R and compensated R Trendelenburg with R stance limb; squats reveal asymmetrical hip flexion with R hip hike at end range

CASE STUDY NO. 10 (*continued*)

Functional Outcome Measures: Quick Dash: 39

EVALUATION: Chronic strain to R hamstring and adductor muscles; chronic strain to R subscapularis and supraspinatus; impingement R shoulder; questionable R shoulder instability

Impairment

- Localized pain R anterior and superior shoulder and R hip
- Hypermobility/instability(?) of R shoulder
- Capsular restriction R hip
- Short ST downward rotators, GH lateral rotators, medial hamstrings, TFL/ITB, R adductors
- Long ST upward rotators, subscapularis, iliopsoas
- Thoracic spine, GH, ST, hip joint restrictions
- Weakness in R shoulder upward rotators, subscapularis, gluteus medius, gluteus maximus, iliopsoas, hip lateral rotators

Activity Limitation

- Unable to reach R hand behind back or overhead without discomfort or unstable feeling
- Unable to sit, climb more than five flights of stairs, or run 2 miles without R hip discomfort

Participation Restriction

- Unable to sit at computer for more than 45 to 60 minutes at a time at work
- Unable to participate in recreational activity of running at desired level

DIAGNOSIS: R shoulder impingement and functional instability; R subscapularis strain and supraspinatus tendinopathy; R medial hamstrings and adductor magnus strain with secondary sciatic nerve injury or entrapment. Need to rule out R glenoid labrum tear and long thoracic nerve injury, which may have occurred during the fall.

PROGNOSIS

Short-Term Goals (2 to 3 months)

1. Elevate R arm through full range of motion and reach behind back and overhead without pain or instability
2. Sit 45 minutes without R hip pain
3. Climb 5 flights of stairs without R hip pain
4. Run 15 miles per week without increased R hip pain
5. Participate in a swimming program of mixed strokes up to 500 yards TIW

Long-Term Goals (6 to 8 months)

1. Unlimited use of R arm without pain or instability
2. Sit unlimited periods (in good alignment) without R hip pain
3. Climb up to 10 flights of stairs without R hip pain
4. Run 30 miles per week without R hip pain
5. Swim 1.0 mile without pain or instability
6. Improve Quick Dash to at least 75

COMPLETE INTERVENTION

A complete intervention for this case study follows on the next few pages—Complete Intervention: Lower Quadrant and Complete Intervention: Upper Quadrant.

COMPLETE INTERVENTION—LOWER QUADRANT
For Case Study No. 10

The following is a comprehensive exercise program for lower quadrant intervention for Pete. It is prescribed in the first week.

AT WEEK 1

ACTIVITY: Hand-knee rocking (see Self-Management 19-7 in Chapter 19).

PURPOSE: To improve the flexibility of the hips, stretch the posterior hip muscles, and train independent movement between the hips, pelvis, and spine.

RISK FACTORS: Watch for symmetry when rocking backward.

SUBSYSTEM OF MOVEMENT SYSTEM EMPHASIZED: Passive subsystem.

STAGE OF MOTOR CONTROL: Mobility.

MODE: Passive movement exclusively of the hips.

POSTURE: Hands and knees with hips directly over the knees and shoulders directly over the hands. Hip joints should be at a 90-degree angle. Knees and ankles are hip-width apart with feet pointing straight back. Hands shoulder-width apart with hands pointing straight forward. Keep a slight extension curve in the low back.

MOVEMENT: First activate intrinsic spinal muscles (see Patient-Related Instruction 17-1 in Chapter 17). The patient is instructed to rock backward at the hip joint only, stopping before the onset of back movement.

SPECIAL CONSIDERATIONS: Motion at the hips should be independent from the lumbopelvic region.

DOSAGE

Special Considerations

Anatomic: Hip joints, not the lumbopelvic region

Physiologic: Asymmetric hip stiffness at end range hip flexion

Learning Capability: Ingrained movement pattern of hip hiking with functional activities; may require high repetitions and significant feedback in early stages of learning

Repetitions/Sets: 30 repetitions, 1 set

Frequency: 7 days per week

Sequence: Begin with this exercise, followed by the open kinetic chain strengthening exercises.

Speed: Slowly to monitor accessory lumbopelvic movements

Environment: At home on a flat, firm surface, initially, in front of a mirror

Feedback: Initially in the clinic with clinician providing tactile and verbal feedback and a mirror providing visual feedback. Begin with knowledge of performance for every repetition, then taper every three to four repetitions with knowledge of results.

FUNCTIONAL MOVEMENT PATTERN TO REINFORCE GOAL OF EXERCISE: Ascending stairs, gait, and running without asymmetric pattern.

RATIONALE FOR EXERCISE CHOICE: This exercise was chosen to improve hip flexion mobility resulting from reduced extensibility in the capsule, ligament, muscle, or myofascial stiffness. For Pete to have a symmetric walking, stair-climbing, and running pattern, hip mobility needs to be WNL bilaterally. It is assumed that the stiffness in his R hip contributes to the hip hiking pattern and that this pattern contributes to the upper quarter asymmetry as well. To recover from both lower and upper quarter conditions, hip mobility impairment should be resolved.

ACTIVITY: Iliopsoas strengthening (see Self-Management 19-5, Level I, in Chapter 19).

PURPOSE: Iliopsoas neuromuscular education to promote recruitment in the shortened range with hip flexion.

RISK FACTORS: Ensure use of iliopsoas and not TFL or RF recruitment. Watch for hip hiking on the R.

SUBSYSTEM OF THE MOVEMENT SYSTEM EMPHASIZED: Active and neural subsystems

STAGE OF MOTOR CONTROL: Mobility.

MODE: Isometric iliopsoas contraction.

POSTURE: Seated with unilateral hip flexion and slight hip lateral rotation.

MOVEMENT: First set intrinsic spinal muscles. The patient passively flexes the hip into end range flexion with slight lateral rotation. Avoidance of hip hike or lumbar flexion is critical. The patient simply holds the limb without any resistance provided.

SPECIAL CONSIDERATIONS: Hip medial rotation will recruit the dominant hip flexor muscle, TFL, over the iliopsoas contributing to further shortening of the IT band. Hip hiking will contribute to lateral pelvic tilt versus hip flexion and should be avoided.

DOSAGE

Special Considerations

Anatomic: R iliopsoas, R hip joint

Physiologic: Length-associated changes in strength; stronger in the lengthened range than the shortened range

Learning Capability: Very ingrained movement pattern from a long history of high-mileage running; may require high repetitions and significant feedback in early stages of learning

Repetitions/Sets: To form fatigue, pain, or 20 to 30 repetitions, up to three sets

Frequency: 6 to 7 days per week

Sequence: After quadruped rocking

Speed: Hold for 10 seconds

Environment: At home on a firm surface

Feedback: Initially in clinic with clinician providing tactile and verbal feedback. Begin with knowledge of performance for every repetition, then taper every three to four repetitions with knowledge of results.

FUNCTIONAL MOVEMENT PATTERN TO REINFORCE GOAL OF EXERCISE: Ascending stairs, gait, and running.

RATIONALE FOR EXERCISE CHOICE: This exercise was chosen to improve muscle performance and motor control strategies of hip flexor muscles. Hip flexion without contributing to IT band shortening or hip hiking patterns depends on proper recruitment of the iliopsoas muscle in the shortened range. This method of neuromuscular reeducation is necessary before translating to dynamic activity and function.

ACTIVITY: Stomach lying gluteus medius strengthening (see Self-Management 19-4, Level I, in Chapter 19).

PURPOSE: Gluteus medius muscle strengthening in the shortened range.

RISK FACTORS: Medial hamstring and adductor magnus strain.

SUBSYSTEM OF THE MOVEMENT SYSTEM EMPHASIZED: Active subsystem

STAGE OF MOTOR CONTROL: Mobility.

MODE: Concentric and eccentric gluteus medius contractions.

POSTURE: Stomach lying with a pillow under the pelvis if indicated by the physical therapist. Legs should be in line with hips and slightly rotated outward.

MOVEMENT: First set intrinsic spinal muscles. Next perform an isometric contraction of the gluteus maximus. Slightly lift the leg into extension and abduction until lateral tilt is seen. Stop just short of lateral tilt of the pelvis. Hold at end range. Ensure the knee remains slightly rotated laterally.

SPECIAL CONSIDERATIONS: Keep the lumbopelvic region stable using the intrinsic spinal muscles. Hold slight hip lateral rotation throughout the range to avoid TFL muscle recruitment. Recruit the gluteus maximus and relax the hamstring muscles.

DOSAGE

Special Considerations

Anatomic: R gluteus medius, R hip joint

Physiologic: Length-associated changes in strength; stronger in the lengthened range than the shortened range

Learning Capability: May be difficult secondary to capsular restrictions. Ingrained muscle recruitment pattern of the TFL muscle and lateral trunk muscles from a long history of high-mileage running; may require high repetitions and significant feedback in early stages of learning

Repetitions/Sets: To form fatigue, pain, or 20 to 30 repetitions

Frequency: 6 to 7 days per week

Sequence: After quadruped rocking

Speed: Slowly

Environment: At home on a firm surface

Feedback: Initially in clinic with clinician providing tactile and verbal feedback. Begin with knowledge of performance for every repetition, then taper every couple repetitions with knowledge of results.

FUNCTIONAL MOVEMENT PATTERN TO REINFORCE GOAL OF EXERCISE: Ascending stairs, gait, and running.

RATIONALE FOR EXERCISE CHOICE: This exercise was chosen to improve motor control strategies and strength of gluteus medius, and gluteus maximus muscles. Lumbopelvic stability and IT band extensibility depends on proper recruitment of the gluteus medius muscle throughout the range. This method of neuromuscular reeducation and strengthening is necessary before returning to functional activities.

AT 3 WEEKS

ACTIVITY: Iliopsoas strengthening (see Self-Management 19-5, Level 2, in Chapter 19).

PURPOSE: Iliopsoas strengthening to improve muscle balance of hip flexor muscles.

RISK FACTORS: Watch for TFL substitution or lateral pelvic tilt.

SUBSYSTEM OF THE MOVEMENT SYSTEM EMPHASIZED: Active subsystem

STAGE OF MOTOR CONTROL: Mobility.

MODE: Resistive isometric iliopsoas contraction.

POSTURE: Sitting with unilateral hip flexion and slight hip lateral rotation.

MOVEMENT: First set intrinsic spinal muscles. The patient passively flexes the hip as far as possible while maintaining neutral lumbopelvic position. Next, the patient holds the position and provides gentle resistance to the hip in the direction of extension and slight lateral rotation. The contraction should be isometric.

SPECIAL CONSIDERATIONS: Hip medial rotation will recruit the dominant hip flexor muscle, TFL, over the iliopsoas contributing to further shortening of the IT band.

(continued)

DOSAGE

Special Considerations

Anatomic: R iliopsoas, R hip joint

Physiologic: Length-associated changes in strength; stronger in the lengthened range than the shortened range

Learning Capability: Very ingrained recruitment pattern from a long history of high-mileage running; may require high repetitions and significant feedback in early stages of learning

Repetitions/Sets: To form fatigue, pain, or 15 repetitions, up to three sets

Frequency: 3 to 4 days per week

Sequence: After quadruped rocking

Speed: Hold for 10 seconds

Environment: At home on a firm surface

Feedback: Initially in clinic with clinician providing tactile and verbal feedback. Begin with knowledge of performance for every repetition, then taper every three to four repetitions with knowledge of results.

FUNCTIONAL MOVEMENT PATTERN TO REINFORCE GOAL OF EXERCISE: Ascending stairs, gait, and running.

RATIONALE FOR EXERCISE CHOICE: This exercise was chosen to improve strength of iliopsoas muscle. This is the progression from isometric hold without resistance. Hip flexion without contributing to IT band shortening depends on proper recruitment of the iliopsoas muscle in the shortened range. Iliopsoas strengthening decreases TFL muscle dominance during dynamic activity and function.

ACTIVITY: Sidelying gluteus medius strengthening (see Self-Management 19-4, Level 4, in Chapter 19).

PURPOSE: Gluteus medius muscle strengthening in the shortened range.

RISK FACTORS: Medial hamstring and adductor magnus strain.

SUBSYSTEM OF THE MOVEMENT SYSTEM EMPHASIZED: Active

STAGE OF MOTOR CONTROL: Mobility/stability.

MODE: Concentric and eccentric gluteus medius contractions.

POSTURE: Sidelying against a wall with a small towel roll behind the superior gluteal. The towel roll ensures the hip slides up the wall in slight extension. Superior hip should be slightly laterally rotated.

MOVEMENT: First set intrinsic spinal muscles. Slide the leg up the wall, keeping the heel in contact with the wall to ensure hip extension, to end range. Stop before lateral pelvic tilt. Hold at end range. Be sure the hip stays laterally rotated.

SPECIAL CONSIDERATIONS: Keep the lumbopelvic region stable using the intrinsic spinal muscles to prevent lateral pelvic tilt. Hold slight hip lateral rotation and extension throughout the range to avoid TFL muscle recruitment.

DOSAGE

Special Considerations

Anatomic: R gluteus medius, R hip joint

Physiologic: Length-associated changes in strength; stronger in the lengthened range than the shortened range

Learning Capability: May be difficult secondary to capsular restrictions. Ingrained muscle recruitment pattern of the TFL muscle from a long history of high-mileage running; may require high repetitions and significant feedback in early stages of learning

Repetitions/Sets: To form fatigue, pain, or six to eight repetitions

Frequency: 3 to 4 days per week

Sequence: After iliopsoas strengthening

Speed: Slowly

Environment: At home on a firm surface

Feedback: Initially in clinic with clinician providing tactile and verbal feedback. Begin with knowledge of performance for every repetition, then taper every couple repetitions with knowledge of results.

FUNCTIONAL MOVEMENT PATTERN TO REINFORCE GOAL OF EXERCISE: Ascending stairs, gait, and running.

RATIONALE FOR EXERCISE CHOICE: This exercise was chosen to improve strength of the gluteus medius muscle. Lumbopelvic stability and IT band extensibility depends on proper recruitment of the gluteus medius muscle throughout the range. Open kinetic chain gluteus medius strengthening is necessary before transferring to dynamic activity and function.

ACTIVITY: Squats (see Self-Management 19-9 in Chapter 19).

PURPOSE: Strengthen hip girdle muscles and train independent movement between hips and spine in a functional context.

RISK FACTORS: Watch for symmetric loading between extremities.

SUBSYSTEM OF THE MOVEMENT SYSTEM EMPHASIZED: Active and neural subsystems

STAGE OF MOTOR CONTROL: Controlled mobility.

MODE: Concentric and eccentric hip girdle muscle contractions.

POSTURE: Standing with weight equally distributed between both feet, and pelvis and spine in neutral in front of a full-length mirror.

MOVEMENT: First set intrinsic spinal muscles. Slowly bend your hips and knees. Return to the start position by using quadriceps and gluteals.

SPECIAL CONSIDERATIONS: Knees should not flex beyond the length of the feet or medial to the second toes.

More emphasis should be placed on gluteal muscles versus hamstring muscles. Keep the lumbopelvic region stable and bend through the hips with equal loading and avoidance of lateral pelvic tilt.

DOSAGE

Special Considerations

Anatomic: Bilateral hip girdle muscles, bilateral hip joints

Physiologic: Length-associated changes in eccentric and concentric strength and asymmetric mobility in hips

Learning Capability: Very ingrained movement pattern from a long history of high-mileage running; may require high repetitions and significant feedback in early stages of learning

Repetitions/Sets: To form fatigue, pain, or 20 to 30 repetitions

Frequency: 6 to 7 days per week

Sequence: After gluteus medius strengthening

Speed: Slowly

Environment: At home with or without a chair, depending on strength

Feedback: Initially in clinic with clinician providing tactile and verbal feedback and mirror providing visual feedback. Taper to continued use of mirror, with knowledge of results of verbal feedback after every three to four repetitions. Withdraw mirror and verbally provide knowledge of results every three to four repetitions.

FUNCTIONAL MOVEMENT PATTERN TO REINFORCE GOAL OF EXERCISE: Ascending stairs, sit to stand, walking, and running.

RATIONALE FOR EXERCISE CHOICE: This functional exercise was chosen to improve strength of hip girdle muscles and hip joint mobility. Improved hip joint mobility and force-generating capability of the gluteus maximus enables increased hip flexion and decreased knee flexion during squatting activities. Squats with shared forces at the hip and knee decrease excessive forces at the low back and knee.

ACTIVITY: Step-ups (see Self-Management 19-3 in Chapter 19)

PURPOSE: Incorporate proper total-body movements in a functional context.

RISK FACTORS: Avoid hip hike patterns and hamstring dominance.

SUBSYSTEM OF THE MOVEMENT SYSTEM EMPHASIZED: Active and neural subsystems

STAGE OF MOTOR CONTROL: Controlled mobility.

MODE: Concentric and eccentric hip girdle muscle contractions.

POSTURE: Standing in front of a 6-in step in front of a mirror.

MOVEMENT: First set intrinsic spinal muscles. Lift the R leg onto the step. Step up.

SPECIAL CONSIDERATIONS: Be sure the patient does not hike his R hip during the hip flexion phase or perform a Trendelenburg pattern during hip extension phase. The pelvis must remain level and stable throughout the entire exercise to adequately recruit iliopsoas during hip flexion and prepare to use gluteus maximus and gluteus medius muscles in their proper length–tension properties during hip extension.

DOSAGE

Special Considerations

Anatomic: R hamstring and adductor

Physiologic: Chronic moderate strain

Learning Capability: Very ingrained movement pattern from a long history of high-mileage running; may require high repetitions and significant feedback in early stages of learning

Repetitions/Sets: To form fatigue as evidenced by hip hike, pain, or 20 to 30 repetitions, up to three sets

Frequency: 6 to 7 days per week

Sequence: Perform after specific exercises for psoas and gluteus medius muscle performance and squats.

Speed: Slow progressed to functional speed

Environment: At home in front of a mirror

Feedback: Initially in clinic with clinician providing tactile and verbal feedback and mirror providing visual feedback. Taper to continued use of mirror, with knowledge of results of verbal feedback after every three to four repetitions. Withdraw mirror and verbally provide knowledge of results every three to four repetitions. Progress toward skill.

FUNCTIONAL MOVEMENT PATTERN TO REINFORCE GOAL OF EXERCISE: Ascending stairs, walking, running.

RATIONALE FOR EXERCISE CHOICE: This functional exercise was chosen to replace the faulty movement with one that is correct. Faulty hip hiking does not emphasize hip flexion and efficient recruitment of the gluteus maximus and medius muscles. Trendelenburg pattern does not emphasize lumbopelvic stability. Correct step-up pattern encourages gluteus maximus and quadriceps recruitment over hamstring and gluteus medius recruitment over TFL or adductors.

COMPLETE INTERVENTION—UPPER QUADRANT

For Case Study No. 10

The following is a comprehensive exercise program for upper quadrant intervention for Peter. It is prescribed in week 3 post initial evaluation.

AT WEEK 3

ACTIVITY: Sidelying lateral rotator and posterior capsule stretch (see Self-Management 25-4 in Chapter 25)

PURPOSE: To lengthen lateral rotators of the shoulder.

RISK FACTORS: Ensure sufficient posterior glide of the humerus on the glenoid to prevent overstretching anterior capsule; i.e., verify normal accessory motion prior to self-stretching

SUBSYSTEM OF THE MOVEMENT SYSTEM EMPHASIZED: Passive subsystem

STAGE OF MOTOR CONTROL: Mobility.

MODE: Contract-relax of the shoulder lateral rotators.

POSTURE: Sidelying with bottom arm elevated to 90 degrees and elbow flexed to 90 degrees and the shoulder starting in neutral rotation.

MOVEMENT: Shoulder joint should internally rotate allowing your forearm to move toward your feet and the floor. At that point, lightly press up into the resistance of the other hand and hold for 6 to 10 seconds. Relax and gently push the bottom forearm further toward your feet and the floor. Repeat three to four times.

SPECIAL CONSIDERATIONS: Scapula should be entirely on your back rather than under your body to target the lateral rotators. If the scapula slips under your body, scapular adductors will stretch instead. Avoid anterior shoulder pain.

DOSAGE

Special Considerations

Anatomic: R shoulder lateral rotators.

Physiologic: Short shoulder lateral rotators. Length-associated changes in strength; stronger in the shortened range than the lengthened range.

Learning Capability: Good with specific verbal and visual instructions.

Repetitions/Sets: Three to four repetitions; two sets

Frequency: Three to five times per day, 7 days per week

Sequence: Begin with this stretch followed by the rest of the exercises.

Speed: Hold for 6 to 10 seconds

Environment: At home on a firm surface

Feedback: Initially in clinic with clinician providing verbal, visual, and tactile feedback. Begin with knowledge of performance for every repetition, then taper every other repetition with knowledge of results.

FUNCTIONAL MOVEMENT PATTERN TO REINFORCE GOAL OF EXERCISE: Reaching overhead without discomfort or unstable feeling.

RATIONALE FOR EXERCISE CHOICE: This stretch was chosen to improve the length of the shoulder lateral rotators. Sufficient shoulder medial rotation is needed for optimal GH congruency and to prevent anterior displacement of the humeral head.

ACTIVITY: Supine GH lateral and medial rotation.

PURPOSE: Develop motor control strategy of the rotator cuff muscles for ideal path of instant center of rotation (PICR) of the GH joint.

RISK FACTORS: Chronic subscapularis strain and supraspinatus tendinopathy.

SUBSYSTEM OF THE MOVEMENT SYSTEM EMPHASIZED: neural and passive subsystems

STAGE OF MOTOR CONTROL: Mobility.

MODE: Concentric and eccentric rotator cuff contractions.

POSTURE: Lying supine with arm abducted to 90 degrees and elbow flexed to 90 degrees on an even, stable surface. R scapular spine should lie at the level of the second vertebra.

MOVEMENT: Slowly rotate arm so that your forearm moves back toward your head, then in the opposite direction so the forearm moves forward.

SPECIAL CONSIDERATIONS: The arm should move independently from the scapula spinning in its socket. The scapula should not displace forward or depress nor should the humeral head displace forward from the socket.

DOSAGE

Special Considerations

Anatomic: R medial and lateral rotator cuff muscles, right GH joint

Physiologic: Chronic moderate strain and tendinitis, questionable instability of the right GH joint

Learning Capability: Existing motor programs may accentuate instability; may require high repetitions and significant feedback in early stages of learning

Repetitions/Sets: To form fatigue, pain, or 20 to 30 repetitions, up to three sets

Frequency: 6 to 7 days per week

Sequence: Begin with this exercise followed by the wall slide with subscapularis bias and muscle performance exercise of the serratus anterior.

Speed: Slowly for good-quality movement.

Environment: At home on the floor or firm bed.

Feedback: Initially in clinic with clinician providing tactile and verbal feedback. Begin with knowledge of performance for every repetition, then taper every three to four repetitions with knowledge of results.

FUNCTIONAL MOVEMENT PATTERN TO REINFORCE GOAL OF EXERCISE: Reaching behind the back without discomfort or unstable feeling.

RATIONALE FOR EXERCISE CHOICE: This exercise was chosen to improve motor control strategies of shoulder medial and lateral rotators. Independent movement of the GH joint with ideal PICR is the goal rather than faulty compensatory scapulothoracic movement.

ACTIVITY: R arm wall slide with medial rotation bias (see Fig. 25-4B in Chapter 25)

PURPOSE: Develop motor control strategy to encourage rotator cuff activation, specifically the subscapularis, as opposed to pectoralis major, latissimus dorsi, and teres major muscles for ideal PICR of the GH joint.

RISK FACTORS: Chronic subscapularis strain.

SUBSYSTEM OF THE MOVEMENT SYSTEM EMPHASIZED: Neural and active subsystems

STAGE OF MOTOR CONTROL: Controlled mobility.

MODE: Isometric rotator cuff activation with subscapularis bias.

POSTURE: Standing with palm of the hand against the door frame. R scapular spine should lie at the level of the second vertebra.

MOVEMENT: Slide the hand upward and downward while maintaining mild pressure into medial rotation against the door frame.

SPECIAL CONSIDERATIONS: More than mild pressure applied into medial rotation against the door frame will recruit pectoralis major, latissimus dorsi, and teres major muscles instead of subscapularis causing anterior translation of the humeral head.

DOSAGE

Special Considerations

Anatomic: R subscapularis, right GH joint

Physiologic: Chronic moderate strain and tendinitis, questionable instability of the right GH joint

Learning Capability: Very ingrained movement pattern from a long history of high-mileage running; may require high repetitions and significant feedback in early stages of learning

Repetitions/Sets: To form fatigue, pain, or 20 to 30 repetitions, up to three sets

Frequency: 6 to 7 days per week

Sequence: After GH rotation but before muscle performance exercise of the serratus anterior.

Speed: Slowly for good-quality movement.

Environment: At home in a door frame.

Feedback: Initially in clinic with clinician providing tactile and verbal feedback. Begin with knowledge of performance for every repetition, then taper every three to four repetitions with knowledge of results.

FUNCTIONAL MOVEMENT PATTERN TO REINFORCE GOAL OF EXERCISE: Reaching overhead and behind the back without discomfort or unstable feeling.

RATIONALE FOR EXERCISE CHOICE: This exercise was chosen to improve motor control strategies of shoulder medial rotators. Proper recruitment of the subscapularis muscle over other medial rotators provides dynamic anterior stability of the GH joint during dynamic activity. It is important that the subscapularis muscle is trained because of its anterior insertion close to the axis of rotation.

ACTIVITY: Supine serratus anterior isometric (see Self-Management 25-3, Level I in Chapter 25)

PURPOSE: Serratus anterior neuromuscular education to promote recruitment in the shortened range with scapular upward rotation.

RISK FACTORS: Impingement of rotator cuff tendons.

SUBSYSTEM OF THE MOVEMENT SYSTEM EMPHASIZED: Neural and active subsystems

STAGE OF MOTOR CONTROL: Mobility.

MODE: Isometric serratus anterior contraction.

POSTURE: Supine with arm elevated resting on pillows placed above your head.

MOVEMENT: Lightly press thumb into pillows engaging the serratus anterior muscle.

SPECIAL CONSIDERATIONS: More than mild pressure applied into the pillows will recruit muscles of the GH joint over the serratus anterior causing anterior translation of the humeral head.

DOSAGE

Special Considerations

Anatomic: R serratus anterior, R scapulothoracic joint

Physiologic: Length-associated changes in strength; stronger in the lengthened range than the shortened range

Learning Capability: May be difficult secondary to painful arc. May require a less than desirable starting point in the range

Repetitions/Sets: To form fatigue, pain, or 20 to 30 repetitions, up to three sets

Frequency: 6 to 7 days per week

(continued)

Sequence: After wall slides and GH rotation

Speed: Hold for 10 seconds

Environment: At home on a firm surface

Feedback: Initially in clinic with clinician providing tactile and verbal feedback. Begin with knowledge of performance for every repetition, then taper every three to four repetitions with knowledge of results.

FUNCTIONAL MOVEMENT PATTERN TO REINFORCE GOAL OF EXERCISE: Reaching overhead without discomfort or unstable feeling.

RATIONALE FOR EXERCISE CHOICE: This exercise was chosen to improve motor control strategies of shoulder elevator muscles. Sufficient scapular upward rotation depends on proper recruitment of the serratus anterior muscle in the shortened range with arm elevation. This method of neuromuscular reeducation is necessary before translating to dynamic activity and function.

AT 3 WEEKS

ACTIVITY: Stomach lying middle and lower trapezius isometric

PURPOSE: Middle and lower trapezius neuromuscular education to hold the scapula in a position of upward rotation

RISK FACTORS: Impingement of rotator cuff tendons and anterior displacement of the humeral head

SUBSYSTEM OF THE MOVEMENT SYSTEM EMPHASIZED: Neural subsystem

STAGE OF MOTOR CONTROL: Stability.

MODE: Isometric middle and lower trapezius contraction (see Self-Management 25-2, Level I in Chapter 25)

POSTURE: Stomach lying with both hands resting on the head. Good cervical and scapular alignment.

MOVEMENT: Barely lift your elbows keeping neck and upper trapezius muscles relaxed. Contract middle and lower trapezius muscles.

SPECIAL CONSIDERATIONS: Lifting elbows excessively will recruit posterior muscles of the GH joint and rhomboids causing anterior translation of the humeral head and scapular adduction, respectively.

DOSAGE

Special Considerations

Anatomic: Bilaterally middle and lower trapezius muscles, scapulothoracic joint

Physiologic: Weak middle and lower trapezius muscles, dominant rhomboids

Learning Capability: May be difficult secondary to painful arc.

Repetitions/Sets: To form fatigue, pain, or 20 to 30 repetitions, up to three sets

Frequency: 6 to 7 days per week

Sequence: Begin with this exercise followed by stomach lying shoulder rotation and sidelying serratus anterior exercises.

Speed: Hold for 10 seconds

Environment: At home on a firm surface

Feedback: Initially in clinic with clinician providing tactile and verbal feedback. Begin with knowledge of performance for every repetition, then taper every three to four repetitions with knowledge of results.

FUNCTIONAL MOVEMENT PATTERN TO REINFORCE GOAL OF EXERCISE: Reaching overhead without discomfort or unstable feeling.

RATIONALE FOR EXERCISE CHOICE: This exercise was chosen to improve motor control strategies of scapular stabilizing muscles. Scapular upward rotation about a stable PICR depends on recruitment of the middle and lower trapezius muscles with arm elevation. This method of neuromuscular reeducation is necessary before translating to dynamic activity and function.

ACTIVITY: Prone GH lateral and medial rotation with 1-lb weight (see Self-Management 25-1 in Chapter 25)

PURPOSE: Develop motor control strategy of the rotator cuff muscles and scapulothoracic muscles for ideal PICR of the GH joint and scapula.

RISK FACTORS: Chronic subscapularis strain and tendinitis.

SUBSYSTEM OF THE MOVEMENT SYSTEM EMPHASIZED: Neural and active subsystems

STAGE OF MOTOR CONTROL: Controlled mobility

MODE: Concentric and eccentric rotator cuff contractions. Isometric contractions of the middle and lower trapezius muscles.

POSTURE: Lying prone with arm abducted to 90 degrees and elbow flexed to 90 degrees on an even, stable surface. A towel roll should be placed under the anterior shoulder joint.

MOVEMENT: Slowly rotate arm so that your forearm moves up toward your head, then in the opposite direction so the forearm moves back toward your feet.

SPECIAL CONSIDERATIONS: The arm should move independent from the scapula spinning in its socket. The scapula should not displace forward nor should the humeral head displace forward from the socket.

DOSAGE

Special Considerations

Anatomic: R medial and lateral rotator cuff muscles, right GH joint, R middle and lower trapezius muscles, R scapula.

Physiologic: Chronic moderate strain and tendinitis, questionable instability of the right GH joint

Learning Capability: Very ingrained movement pattern from a long history of high-mileage running; may require high repetitions

Repetitions/Sets: To form fatigue, pain, or six to eight repetitions with fatigue

Frequency: 3 to 4 days per week

Sequence: Begin with this exercise followed by the wall slide with subscapularis bias and muscle performance exercise of the serratus anterior.

Speed: Slowly for good-quality movement.

Environment: At home on the floor or firm bed.

Feedback: Initially in clinic with clinician providing tactile and verbal feedback. Begin with knowledge of performance for every repetition, then taper every couple of repetitions with knowledge of results.

FUNCTIONAL MOVEMENT PATTERN TO REINFORCE GOAL OF EXERCISE: Reaching behind the back without discomfort or unstable feeling.

RATIONALE FOR EXERCISE CHOICE: This exercise was chosen to improve motor control strategies of scapular stabilizers and shoulder medial and lateral rotators. Independent movement of the GH joint with ideal PICR and a stable scapula are the goals.

ACTIVITY: Sidelying serratus anterior dynamic contractions with resistive band (see Self-Management 25-3, Level II in Chapter 25)

PURPOSE: Serratus anterior muscle strengthening throughout the range with scapular upward rotation.

RISK FACTORS: Impingement of rotator cuff tendons.

SUBSYSTEM OF THE MOVEMENT SYSTEM EMPHASIZED: Neural and active subsystems

STAGE OF MOTOR CONTROL: Controlled mobility.

MODE: Concentric and eccentric serratus anterior contractions.

POSTURE: Sidelying with arm rested on pillows placed in front of your head and shoulders. Resistive band is attached on the upper foot and the other end grasped in the resting hand.

MOVEMENT: Slide your arm upward toward your head, keeping it in contact with the pillows. On the return, slowly lower the arm back down to the starting position against the resistance of the band.

SPECIAL CONSIDERATIONS: Keep the scapula on your back upwardly rotating about a stable PICR.

DOSAGE

Special Considerations

Anatomic: R serratus anterior, R scapulothoracic joint.

Physiologic: Faulty eccentric motor control of serratus anterior muscle.

Learning Capability: May be difficult secondary to painful arc. May require a less than desirable starting point in the range.

Repetitions/Sets: To form fatigue, pain, or six to eight repetitions.

Frequency: 3 to 4 days per week.

Sequence: After wall slides and GH rotation.

Speed: Slowly.

Environment: At home on a firm surface.

Feedback: Initially in clinic with clinician providing tactile and verbal feedback. Begin with knowledge of performance for every repetition, then taper every couple of repetitions with knowledge of results.

FUNCTIONAL MOVEMENT PATTERN TO REINFORCE GOAL OF EXERCISE: Reaching overhead and behind the back without discomfort or unstable feeling.

RATIONALE FOR EXERCISE CHOICE: This exercise was chosen to improve motor control strategies and strength of shoulder elevator muscles. Sufficient scapular upward rotation depends on proper recruitment of the serratus anterior muscle throughout the range with arm elevation. This method of neuromuscular reeducation and strengthening is necessary before returning to functional activities.

CASE STUDY NO. 11

Mr. Lawn, a 67-year-old man, had a right (R) total hip replacement (THR) 4 years ago. He also has left (L) hip degenerative joint disease (DJD). For the last 4 months he has been noticing increasing L hip pain and is beginning to have pain in the R hip as well if he attempts to play more than nine holes of golf. He states that 18 holes is usual, and he pulls his own cart. Recent muddy conditions seem to have made symptoms worse. His main concern is that R low back pain will be triggered by R hip pain, as it has been in the past. During the last episode of low back pain, he had to sleep sitting up in his chair, because it was the only place he could get comfortable. Mr. Lawn lives with his wife, who is in the early stages of Alzheimer disease, and his golf games are his main social contact with friends. He is otherwise healthy and does all the driving, shopping, and housework.

EXAMINATION

Pain: L hip at rest 2/10, after 18 holes of golf 7/10; R hip at rest 1/10, after golf 3/10; R low back at rest 0/10, after golf 1/10

Posture: In standing: bilateral (B) supinated feet; marked B tibial bowing; B femoral internal rotation; high L iliac crest; anterior tilted pelvis; mild hip flexion; supine apparent short R leg; R iliac crest and ischial tuberosity high compared with L

Gait: Marked B trunk sidebend to side of stance leg, decreased hip and knee flexion; slight circumduction B; decreased pronation B feet; R stance time decreased compared with L

Active Range of Motion (open chain):

	R hip	L hip
Extension/flexion	5 to 110 degrees	5 to 115 degrees (pain)
Internal/external rotation	20 to 25 degrees	20 to 15 degrees (pain)
Abduction	30 degrees	20 degrees
Knee flexion/extension	2 to 125 B degrees	
Lumbar flexion	Hands 4 in below knees	
Lumbar extension	25% normal range (pain)	

Accessory Motion: L Hip—hypomobile in distal glide, capsular tightness in internal and external passive rotation. Lumbar spine—extension and R sidebend with overpressure restricted and painful compared with L

Palpation: B rectus femoris, iliopsoas, hip adductors, and R quadratus lumborum dense/tender

Strength Testing: Rectus femoris (B) 5/5; iliopsoas (R) 4−/5, (L) 5/5; gluteus maximus (R) 4−/5, (L) 4/5; gluteus medius (R) 4−/5, (L) 3+/5; quadriceps (B) 5/5; gastroc/soleus (B) 5/5; abdominals 4−/5 by leg lowering test

Balance: R single-leg stance time: 5 seconds; L single-leg stance time: 12 seconds

Neurologic Signs: Normal for L3–S1 light touch, deep tendon reflexes, and key muscle strength.

Active Movement Testing (open chain): Pain is elicited with L hip flexion. Internal rotation and abduction at end of available range in each motion. Standing lumbar sidebend and R rotation is painful. Single-leg stance (R) causes R hip pain, and closed chain testing was deferred because of initial apprehension and balance deficits.

Functional Outcome Score: Hip Harris score (0 to 100) (Accessed February 3, 2015, from http://www.orthopaedicscore.com/scorepages/harris_hip_score.html): 70 (moderate activity limitation), Modified Oswestry Back Index score: 30 (moderate activity limitation); Mini- BESTest (0 to 28) 25 (low fall risk)

EVALUATION: DJD-related hip muscle strength and range deficits leading to gait and pelvic asymmetry and hip joint pain and to R L5/S1 compression and irritation.

Impairment

- B hip range of motion restriction
- B hip joint muscle weakness
- Abdominal muscle overstretch
- Frontal plane pelvic asymmetry
- Sagittal plane lumbopelvic asymmetry
- Decreased standing balance
- Gait abnormality
- Unable to maintain neutral pelvis

Activity Limitation

- Pain limits walk endurance

Participation Restriction

- Unable to play golf
- Unable to socialize and restore self mentally and emotionally for wife's care

CASE STUDY NO. 11 (*continued*)

DIAGNOSIS: Condition after R hip THR; L hip DJD with muscle imbalance leading to probable R L5–S1 facet compression irritation

PROGNOSIS

Short-Term Goals (14 to 21 days)

1. Regain sagittal and frontal plane alignment in standing and walking
2. Regain at least 4/5 strength in all hip and abdominal muscle groups
3. Equalize L hip range of motion to that of R hip
4. Able to balance 30 seconds in single-leg stance (B)
5. Improve Hip Harris Score to 80 (mild activity limitation)
6. Improve Oswestry Score to 20 (mild activity limitation)

Long-Term Goals (4 to 6 weeks)

1. Ambulate with normal gait pattern
2. Walk 18 holes of golf, pulling cart, without pain in hips or low back
3. Improve Hip Harris Score to 90 (no activity limitation)
4. Improve Oswestry Score to 5 (no activity limitation)

CASE STUDY NO. 12

Harriet is a retired 70-year-old female who presented with burning at her perineum and some mixed urge and urinary incontinence in the last 1.5 to 2 years. She has a long history of mid-back pain since a motor vehicle accident 4 years ago. Since the accident, she wears a brace for prolonged sitting that puts her in a flexed position. Her primary complaint is that she has constant burning pain at her perineum, worsened with direct contact over the region, limiting ability to wear underwear, wear pants, and sit for >30 minutes. She has managed by lying on her back and wearing skirts without underwear. She enjoys primarily sedentary tasks such as reading and knitting. She volunteers weekly as a tutor and travels to visit her grandchildren about every other weekend (2-hour car ride) which flares up symptoms.

EXAMINATION

Observation: Forward head, moderate to severely rounded shoulders, moderate kyphosis of thoracic spine

Gait: Pelvis demonstrates a mild bilateral Trendelenburg, mild hip ER on R, mild hip flexion and forward head with scapular protraction, moderate. Foot mechanics appear unremarkable.

Range of Motion:

Cervical Spine: Flexion 25, extension 45, rotation 45 to R and L; Thoracic Spine: seated rotation 45 R and 60 L, pain at mid-back at end range

Shoulder AROM: Flexion 0 to 135 R, 0 to 150 L, abduction 0 to 150 R and 0 to 160 L

Hip flexion: Full range noted, extension limited to −10 bilaterally, internal rotation: 25 R, 35 L, external rotation: 65 R, 55 L

Neurologic screen: Negative for lower and upper extremity normal myotome, dermatome, and reflexes

Upper Limb Neural Tension: + ulnar and median nerve bilaterally

Functional and Special Tests

Pelvis: No obvious asymmetry in alignment and sacroiliac joint screening negative for hyper and hypomobility

Scour: Negative bilaterally

Sacroiliac Joint Shearing: Negative bilaterally

Sacroiliac Joint Compression: Negative bilaterally

Muscle Length: Hamstrings 0 to 80 degrees bilaterally from 90/90 test position, Gluteus maximus, quadriceps all negative bilaterally; lengthened rhomboids and mid-lower trapezius; shortened pectoralis major

Pelvic Floor Examination:

Palpation: External, nontender, constant burning at vulvar region, moderate activity of pelvic floor superficial muscles

Reflexes: Intact for bulbocavernosus and anal wink

Sharp/dull discrimination: Intact

Internal Pelvic Examination:

Internal exam: Performed vaginally, unable to assess rectally due to external anal sphincter very tight, tender

Tissue quality: Increased tension with right perineal muscles

Palpation: Tender at deep pelvic floor layer R > L, also triggers mid-back pain

MMT: Gluteus medius: 3+/5 R and 4−/5, gluteus maximus 4/5 bilaterally

Performance Score of Pelvic Floor Musculature Using the "PERF" Scale

Power: 2/5 (0 = no contraction; 1 = trace flicker; 2 = poor, contraction with no lift; 3 = fair, palpable contraction and lift from posterior to anterior; 4 = good, strong contraction and lift with compression from ant, post, and side walls; 5 = strong, stronger lift and compression with inferior deflection from finger)

Endurance: Patient able to hold pelvic floor contraction for 5 seconds (10 seconds = strong performance; 2 seconds = fair performance)

CASE STUDY NO. 12 (*continued*)

Repetitions: She completes four repetitions of 5-second holds prior to fatigue

Fast Twitch: Able to perform three quick flick repetitions in 10 seconds, incomplete relaxation

Additional Findings Related to Pelvic Floor

Elevation: Absent

Cocontraction of abdominals: Present, excessive

Timing: Absent

Abdominal, adductor and gluteal muscle substitution pattern is evident.

Cystocele is present; Rectocele is absent.

Pelvic floor descent, Valsalva: unable

Paradoxical relaxation: Present

EVALUATION: Chronic pelvic pain possibly related to chronic postural dysfunction and sympathetic nervous system from a hypomobility of the thoracic spine.

Impairment

- Hypomobility of thoracic spine
- Hypersensitivity of perineum, reduced tolerance to contact
- Faulty postural mechanics: tight pecs, lengthened mid-back muscles

Activity Limitations

- Unable to wear underwear or pants
- Unable to sit for longer periods of time

Participation Restriction

- Unable to tolerate internal exam for gynecologic health maintenance
- Unable to sit in waiting room for >30 minutes for medical appointments
- Unable to drive or ride in car for 2 hours which would take to visit family members
- Unable to sit for volunteer work as tutor

DIAGNOSIS: Vulvodynia and thoracic back pain

PROGNOSIS

Short-Term Goals (2 to 3 months)

1. Management of urge/stress incontinence
2. Improve pelvic floor coordination

Long-Term Goals (4 to 6 months)

1. Reduced pelvic pain to be able to wear pants and underwear
2. Reduced pelvic pain to be able to tolerate sitting 1 hour for tutoring sessions
3. Management of back pain to be able to put away dishes
4. Management of back pain to tolerate prolonged sitting 2 hours to be able to visit her family

APPENDIX 1

Red Flags: Recognizing Signs and Symptoms

DAVID MUSNICK* • CARRIE M. HALL

Because therapists often have consistent daily or weekly contact with patients, they may be the health professionals to recognize serious neuromusculoskeletal pathology or systemic disease requiring medical referral. A thorough history, carefully conducted interview, systems review, and screening examinations must be completed during the initial evaluation. Any red flags—signs or symptoms that signal pathologic conditions—may indicate serious somatic or visceral disease or disorders that are beyond the scope of physical therapy intervention. The information outlined in this appendix delineates signs and symptoms of somatic and visceral origin.

Physical therapists often perform interventions, such as therapeutic exercise, to alleviate pain. The physical therapist must be sure that the pain is of neuromusculoskeletal origin and is within the scope of physical therapy practice. A patient with pain that may be caused by serious pathology or referred from a visceral source should be immediately referred to a medical physician for further testing.

Visceral structures can be a source of referred pain to musculoskeletal regions, particularly to the shoulder, back, chest, hip, or groin. The mechanism by which visceral structures refer pain to musculoskeletal regions is twofold:

1. Visceral afferents that supply internal organs transmit impulses to the dorsal horn in which somatic and visceral pain fibers share second-order neurons. Impulses from visceral nerve endings arrive at similar interneuron pools as impulses from somatic origin. Visceral pain may then be felt in somatic segments and skin areas with which it shares neurons in the dorsal horn. This pattern is called referred visceral sensation. Broader pain referral from visceral structures can occur with multiple-segment overlap. Referred visceral sensation may coexist with reflex muscle spasm and vasomotor changes.
2. Visceral structures in the thoracic and abdominal cavities have free nerve endings in loose connective tissue in epithelial and serous linings and in blood vessels. Neural afferent information is transmitted along small, unmyelinated, type C nerve fibers within sympathetic and parasympathetic nerves of the autonomic nervous system. The pain is usually not well localized by the patient and is usually described as vague, deep, and aching.

Signs and symptoms associated with referred visceral pain are the most common red flags signaling the need for further evaluation. The cause of this pain is related to the pathologic function of the primary visceral structure involved. Viscera may refer pain caused by tissue ischemia, obstruction, mechanical distention, or inflammation. **Tables A-1** and **A-2** describe the sources and characteristics of somatic and visceral pain. **Tables A-3** and **A-4** review the signs and symptoms associated with referred visceral pain. Whenever a patient reports symptoms described in Tables A-3 and A-4, screening for systemic disease is appropriate. The decision to screen for systemic disease may be even more critical if the patient is older than 45 years of age and the symptoms have an insidious onset.

Table A-5 describes systemic, visceral, or nonmechanical causes of regional musculoskeletal pain. The physical therapist should be aware of constant, severe pain with increases in intensity, nonmechanical patterns, or the symptoms or signs described in Table A-4 in association with regional musculoskeletal pain. Referral of the patient to a physician is indicated when pain in a musculoskeletal region is accompanied by symptoms and signs indicating systemic or nonmechanical disease. Some types of referred visceral pain are made worse with mechanical stress. Mechanical exacerbation on examination is not 100% specific and cannot alone be used for diagnosing mechanical problems.

Female patients, persons older than 50 years of age, and children may present with symptoms about which the practitioner should be aware:

- Female patients with new-onset thoracolumbar, lumbosacral, or sacroiliac pain should be screened through a renal and reproductive history and lumbar scanning examination. Prompt medical screening is indicated if the person has fever, costovertebral angle tenderness, urinary symptoms, pelvic or suprapubic pain or tenderness, tachycardia, orthostatic changes, or an unclear diagnosis. Renal and reproductive organ disease can cause significant morbidity if not treated quickly.
- Malignant disease should be suspected in patients older than 50 years of age who have constant back pain that is increased with recumbency, history of primary tumor, pathologic fractures, night pain, or multiple painful areas in the spine. The axial skeleton is involved more commonly than the appendicular

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TABLE A-1

Sources and Characteristics of Somatic and Visceral Pain

Somatic Sources

Superficial Somatic Cutaneous Pain

- Localized but may refer within 6–12 inches
- Aching
- Burning
- Throbbing (e.g., abscesses)
- Neck, hip, or elbow pain with reactive lymph nodes
- Reactive lymph glands are aggravated by pressure or stretching

Deep Somatic Pain[a]

Muscles

- Localized or may be in referred patterns
- Increases with direct pressure on a tender area or site of lesion, locally or in a referral pattern

Joints

- Deep aching that is vague within the area (more common with peripheral joints) and a referred pattern that is felt more distally from the area (especially spinal joints)
- May decrease with rest or when stressful action has stopped
- May increase with activity
- Increases with stress testing or palpation

Ligaments

- Deep aching in the region of the ligament but may also be perceived distally
- Increases with stress testing or palpation

Neurologic Pain

- Characteristic pain referral patterns based on the site of the lesion
- May be associated with bone pain if the origin of neurologic compression is bone

Bone Pain

- Perceived close to the bone (see Table A-2)
- Constant and not relieved by rest
- May be worse with walking, jumping, or other impact
- If a tumor is growing in a bone the pain will be gradually increasing and may be worse at night when the patient is trying to sleep

Visceral Sources

- Vague pain
- Deep pain
- Aching pain
- Boring pain
- Tearing pain
- If a hollow organ is involved, pain may be more colicky (i.e., crescendo and decrescendo)

[a]Pain may originate in muscles, ligaments, joints, periosteum, vessels, dura, and fascia.

skeleton, with the lumbar and thoracic spine affected similarly (incidence of approximately 45% to 50%). Cord compression signs require immediate referral to a physician.

- Back pain is rare in patients younger than 16 years of age, especially in nongymnasts and in patients without trauma. Pediatric patients with low back pain and without history of trauma or overuse should be screened by a medical practitioner.
- Pediatric patients with hip pathology may complain of knee or hip pain or a vague pain with walking. Any pediatric patient seen for recent onset, undiagnosed limping should be evaluated with a medical history and scan of the lumbar spine, hip, knee, and lower extremity (including temperature). Patients with these complaints should be seen promptly by a medical practitioner and have an x-ray examination to evaluate the hip, if indicated.

TABLE A-2

Causes of Bone Pain and Associated Signs and Symptoms

CAUSES	ASSOCIATED CONDITIONS AND SYMPTOMS
Stress and compression fractures	Overuse Osteoporosis Evaluate for menstrual and eating disorders in young females
Avascular necrosis (wrist, femoral head, shoulders, feet)	Corticosteroid use Trauma
Osteomyelitis	Fever or other source of infection
Hematologic disorders of the bone marrow	Fatigue Multiple areas of bone pain, especially in the spine and pelvis
Paget disease	Cranial neuropathies Leg deformities Warm bones on examination
Benign tumor	Scoliosis if in the spine, especially in a child
Cancer (primary or metastatic)	Symptoms of primary cancer Fatigue Pain of bone origin in more than one spine site; a spine site combined with a rib or long bone site may be metastatic cancer and should be referred for evaluation

TABLE A-3

Characteristics of Systemic Symptoms

DATA OBTAINED FROM THE HISTORY	CONSTITUTIONAL SYMPTOMS
■ Insidious onset or no known cause (or both)	■ Fever
■ Pattern of presentation: gradual, progressive, cyclical	■ Chills
■ Constant	■ Malaise
■ Intense	■ Fatigue
■ Bilateral	■ Night sweats
■ Unrelieved by rest or change of position	■ Gastrointestinal symptoms
■ Night pain	■ Skin rash
■ History of infection	■ Weight loss
■ Migratory arthralgias	■ Dyspnea (i.e., shortness of breath)
	■ Diaphoresis at rest or with minimal exertion

TABLE A-4

Visceral Symptoms and Signs Categorized by Origin

Infection
- Fever
- Chills
- Malaise
- Fatigue
- Night sweats
- Red rash
- Swelling
- Purulence
- Constant pain
- Painful, enlarged lymph nodes
- Superficial palpation or percussion tenderness
- Root or cord compression by space-occupying lesion in spine

Pulmonary
- Cough
- Sputum
- Wheezing
- Shortness of breath
- Chest pain
- Pain worsened by deep inspiration
- Hemoptysis (i.e., coughing up blood)
- Decreased aerobic exercise capacity

Cardiac
- Arrhythmia (fast >120, slow <40)
- Pauses
- Irregular pulse
- Chest, jaw, scapular, or left arm pain
- High or low blood pressure (>180 or <85)
- Dizziness
- Syncope (i.e., fainting)
- Bilateral leg and foot swelling
- Shortness of breath

Vascular
- Low-amplitude pulse
- Coldness
- Paleness
- Swelling
- Constant pain
- Tearing or boring pain
- Color change

Gastrointestinal
- Nausea
- Vomiting
- Bloating
- Weight loss
- Loss of appetite
- Change in stools
- Bloody stools
- Diarrhea
- Absence of bowel movement
- Abdominal pain
- Yellow eyes or skin
- Food may help or aggravate

Renal
- Costovertebral angle tenderness
- Hematuria (i.e., red urine)
- Painful or frequent urination

Endocrine
- Energy or temperature changes
- Urinary volume change
- Possible bone pain

Neoplastic
- Constant or night pain
- Age >45 y
- Myelopathy signs (e.g., spinal cord compression)
- Previous primary tumor
- Pathologic fracture
- Generalized weakness
- Pain in multiple bony locations

Gynecologic
- Pelvic or low back pain
- Menstrual abnormalities
- Pelvic mass

Rheumatologic
- Peripheral joint swelling
- Deformity
- Redness or pain
- Rash

TABLE A-5

Systemic Disease or Visceral Pain Referred from the Musculoskeletal Region

Headache
- Intracranial tumor (U)
- Meningitis (U)
- Subarachnoid hemorrhage (U)
- Sinus infection
- Temporal arteritis; refer patients with visual problems immediately to prevent blindness (U)

Cervical Spine Region Pain
Visceral Referred Pain
Thoracic Origin
- Cardiac ischemia or infarction (U)
- Pneumomediastinum (U)
- Pericarditis (U)
- Aortic arch dissection (U)
- Pancoast tumor
- Pleuritis

Infectious Origin
- Meningitis (U)
- Epidural abscess (U)
- Osteomyelitis (U)
- Disk space infection (U)
- Transverse myelitis (U)
- Lyme disease

Neoplastic Causes
- Metastatic tumor
- Intramedullary or extramedullary tumor
- Epidural hematoma (U)

Vascular Origin
- Subarachnoid hemorrhage (U)
- Vertebral artery dissection (U)
- Carotid artery thrombosis (U)

Other Visceral Referred Pain
- Sphenoid sinusitis
- Thyroiditis
- Parotitis
- Cervical lymphadenitis (from a throat or skin source)
- Pharyngeal space infection (P) (U)
- Cysts (P)

Nonviscerogenic Referred Pain
Rheumatologic Disease
- Fibromyalgia
- Polymyalgia rheumatica
- Rheumatoid arthritis
- Ankylosing spondylitis
- Gout or other crystal-induced inflammation

Shoulder Pain
Visceral Referred Pain
Neoplastic Causes
- Metastatic lesions
- Breast
- Prostate
- Kidney
- Lung
- Thyroid
- Cervical cord or root compression
- Pancoast tumor
- Lung cancer

Cardiac Origin (Left Shoulder)
- Angina or myocardial infarction (U)
- Pericarditis (U)
- Aortic aneurysm (U)

Pulmonary Origin
- Empyema and lung abscess
- Pulmonary tuberculosis
- Spontaneous pneumothorax (U)
- Lung cancer

Breast Origin
- Mastodynia
- Primary or secondary cancer

Abdominal Origin
- Liver disease
- Ruptured spleen (U)
- Gallbladder disease
- Subphrenic abscess

Systemic Disease
- Collagen vascular disease
- Gout
- Syphilis, gonorrhea
- Sickle cell anemia
- Hemophilia
- Rheumatic disease

Thoracic-Scapular Region Pain
Visceral Referred Pain
Cardiac Origin
- Myocardial ischemia or infarction (U)
- Dissecting aortic aneurysm (U)

Pulmonary Origin
- Pneumonia (U)
- Pleuritis
- Pulmonary embolism (U)
- Pneumothorax (U)
- Empyema (U)

Neoplastic Causes
- Mediastinal tumors
- Pancreatic carcinoma

Neck Origin
- Esophagitis
- Abdominal Origin
- Liver disease (e.g., hepatitis, cirrhosis, metastatic tumors)
- Gallbladder disease

Anterior or Lateral Chest Pain
Serious Causes (U)
Pulmonary Origin
- Pulmonary embolism
- Pneumothorax
- Pneumomediastinum
- Pneumopericardium
- Mediastinal tumor
- Asthma
- Pneumonia (if respiratory rate >20 and short of breath)

Cardiac Origin
- Pericarditis
- Dissecting coronary artery or aorta (e.g., Marfan syndrome)
- Cardiac hypertrophy
- Primary pulmonary hypertension
- Myocarditis
- Tachycardia (heart rate >140–160 at rest)
- Suspected myocardial infarction (may occur in younger patient using cocaine)

Less Serious Causes
Infectious Origin
- Herpes zoster infection
- Pneumonia (if no respiratory compromise)
- Pleurisy
- Bronchitis

Gastrointestinal Origin
- Esophageal tear
- Spasm
- Reflux

Thoracolumbar Spine and Sacroiliac Region Pain
Visceral Referred Pain
Neoplastic Causes
- Malignant tumors of the spinal cord or meninges (neurologic deficit)
- Lymphoma (night sweats, weight loss, lymphadenopathy)
- Multiple myeloma (>40 y of age, moderately severe bone pain, multiple osteopenic spine lesions, kidney disease, fatigue from excessive calcium)
- Metastatic tumors (e.g., prostate, breast, lung, kidney, thyroid, colon)
- Pediatric malignancies (e.g., Ewing sarcoma, osteosarcoma, lymphoma, leukemia, skeletal metastasis from Wilms tumor, neuroblastoma, rhabdomyosarcoma) (P)

Abdominal Origin
- Abdominal aortic aneurysm (U)
- Peptic ulcer
- Pancreatic disorders
- Pyelonephritis (U)
- Nephrolithiasis (renal stone) (U)
- Hydronephrosis
- Renal tumor
- Renal infarction (U)

Pelvic Origin
- Urinary bladder retention
- Crohn disease of the rectum
- Chronic prostatitis
- Uterine masses
- Retroverted or prolapsed uterus
- Endometriosis
- Pelvic inflammatory disease (fever, nausea, pelvic pain) (U)
- Ectopic pregnancy (missed menstrual cycle, pelvic pain) (U)
- Benign ovarian tumor
- Colon diverticulitis
- Retroperitoneal fibrosis

Rheumatologic Causes
- Ankylosing spondylitis
- Reiter syndrome
- Psoriatic arthritis

(continued)

TABLE A-5

Systemic Disease or Visceral Pain Referred from the Musculoskeletal Region (*continued*)

Infectious Origin (U)
- Osteomyelitis
- Disk space infection
- Epidural abscess
- Pyogenic sacroiliitis

Endocrine and Metabolic Causes
- Osteoporosis with compression fracture

Hip, Groin, and Thigh Pain
Visceral Referred Pain

Neoplastic Causes
- Bone tumors
- Spinal metastasis

Abdominal Origin
- Inguinal or femoral hernia
- Appendicitis (U)
- Crohn disease
- Ureteral colic

Pelvic Origin

Systemic disease
- Pelvic inflammatory disease (P)
- Thrombosis Syndromes (U)
- Deep venous thrombosis (DVT) with proximal extension to femoral vein and/or pelvic veins (calf pain and swelling)
- Greater saphenous vein phlebitis (superficial, may progress to DVT)

Arthritis
- Osteoarthritis
- Gout, pseudogout
- Rheumatoid arthritis
- Ankylosing spondylitis (degenerative joint disease of hip in a younger male)
- Reiter syndrome

Pediatric Hip Disease (P)
- Legg–Calvé–Perthes (proximal femoral epiphyseal blood flow interruption and necrosis; collapse of femoral head; hip pain, limp, adductor and iliopsoas spasm, possible Trendelenburg sign; child 4–8 y old)
- Slipped capital femoral epiphysis (hip, thigh, or knee pain; hip hypomobility especially in medial rotation; older child or adolescent)
- Transient synovitis (hip, thigh, or knee pain; difficulty walking and possible fever, 2–12 y of age with peak incidence at 6–7 y)

Infectious Origin
- Lymphadenitis caused by cellulitis distally or abdominal wall, perineum, or genital areas or other infections, including sexually transmitted diseases (U)
- Iliopsoas abscess (retroperitoneal infection or inflammation) (U)

P, pediatric; U, urgent.

APPENDIX 2

Red Flags: Potentially Serious Symptoms and Signs in Exercising Patients

SCOTT TAUFERNER • CARRIE M. HALL

Certain symptoms occurring during exercise may indicate significant medical problems and may be the reason for referral. **Display A-1** lists the symptoms associated with medical conditions and the tests that should be performed to exclude a medical emergency. **Display A-2** lists signs indicating medical problems that necessitate medical referral.

During supervised exercise, a patient may develop serious signs and symptoms. **Display A-3** describes the signs and symptoms related to exercise and the appropriate course of action with respect to various comorbidities:

- Asthma or other pulmonary disease
- Cough
- Cardiovascular disorders
- Syncope
- Hypoglycemia
- Allergic reactions
- Deep vein thrombosis (DVT)
- Pulmonary embolus (PE)
- Spinal cord compression from metastatic disease

DISPLAY A-1

Symptoms Associated with Medical Conditions

CONDITION	SYMPTOMS	TESTS
Asthma, pulmonary disease	■ Wheezing ■ Pleuritic pain (chest pain increased by a deep breath) ■ Cough ■ Significant shortness of breath	■ Pulse ■ Respiratory rate ■ Blood pressure ■ Peak flow
Coronary artery, heart valve, myocardial infarction	■ Tightness or pain in the left chest, jaw, scapula, or left arm ■ Light-headedness ■ Nausea	■ Pulse ■ Blood pressure in both arms to determine differential
Cardiac rhythm disturbance	■ Light-headedness ■ Fainting ■ Bradycardia (heart rate <50) ■ Pauses between beats, especially if associated with light-headedness	■ Postural pulse ■ Blood pressure ■ Neurologic screen
Chronic fatigue or fibromyalgia	■ Flare-up of fatigue after exercise ■ Intolerance to aerobic or strength training	■ Screen for tender points
Cervical or intracerebral pathologies Neurogenic, vascular claudication, or DVT	■ Exercise-induced headaches ■ Calf pain with exercise	■ Complete neurologic and cervical screen ■ Peripheral pulses ■ Straight-leg raise ■ Neurologic screen ■ Homans test ■ Calf circumference

DISPLAY A-2

Signs Associated with Medical Conditions

SIGNS	CONDITION
Heart Rate	
Less than 50 beats per minute (unless very aerobically fit individual) Pauses >3 seconds between beats (especially if associated with light-headedness) Moderately elevated heart rates during and after cessation of exercise	▪ Bradycardia ▪ Diseased sinus node ▪ Serious bradycardia ▪ Chronic pulmonary or cardiac disease ▪ Arrhythmia
Elevated heart rate before exercise	▪ Fever ▪ Pulmonary compromise ▪ Hyperthyroidism ▪ Volume depletion (from bleeding or other fluid loss)
Heart rate elevation >120 beats per minute, 5 minutes after exercise; if heart rate is >140 beats per minute and accompanied by chest pain, considered a medical emergency	▪ Possible myocardial infarction ▪ Fever ▪ Hyperthyroidism ▪ Arrhythmia (tachycardia) ▪ Volume depletion
Blood Pressure	
Systolic blood pressure <85 mm Hg (exercise is contraindicated) Systolic blood pressure >140 (exercise not contraindicated until systolic reaches 170; isometric exercise contraindicated)	▪ Hypotension ▪ Hypertension
Respiratory Rate	
Greater than 20 (exercise contraindicated unless there is a known chronic lung condition)	▪ Asthma ▪ Pulmonary infections ▪ Chronic lung conditions ▪ Acute pain ▪ Fever

DISPLAY A-3

Common Medical Conditions That May Produce Serious Signs and Symptoms During Exercise

Asthma, Pulmonary Diseases, and Shortness of Breath

If a patient has a history of asthma, chronic pulmonary disease, or recent upper respiratory tract infection with any of the symptoms listed below during or after exercise, he or she may have an asthma flare, temporary bronchospasm, or another pulmonary problem (e.g., bronchitis, pneumonia). Any patient with active asthma should be managed by a physician and encouraged to bring his or her asthma inhaler and peak flow meter to the therapy department.

Symptoms and Signs

- Coughing
- Wheezing
- Substernal chest tightness
- Mild shortness of breath at rest or precipitated by exercise or cold weather
- Use of accessory muscles of respiration (e.g., scalenes, pectoralis minor, intercostals)
- Elevated respiratory rate (>18 breaths per minute) 5 minutes after cessation of exercise
- Low peak flow level for age, sex, and height

Clinical Actions

- Administer the patient's bronchospasm inhaler. A second inhalation should be administered after 1 to 2 minutes. Recheck signs and symptoms within 5 to 10 minutes.
- Peak flow of <80% of predicted indicates asthma or chronic obstructive pulmonary disease, indicating referral for a medical evaluation.
- Peak flow of <250 indicates severe airway obstruction and is reason for referral to the emergency room.
- Respiratory rate >24, resting heart rate >100, and a peak flow of <200 to 250 are signs of pulmonary compromise or a severe exacerbation and poor clinical response to the medication. If the patient does not show improvements significantly after the inhalation of medication, the patient's physician should be called immediately. If the patient appears to be in respiratory distress, he or she should be transferred to an emergency room.
- Exercise can be continued if the patient responds well to the medication. The physician should be called regarding management of the medications to prevent future exacerbations.

DISPLAY A-3

Common Medical Conditions That May Produce Serious Signs and Symptoms During Exercise (*continued*)

Cough

Associated Conditions

- Pulmonary infection (accompanied by colored sputum, fever, chills)
- Medication side effect
- Serious lung disorder
- Asthma
- Reactive airway disease
- Congestive heart failure
- Mild respiratory tract infection

Increased intraabdominal and intrathoracic pressure induced by coughing can greatly exacerbate spine pain conditions of a mechanical nature. Patients with spinal disorders should be advised to suppress cough with over-the-counter medications and consult their physician to determine the cause and receive definitive treatment. Patients with a persistent cough should be referred to a physician.

Cardiovascular Disorders

Symptoms

- Chest, substernal, left arm, anterior neck, jaw, and periscapular pain
- Headache, blurred vision, exacerbation of neck pain (symptoms of severe hypertension)
- Uncontrolled hypertension that exacerbates headache and neck pain
- Chest pain, light-headedness, fainting, and perceptions of strong beats or irregularity (symptoms of heart rhythm abnormalities)

Clinical Actions

- If heart rate is <45 or >150 beats per minute after cessation of exercise for more than 5 minutes, refer the patient immediately or call 911.
- If the patient has a heart rate >150 and is younger than 50 years old, an attempt to decrease the heart rate by putting slight pressure on the carotid body can be made by massaging the carotid pulse just inferior to the angle of the jaw. The radial pulse can be monitored with another hand, and if it begins to slow, pressure can be taken off the carotid body. If there is no effect within 10 to 15 seconds, this procedure should be stopped.
- If the patient has angina symptoms (i.e., severe, constricting chest pain) with known coronary disease, administer his or her own nitroglycerin while sitting or lying down. You may repeat this after 5 minutes. If no relief occurs after a total of three doses in 15 minutes, call 911.
- If systolic blood pressure is >180 or diastolic pressure is >110, the therapy appointment should be terminated and the patient referred to his physician.
- If the systolic blood pressure is >220 and the diastolic pressure is >130, the patient should go to the emergency room, and the referring physician should be called.
- High blood pressure, midline thoracic pain, and between-arm blood pressure differences of 10 mm Hg should be referred immediately.
- A patient with a history of coronary disease should be referred immediately if he or she is experiencing arrhythmia and has chest pain.
- If the patient is unconscious, call 911 and begin cardiopulmonary resuscitation.

Syncope

Syncope is defined as a sudden and reversible loss of consciousness and decrease or loss of postural muscle tone. It can be caused by transient cerebral ischemia (a total loss of cerebral flow for 10 seconds leads to a blood pressure <70) or altered chemical composition of blood flow to the brain (brain cells depend on a constant level of glucose for energy).

Symptoms

- Changes in vision
- Nausea
- Sweating
- Feeling of dizziness
- Feeling of leg or trunk postural weakness
- Palpitations or chest pain if tachycardia
- Calf or chest pain if pulmonary embolism

To determine if the syncope is caused by postural changes, the blood pressure and heart rate are taken in three positions: supine, sitting, and standing. The blood pressure is assessed in each position. If the systolic pressure lowers by more than 20 points or the heart rate elevates by more than 20 points with each positional change, the patient can be determined to have posturally related syncope.

Clinical Actions

- The patient should be positioned in supine with legs elevated for at least 3 minutes to increase venous return of blood.
- A patient with posturally related syncope and a history of vomiting or diarrhea is usually dehydrated and requires significant rehydration with more than 2 L of fluid. The patient should have arrangements made for transportation to a physician's office or a medical facility. It may be possible for the patient to take in enough fluid orally. Rehydration may be started in the therapy department, but it should not be completed in the therapy department.
- Syncope that occurs more than one time requires termination of the therapy appointment and transportation to the emergency room (unless it is clearly a vasovagal faint). A vasovagal faint is one in which there is no ongoing pathology and the blood pressure and pulse become normal after 3 to 5 minutes in all positions. Patients who faint more than one time should not be allowed to transport themselves to a medical facility.

Hypoglycemic Episodes

Hypoglycemic episodes most commonly occur in patients with diabetes. The causes vary, including improper timing of meals or snacks, excessive insulin or improper dosing or timing of insulin, and excessive or unplanned exercise coupled with inadequate food intake.

Symptoms and Signs

- Shakiness
- Weakness
- Sweaty
- Blurred vision
- Excessive anxiety
- Irritability
- Light-headedness
- Confusion
- Decreased cognitive abilities
- Unconsciousness
- Blood sugar levels <50 to 60

(continued)

DISPLAY A-3

Common Medical Conditions That May Produce Serious Signs and Symptoms During Exercise (*continued*)

All diabetes patients should be asked to bring their meters with strips to every therapy visit in case of a hypoglycemic episode. Any of the above symptoms should prompt blood sugar assessment.

Clinical Actions

- If the glucose level is <60, and the patient is awake, give a carbohydrate snack of three glucose tablets, a tube of Insta-Glucose gel, *or* 1/2 to 1 cup of juice. Ask the patient to take a snack including carbohydrate and protein or fat.
- Do not begin any aerobic exercise.
- Recheck the serum glucose level in 30 minutes. If the patient feels significantly better, he or she can resume exercise.
- If the patient is unconscious, administer glucagon immediately. Mix the liquid in the syringe with the powder in the bottle, and then inject the whole clear solution that is in the syringe into the deltoid muscle or the quadriceps muscle. Place the patient in a sidelying position to protect the airway. When the patient awakens and is fully conscious, give a glucose snack and protein, refer the patient to the emergency room, and call the primary physician.

Instructions for Diabetic Patients Before Exercise

- If the glucose level is 100 to 180, administer 15 g of carbohydrate.
- If the glucose level is 180 to 250, it is not necessary to increase food intake.
- If the glucose level is more than 250, do not start aerobic exercise.

Allergic Reactions

Patients may develop allergic reactions to exercise that can occur for the first time in the therapy department:

- Exercise-related hives (i.e., itchy, raised skin areas filled with fluid)
- Angioedema (i.e., swelling in the subcutaneous tissues around the eyes, lips, hands, and feet, and possibly in the tongue and posterior pharynx and airway)
- Anaphylactic shock (i.e., associated with decreased blood pressure, increased pulse, sweatiness, pallor, angioedema, and asthma symptoms)

Anaphylactic shock may occur as a reaction to a medication such as antibiotics, angiotensin-converting enzyme inhibitors, aspirin, or nonsteroidal anti-inflammatory drugs. Exercise-induced anaphylaxis may occur with vigorous aerobic exercise as the only precipitating factor. Any patient with a history of exercise-induced shock should always exercise with another person and should always carry an epinephrine kit.

A patient may also develop any of these reactions in response to latex gloves or another allergen that he or she is severely allergic to that may be used in the therapy department. A patient may also react to medications.

Clinical Actions

- Hives usually do not cause emergent problems unless this condition progresses to other, more serious problems. Stop exercise, and consider having the patient take an antihistamine such as Benadryl. Call the patient's primary physician.
- Angioedema is an emergency if it involves swelling of the tongue and airway. If the patient displays difficulty controlling saliva or breathing, the treatment of choice is to administer one dose of epinephrine (0.3 mL of 1:1,000 solution) in the deltoid area. If a qualified person is not on the premises to administer this treatment, call 911.
- Anaphylactic shock is a **severe, life-threatening emergency**. Blood pressure and pulse should be taken, although blood pressure may be difficult to detect. The patient should lie down with legs elevated. A dose of epinephrine should be administered immediately and 911 called.

Deep Vein Thrombosis

Individuals at risk of DVT include those who have sustained local trauma to a vessel, have a hypercoagulable disorder, or have been immobilized by bed rest or casts. The most common locations of DVT include the calf, thigh, arms, and pelvis.

Symptoms and Signs

- Pain in the calf or thigh
- Swelling of the calf (circumferential tape measurements are indicated to verify swelling)
- Pain in the calf with walking
- Tenderness with palpation of the deep calf along the midline
- Complete the Well's scale for DVT

Any patient complaining of calf pain or swelling should be evaluated for DVT.

Clinical Actions

- Suspicion of DVT warrants referral to a physician or emergency room within the next few hours.
- The patient should walk minimally, because there is a danger of the clot breaking off from the vessel.

Pulmonary Embolus

PE is an **urgent condition** in which an area of lung is infarcted as a result of a thrombus occluding a pulmonary artery. The thrombus usually originates in a deep vein of the leg and travels through the venous return circulation into the right side of the heart and out through the pulmonary circulation to occlude a pulmonary artery. Small thrombi may progress to the periphery of the lung and infarct the peripheral lung tissue, with resultant inflammation and pleuritic pain. Large thrombi may occlude the pulmonary circulation and lead to severe cardiac compromise.

Symptoms and Signs

- Pleuritic pain with referred areas of pain
- Shortness of breath
- Fast respiratory rate
- Coughing up blood
- Rapid pulse rate

Suspicion of PE requires immediate referral to the emergency room. If not on the hospital premises, call 911.

Spinal Cord Compression and Metastatic Disease

Patients with metastatic spine lesions can develop cord compression that is manifested by sensory, motor, or bladder symptoms. For a patient with multisite bone pain and new-onset neurologic symptoms, a complete neurologic examination is indicated. If you suspect a cord compression syndrome, check for upper motor neuron (UMN) signs on examination (e.g., clonus, Babinski, Hoffman's, hypertonicity). If UMN signs and motor, sensory, or bladder symptoms are present, refer the patient immediately.

APPENDIX 3

2016 PAR-Q +: The Physical Activity Readiness Questionnaire for Everyone

Source: Physical Activity Readiness Questionnaire (PAR-Q). © 2016. Reprinted from the Canadian Society for Exercise Physiology. Available at: http:/www.csep.ca/forms.asp. Accessed December 28, 2015, with permission.

2016 PAR-Q+

The Physical Activity Readiness Questionnaire for Everyone

The health benefits of regular physical activity are clear; more people should engage in physical activity every day of the week. Participating in physical activity is very safe for MOST people. This questionnaire will tell you whether it is necessary for you to seek further advice from your doctor OR a qualified exercise professional before becoming more physically active.

GENERAL HEALTH QUESTIONS

Please read the 7 questions below carefully and answer each one honestly: check YES or NO.	**YES**	**NO**
1) Has your doctor ever said that you have a heart condition ☐ OR high blood pressure ☐?	☐	☐
2) Do you feel pain in your chest at rest, during your daily activities of living, **OR** when you do physical activity?	☐	☐
3) Do you lose balance because of dizziness **OR** have you lost consciousness in the last 12 months? Please answer **NO** if your dizziness was associated with over-breathing (including during vigorous exercise).	☐	☐
4) Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)? **PLEASE LIST CONDITION(S) HERE:** ______	☐	☐
5) Are you currently taking prescribed medications for a chronic medical condition? **PLEASE LIST CONDITION(S) AND MEDICATIONS HERE:** ______	☐	☐
6) Do you currently have (or have had within the past 12 months) a bone, joint, or soft tissue (muscle, ligament, or tendon) problem that could be made worse by becoming more physically active? Please answer **NO** if you had a problem in the past, but it ***does not limit your current ability*** to be physically active. **PLEASE LIST CONDITION(S) HERE:** ______	☐	☐
7) Has your doctor ever said that you should only do medically supervised physical activity?	☐	☐

If you answered NO to all of the questions above, you are cleared for physical activity.
Go to Page 4 to sign the PARTICIPANT DECLARATION. You do not need to complete Pages 2 and 3.

- Start becoming much more physically active—start slowly and build up gradually.
- Follow International Physical Activity Guidelines for your age (www.who.int/dietphysicalactivity/en/).
- You may take part in a health and fitness appraisal.
- If you are over the age of 45 yr and **NOT** accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.
- If you have any further questions, contact a qualified exercise professional.

If you answered YES to one or more of the questions above, COMPLETE PAGES 2 AND 3.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant—talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ at **www.eparmedx.com** before becoming more physically active.
- Your health changes—answer the questions on Pages 2 and 3 of this document and/or talk to your doctor or a qualified exercise professional before continuing with any physical activity program.

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FOLLOW-UP QUESTIONS ABOUT YOUR MEDICAL CONDITION(S)

1. Do you have Arthritis, Osteoporosis, or Back Problems?

If the above condition(s) is/are present, answer questions 1a–1c   If **NO** ☐ go to question 2

1a. Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments) YES ☐ NO ☐

1b. Do you have joint problems causing pain, a recent fracture or fracture caused by osteoporosis or cancer, displaced vertebra (e.g., spondylolisthesis), and/or spondylolysis/pars defect (a crack in the bony ring on the back of the spinal column)? YES ☐ NO ☐

1c. Have you had steroid injections or taken steroid tablets regularly for more than 3 months? YES ☐ NO ☐

2. Do you currently have Cancer of any kind?

If the above condition(s) is/are present, answer questions 2a–2b   If **NO** ☐ go to question 3

2a. Does your cancer diagnosis include any of the following types: lung/bronchogenic, multiple myeloma (cancer of plasma cells), head, and/or neck? YES ☐ NO ☐

2b. Are you currently receiving cancer therapy (such as chemotheraphy or radiotherapy)? YES ☐ NO ☐

3. Do you have a Heart or Cardiovascular Condition? *This includes Coronary Artery Disease, Heart Failure, Diagnosed Abnormality of Heart Rhythm*

If the above condition(s) is/are present, answer questions 3a–3d   If **NO** ☐ go to question 4

3a. Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments) YES ☐ NO ☐

3b. Do you have an irregular heart beat that requires medical management? (e.g., atrial fibrillation, premature ventricular contraction) YES ☐ NO ☐

3c. Do you have chronic heart failure? YES ☐ NO ☐

3d. Do you have diagnosed coronary artery (cardiovascular) disease and have not participated in regular physical activity in the last 2 months? YES ☐ NO ☐

4. Do you have High Blood Pressure?

If the above condition(s) is/are present, answer questions 4a–4b   If **NO** ☐ go to question 5

4a. Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments) YES ☐ NO ☐

4b. Do you have a resting blood pressure equal to or greater than 160/90 mm Hg with or without medication? (Answer **YES** if you do not know your resting blood pressure) YES ☐ NO ☐

5. Do you have any Metabolic Conditions? *This includes Type 1 Diabetes, Type 2 Diabetes, Pre-Diabetes*

If the above condition(s) is/are present, answer questions 5a–5e   If **NO** ☐ go to question 6

5a. Do you often have difficulty controlling your blood sugar levels with foods, medications, or other physician-prescribed therapies? YES ☐ NO ☐

5b. Do you often suffer from signs and symptoms of low blood sugar (hypoglycemia) following exercise and/or during activities of daily living? Signs of hypoglycemia may include shakiness, nervousness, unusual irritability, abnormal sweating, dizziness or light-headedness, mental confusion, difficulty speaking, weakness, or sleepiness. YES ☐ NO ☐

5c. Do you have any signs or symptoms of diabetes complications such as heart or vascular disease and/or complications affecting your eyes, kidneys, **OR** the sensation in your toes and feet? YES ☐ NO ☐

5d. Do you have other metabolic conditions (such as current pregnancy-related diabetes, chronic kidney disease, or liver problems)? YES ☐ NO ☐

5e. Are you planning to engage in what for you is unusually high (or vigorous) intensity exercise in the near future? YES ☐ NO ☐

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6. Do you have any Mental Health Problems or Learning Difficulties? *This includes Alzheimer's, Dementia, Depression, Anxiety Disorder, Eating Disorder, Psychotic Disorder, Intellectual Disability, Down Syndrome*

If the above condition(s) is/are present, answer questions 6a–6b — If **NO** ☐ go to question 7

6a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
6b.	Do you have Down Syndrome **AND** back problems affecting nerves or muscles?	YES ☐ NO ☐

7. Do you have a Respiratory Disease? *This includes Chronic Obstructive Pulmonary Disease, Asthma, Pulmonary High Blood Pressure*

If the above condition(s) is/are present, answer questions 7a–7d — If **NO** ☐ go to question 8

7a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
7b.	Has your doctor ever said your blood oxygen level is low at rest or during exercise and/or that you require supplemental oxygen therapy?	YES ☐ NO ☐
7c.	If asthmatic, do you currently have symptoms of chest tightness, wheezing, laboured breathing, consistent cough (more than 2 days/week), or have you used your rescue medication more than twice in the last week?	YES ☐ NO ☐
7d.	Has your doctor ever said you have high blood pressure in the blood vessels of your lungs?	YES ☐ NO ☐

8. Do you have a Spinal Cord Injury? *This includes Tetraplegia and Paraplegia*

If the above condition(s) is/are present, answer questions 8a–8c — If **NO** ☐ go to question 9

8a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
8b.	Do you commonly exhibit low resting blood pressure significant enough to cause dizziness, light-headedness, and/or fainting?	YES ☐ NO ☐
8c.	Has your physician indicated that you exhibit sudden bouts of high blood pressure (known as Autonomic Dysreflexia)?	YES ☐ NO ☐

9. Have you had a Stroke? *This includes Transient Ischemic Attack (TIA) or Cerebrovascular Event*

If the above condition(s) is/are present, answer questions 9a–9c — If **NO** ☐ go to question 10

9a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
9b.	Do you have any impairment in walking or mobility?	YES ☐ NO ☐
9c.	Have you experienced a stroke or impairment in nerves or muscles in the past 6 months?	YES ☐ NO ☐

10. Do you have any other medical condition not listed above or do you have two or more medical conditions?

If you have other medical conditions, answer questions 10a–10c — If **NO** ☐ read the Page 4 recommendations

10a.	Have you experienced a blackout, fainted, or lost consciousness as a result of a head injury within the last 12 months **OR** have you had a diagnosed concussion within the last 12 months?	YES ☐ NO ☐
10b.	Do you have a medical condition that is not listed (such as epilepsy, neurological conditions, kidney problems)?	YES ☐ NO ☐
10c.	Do you currently live with two or more medical conditions?	YES ☐ NO ☐

PLEASE LIST YOUR MEDICAL CONDITION(S) AND ANY RELATED MEDICATIONS HERE: ____________________

GO to Page 4 for recommendations about your current medical condition(s) and sign the PARTICIPANT DECLARATION.

OSHF Ontario Society for Health and Fitness

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If you answered NO to all of the follow-up questions about your medical condition, you are ready to become more physically active—sign the PARTICIPANT DECLARATION below:

- It is advised that you consult a qualified exercise professional to help you develop a safe and effective physical activity plan to meet your health needs.
- You are encouraged to start slowly and build up gradually—20 to 60 minutes of low to moderate intensity exercise, 3 to 5 days per week including aerobic and muscle strengthening exercises.
- As you progress, you should aim to accumulate 150 minutes or more of moderate intensity physical activity per week.
- If you are over the age of 45 yr and **NOT** accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.

If you answered **YES** to **one or more of the follow-up questions** about your medical condition:

You should seek further information before becoming more physically active or engaging in a fitness appraisal. You should complete the specially designed online screening and exercise recommendations program—the **ePARmed-X+ at www.eparmedx.com** and/or visit a qualified exercise professional to work through the ePARmed-X+ and for further information.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant—talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ **at www.eparmedx.com** before becoming more physically active.
- Your health changes—talk to your doctor or qualified exercise professional before continuing with any physical activity program.

- You are encouraged to photocopy the PAR-Q+. You must use the entire questionnaire and NO changes are permitted.
- The authors, the PAR-Q+ Collaboration, partner organizations, and their agents assume no liability for persons who undertake physical activity and/or make use of the PAR-Q+ or ePARmed-X+. If in doubt after completing the questionnaire, consult your doctor prior to physical activity.

PARTICIPANT DECLARATION

- All persons who have completed the PAR-Q+ please read and sign the declaration below.
- If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian, or care provider must also sign this form.

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that a Trustee (such as my employer, community/fitness centre, health care provider, or other designate) may retain a copy of this form for their records. In these instances, the Trustee will be required to adhere to local, national, and international guidelines regarding the storage of personal health information ensuring that the Trustee maintains the privacy of the information and does not misuse or wrongfully disclose such information.

NAME ________________________ DATE ________________________

SIGNATURE ________________________ WITNESS ________________________

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER ________________________

For more information, please contact
www.eparmedx.com
Email: eparmedx@gmail.com

Citation for PAR-Q+
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OSHF Ontario Society for Health and Fitness

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