

Movement System Syndromes of the Knee

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INTRODUCTION

Common knee pain problems seen by physical therapists include overuse injuries, such as patellofemoral pain syndrome (PFPS); traumatic injuries, such as anterior cruciate ligament (ACL) tears; and degenerative conditions, such as osteoarthritis (OA). Treatment directed at the identified source, such as soft tissue injury, may be useful after injury to reduce pain and return to function, however may not address the cause or contributing factors of the condition. One of the proposed contributing factors to injury is abnormal movement patterns or movement impairments. There is growing support that movement impairments may contribute to knee problems such as PFPS,¹⁻³ iliotibial band (ITB) friction syndrome,⁴⁻⁵ ACL tears,⁶ and OA.^{7,8} In addition, studies have shown that addressing movement impairments can improve symptoms, enhance patient function after injury,⁹⁻¹² and prevent future injury.^{13,14}

In this chapter, we will focus on the syndromes and treatment of movement impairments proposed to contribute to mechanical knee pain and injury. The diagnosis of acute, traumatic injuries, such as ligamentous and meniscal tears is described in Chapter 2. The treatment of acute, traumatic injuries is not discussed in detail here because many excellent sources are available to describe the rehabilitation of these conditions.* The syndromes described in this chapter will, however, assist the therapist in identifying possible underlying movement impairments present during the early stages of rehabilitation.

Movement system syndromes (MSS) are influenced by a variety of factors that are important to consider during examination and treatment. Factors to consider are intrinsic characteristics, such as age, gender, and

structural variations, and extrinsic characteristics, such as work or sport activity and work environment. For each patient, the examiner must consider the contribution of individual factors, as well as the possible interaction of these factors. OA provides an example of how multiple factors may contribute to the progression of a musculoskeletal problem. Increased age,¹⁵ high body mass,¹⁵⁻¹⁷ structural alignment,^{8,18} knee laxity,^{19,20} and participation in activities that involve deep knee flexion²¹ have all been shown to increase the risk of knee OA or the progression of knee OA. The interaction of these factors may further compound the risk. For example, Sharma et al¹⁶ found a positive relationship between body mass index (BMI) and the severity of radiographic OA in the varus-aligned knee. How quickly a joint degenerates or an injury occurs is likely determined by the interaction of multiple factors specific to the individual. These factors must be taken into account during the treatment of knee pain problems.

The relationship of the knee to the entire lower quarter should be considered when evaluating individuals with knee pain problems. The knee is the interface between the ankle/foot complex and the hip and is often affected by these neighboring joints. Many muscles crossing the knee joint also cross either the hip or the ankle/foot. Thus alignment faults, structural variations, or movement impairments at the hip or ankle/foot may result in altered stresses at the knee. For example, excessive femoral adduction while performing sit-to-stand may result in increased knee valgus, which is an alignment that has been associated with knee pain and knee injury.³⁻⁵

Based on the theory of relative stiffness/flexibility, as described in Chapter 1, the body takes the path of least resistance when completing a task. An illustration of relative stiffness/flexibility between the knee and the hip may be seen in a ballet dancer who has a limitation in hip lateral rotation as the result of structural femoral anteversion. To achieve sufficient turn out for first position, the dancer demonstrates lateral rotation of the tibia to

*Suggested Readings:

Maxey L, Magnusson J: *Rehabilitation for the postsurgical orthopedic patient*, ed 2, St Louis, Mosby, 2007.

Cioppa-Mosca J, Cahill JB, Cavanaugh JT, et al: *Postsurgical rehabilitation guidelines for the orthopedic clinician*, St Louis, Mosby, 2006.



Figure 7-1. Excessive tibial lateral rotation. Ballet dancer in sitting position demonstrating excessive tibial lateral rotation. Excessive tibial lateral rotation may be the consequence of limited hip lateral rotation.

compensate for the lack of hip lateral rotation. The tibiofemoral joint is less stiff than the hip and therefore moves into lateral rotation more easily (Figure 7-1). With continued practice of first position using compensatory rotation of the tibia, the knee undergoes repeated mechanical stresses that accumulate over time, resulting in microtrauma and potentially macrotrauma or injury.

Relative stiffness/flexibility may also occur between a muscle and a joint. The tibiofemoral joint may be relatively less stiff than the tensor fasciae latae-iliotibial band (TFL-ITB). The relative stiffness/flexibility of the TFL-ITB can be observed during the two-joint hip flexor length. If the structures surrounding the tibiofemoral joint do not provide sufficient passive stiffness to stabilize the joint and the TFL-ITB does not easily stretch because of stiffness or shortness, lateral rotation of the tibia may be observed. In a sprinter, this relative stiffness/flexibility could result in repetitive tibial lateral rotation each time the limb initiates swing phase, the position in which the TFL-ITB should be in its most lengthened position. The stresses of repetitive rotation at the tibiofemoral joint may eventually lead to a knee pain problem.

Using the MSS concepts, a standardized examination²² is performed to determine the movement system syndrome and identify the factors contributing to the syndrome. The movement system syndrome is named for the direction of motion that is associated with an increase

in the patient's pain. For example, if the patient reports an increase in symptoms during the primary test of a single-leg squat and demonstrates femoral adduction with knee valgus, then tibiofemoral rotation with valgus (TFRVal) is suspected as the movement impairment. To confirm that TFRVal is associated with the pain complaint, the patient is asked to perform a secondary test by repeating the task while controlling the femoral adduction and knee valgus and keeping the knee aligned properly. If the patient reports a decrease in pain during the secondary test compared to the primary test, the movement system diagnosis of TFRVal is supported. Further substantiation of the diagnosis occurs if the examiner finds that the patient demonstrates the same direction of motion during multiple test items.

Specific to the knee, the movement system syndrome may not be obvious from the standard examination and basic functional activities. This is particularly true in high-level athletes because their impairments and/or symptoms may not be revealed until the knee is physically taxed with higher level activities. Therefore sport-specific or work-specific tasks may need to be assessed. Examples include running, jumping, and landing from a jump. In addition, the specific activity that the patient reports as most problematic should be assessed. Using the concepts of the MSS examination, primary and secondary tests of the higher level activities can be performed to confirm the suspected movement system diagnosis.

Once the movement system syndrome is identified and the stage for rehabilitation is determined, treatment can be provided. Treatment emphasis is on educating the patient in how to restore precise movement during all functional and athletic activities. Therapeutic exercise is also prescribed to address physical impairments, such as poor muscle performance or reduced muscle extensibility, thought to contribute to the movement system syndrome. Traditionally, the focus of rehabilitation of the knee has been placed on strengthening of the thigh musculature in the sagittal plane (quadriceps and hamstrings) with little regard to the influence of transverse or coronal plane motion at the tibiofemoral joint. We have found, however, that many knee pain problems, including PFPS and OA are treated effectively by addressing movement impairments related to excessive rotation or varus/valgus at the tibiofemoral joint. In addition, fitness activities are encouraged; however, modifications may need to be provided during the early stages of rehabilitation.

This chapter describes the normal alignment and movement of the knee and the actions of the surrounding musculature, as well as the structural and acquired faults that affect the knee and must be considered as part of the overall assessment. Finally, the proposed movement system syndrome of the knee and specific treatment recommendations associated with each syndrome are described (Table 7-1). Case examples are used to illustrate the major points.

TABLE 7-1

Movement System Syndromes of the Knee

Symptom	Source of Pain	Treatment
TIBIOFEMORAL ROTATION (TFR) WITH VALGUS (TFRVAL) OR TFR WITH VARUS (TFRVAR) SYNDROME		
<i>Impaired motion at the tibiofemoral joint, transverse or frontal plane</i>		
- Pain location: - Joint line - Peripatellar region - Pain associated with tibiofemoral rotation (WB or NWB)	- Patellofemoral joint - Hamstrings - Iliotibial band - Popliteus - Pes anserinus - Meniscus - Saphenous nerve - Subchondral bone - Synovium - Retinaculum - Joint capsule and ligaments	<i>Both:</i> - Education and modification of functional activities that contribute to impaired motion between the femur and tibia - Improve muscle performance of hip lateral rotators and abductors - Improve extensibility of TFL-ITB - Posterior X taping - Encourage fitness without increasing symptoms <i>TFRVal:</i> - Address pronation at foot <i>TFRVar:</i> - Improve shock absorption—heel to toe pattern
TIBIOFEMORAL HYPOMOBILITY (TFHYPO) SYNDROME		
<i>Physiologic loss of ROM</i>		
- Pain location: - Deep in joint - Pain with WB that decreases with rest - Stiffness	- Collateral ligaments - Subchondral bone - Patellofemoral joint - Meniscus - Joint capsule and ligaments	- Instruct in rolling heel-to-toe gait pattern - Reduce rotation and compressive forces on joint - Improve knee ROM - Mobilization for ROM and pain relief - Strengthen gluteus maximus and gastrocnemius muscles - Improve extensibility of hip flexors - Encourage fitness without increasing symptoms Bracing is an option <i>In patients with OA:</i> Caution should be taken to avoid excessive strengthening of quadriceps and hamstrings in patients with malalignment or laxity in the knee²⁰
KNEE EXTENSION (KEXT) SYNDROME AND KEXT SYNDROME WITH PATELLAR SUPERIOR GLIDE (KEXTSG) SYNDROME		
<i>Associated with dominance or shortness/stiffness of quadriceps muscle</i>		
<i>Kext</i>	<i>Kext</i>	<i>Both</i>
- Pain location: - Suprapatellar region	- Quadriceps tendon - Bursa	- Education and modification of functional activities to reduce recruitment of quadriceps (i.e., stairs and fitness activities) - Shift weight anteriorly during gait - Improve muscle performance of hip extensors - Improve extensibility of quadriceps - Encourage fitness without increasing symptoms
<i>KextSG</i>	<i>KextSG</i>	<i>KextSG</i>
- Pain location: - Infrapatellar or peripatellar region	- Patellofemoral joint - Fat pad - Patellar tendon - Plica	- Mobilization: Patellar inferior glide - Horseshoe taping of patella may be indicated - Patellar strap to reduce stresses on the source of the symptoms (patellar tendon)
KNEE HYPEREXTENSION (KHEXT) SYNDROME		
<i>Associated with dominance of hamstrings</i>		
- Pain location: - Anterior or posterior joint line - Peripatellar region	- Patellofemoral joint - Fat pad - Bursa - Plica - Meniscus - Joint capsule and ligaments - Hamstrings - Popliteus	- Education and modification of functional activities to decrease knee hyperextension (i.e., walking and standing): Keep knees unlocked - Improve muscle performance of quadriceps and gluteals - Improve extensibility of hamstrings and gastrocnemius - Posterior X taping - Unloader V taping (source: fat pad) - Encourage fitness without increasing symptoms

TABLE 7-1
Movement System Syndromes of the Knee—cont'd

Symptom	Source of Pain	Treatment
PATELLAR LATERAL GLIDE (PLG) SYNDROME		
<i>Impaired alignment or tracking of the patella in the trochlear groove</i>		
- Pain location: - Peripatellar region	- Patellofemoral joint - Patellar tendon - Fat pad - Plica - Subchondral bone - Synovium - Retinaculum - Joint capsule and ligaments	- Limit prolonged knee flexion - Improve muscle performance of quadriceps - Improve extensibility of TFL-ITB - Mobilization—patellar medial glide - Taping of patella may be indicated - Encourage fitness without increasing symptoms
TIBIOFEMORAL ACCESSORY HYPERMOBILITY (TFAH) SYNDROME		
<i>Excessive motion at the tibiofemoral joint</i>		
May or may not have pain. Instability or giving way	May have deficient ligamentous integrity from previous injury - ACL - PCL - Lateral corner/complex	- Rule out other diagnoses - Neuromuscular retraining - Improve muscle performance of lower extremity musculature - Posterior X taping - Consider bracing - Encourage fitness without increasing symptoms
KNEE IMPAIRMENT		
<i>No movement system syndrome identified or unable to perform a movement examination as occurs in cases of acute trauma or post-surgery</i>		
Pain is associated with trauma or surgery	Any structure of the knee associated with trauma or surgery	Improve ROM, strength, and neuromuscular control according to the healing of the involved structure. - Stage 1: Tissue protection to reduce stress to injured structure - Stage 2: Gradual progression of activities to gradually increase stress to structure without imposing new injury - Stage 3: Tissue stress progression to prepare tissue for return to normal activities

ACL, Anterior cruciate ligament; ITB, iliotibial band; LR, lateral rotation; MR, medial rotation; NWB, non-weight-bearing; OA, osteoarthritis; PCL, posterior cruciate ligament; ROM, range of motion; TFL, tensor fascia latae; WB, weight-bearing.

Modified from Harris-Hayes M, Sahrmann SA, Norton BJ, et al: Diagnosis and management of a patient with knee pain using the movement system impairment classification system, *J Orthop Sports Phys Ther* 38(4):203-213, 2008.

ALIGNMENT OF THE KNEE

The alignment of the entire lower extremity, including the hip, knee, ankle, and foot must be considered when assessing an individual with knee pain. Alignment of the knee is discussed in detail, and alignment of the hip and the ankle and foot is referred to briefly. Additional information on the ankle and foot can be found in Chapter 8, and additional information on the hip can be found in Sahrmann.²²

When assessing alignment, one must consider the possibility of structural impairments and distinguish structural from acquired impairments. Structural impairments are related to bony structure and cannot be corrected with training or exercise. Acquired impairments are often the result of postural habits and can be changed with

training. Examples of structural impairments that affect the knee include femoral or acetabular anteversion or retroversion, genu valgus or varus, tibial varum, tibial torsion, and a rigid supinated foot. Although structural impairments cannot be changed or corrected, exercises and activities may need to be modified to accommodate the structural impairment. For example, if an individual's hip lateral rotation is limited by femoral anteversion, the patient should be encouraged not to force hip lateral rotation during posterior gluteus medius strengthening.²² The patient should also be educated about the problems that can occur if he or she participates in activities that require excessive hip lateral rotation, such as ballet, because compensations often occur at other joints such as the knee. In addition, the patient should be instructed to avoid excessive lateral rotation of the hip during all



Figure 7-2. Normal alignment of the knee. Tibia and femur should be aligned vertically with the knee angle at approximately 0 degrees of flexion/extension.

functional activities such as sitting on the floor in the tailor position or stretching during dance warm-ups.

Normal Alignment

Sagittal Plane

Alignment of the lower extremity in the sagittal plane is viewed from the lateral aspect of the individual. The tibia and femur should be aligned vertically with the knee angle at approximately 0 degrees of flexion/extension (Figure 7-2). The angle of the hip joint, measured by a line bisecting the pelvis and a line bisecting the femur, should be 0 degrees in normal alignment. The ankle should be in a neutral position, with 0 degrees of dorsiflexion in relaxed standing.

Impairments

Genu recurvatum or knee hyperextension, defined as knee extension greater than 5 degrees, is commonly observed in children or young adults (Figure 7-3). Genu recurvatum may lead to many other impairments, including tibial bowing in the frontal or sagittal plane, altered compressive forces at the tibiofemoral joint, functional weakness of the quadriceps and gluteus maximus along with possible overrecruitment of the hamstrings, and posterior capsule stretching with ligamentous laxity.²²⁻²⁴ The knee may appear hyperextended when there is significant posterior bowing of the tibia in the sagittal plane.²² Standing with the knees in flexion is most typically seen in older individuals with end-stage OA or individuals with an acute injury (Figure 7-4).

Alignment of the knee may be related to alignment deviations of the hip and ankle. For example, knee



Figure 7-3. Genu recurvatum. Knee extension greater than 5 degrees. Note ankle plantarflexion.



Figure 7-4. Excessive knee flexion.

hyperextension is often associated with posterior pelvic tilt, hip extension, and ankle plantarflexion.^{22,23} Knee flexion is often present with anterior pelvic tilt, hip flexion, and ankle dorsiflexion.

Frontal Plane

Normal Alignment

Frontal plane alignment is viewed from the anterior and posterior aspect. The femoral shaft angles medially as a result of the angle of inclination of the proximal femur. The long axis of the femur diverges about 10 degrees

from the long axis of the tibia, therefore knee alignment in the frontal plane is a physiologic valgus angle of 170 to 175 degrees in the adult (Figure 7-5).^{25,26}

The amount of physiologic valgus changes with normal aging in children. Newborns demonstrate genu varum until about 20 months. Then the angle progresses toward valgus and peaks at approximately 168 degrees when the child reaches about 3 years.²⁷ The valgus then gradually decreases and reaches the adult value of approximately 170 to 175 degrees by age 6.^{25,27,28}

Impairments

If the described angle is less than 170 degrees, it is considered genu valgum (Figure 7-6), and if the angle is greater than 180 degrees, it is considered genu varum (Figure 7-7).²⁵ Genu valgum may place excessive tensile stresses or strain on the structures on the medial side of the knee and compressive forces on the lateral compartment of the knee. Genu varum may place excessive tensile stresses or strain on the structures on the lateral side of the knee and compressive forces on the medial compartment of the knee. In the young adult, genu varum appears to be more common in men than women.

Malalignment of the tibiofemoral joint in the frontal plane has been associated with osteoarthritis and functional limitations. People with knee OA and a varus or valgus alignment impairment have an increased risk of progression of tibiofemoral OA^{8,18,20} and patellofemoral OA.²⁹⁻³¹ In addition, an alignment change of 5 degrees in the frontal plane is associated with decreased ability to perform sit-to-stand and increased pain in people with knee OA.¹⁸ Alignment impairments may also be associated with compartment-specific OA, such as genu varum with medial compartment OA, and genu valgum with lateral compartment OA, which is discussed in detail in the “Tibiofemoral Rotation Syndrome” section.³²

The structure of the tibia and femur should be considered when assessing frontal plane alignment. Tibial varum is present if the distal one third of the tibia deviates medially from a vertical reference line. Tibial varum has more commonly been measured from the posterior view in resting calcaneal stance with average amounts ranging from 4.6 degrees to 8.3 degrees.^{33,34} Our preference is to observe and measure tibial varum from the anterior view because the tibial shaft is more visible and palpable. Keeping in mind the norms stated above, a reasonable criterion for excessive tibial varum would be a deviation greater than 10 degrees (Figure 7-8). Tibial varum is often associated with subtalar joint pronation,^{33,34} although we have seen it occur with a supinated foot. Tibial varum is more commonly observed with genu varum than genu valgum.

The structure of the femur may also be associated with genu valgum and varum; however, studies to confirm this have not been reported. Coxa varum, an angle of inclination at the hip that is notably less than 125 degrees,²⁶ may contribute to a genu valgum. Coxa valgum, an angle of inclination at the hip that is notably greater than 125

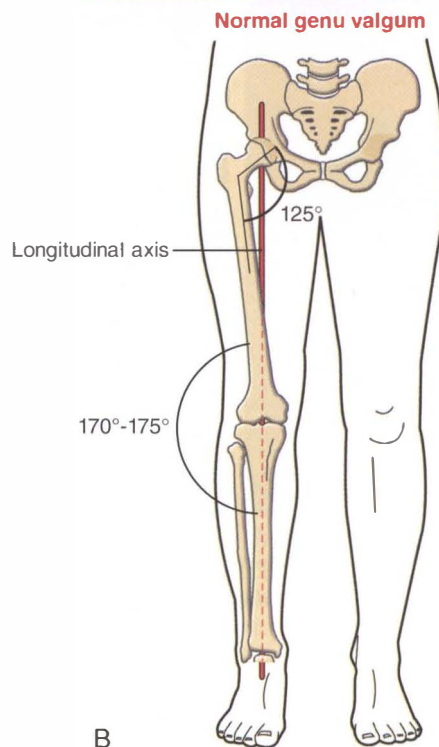


Figure 7-5. A and B, Normal physiologic valgus. The normal 125-degree angle of inclination of the proximal femur and the longitudinal axis of rotation throughout the entire lower extremity are also shown. (B, From Neuman DA: *Kinesiology of the musculoskeletal system: foundations for rehabilitation*, ed 2, St Louis, 2010, Mosby.)

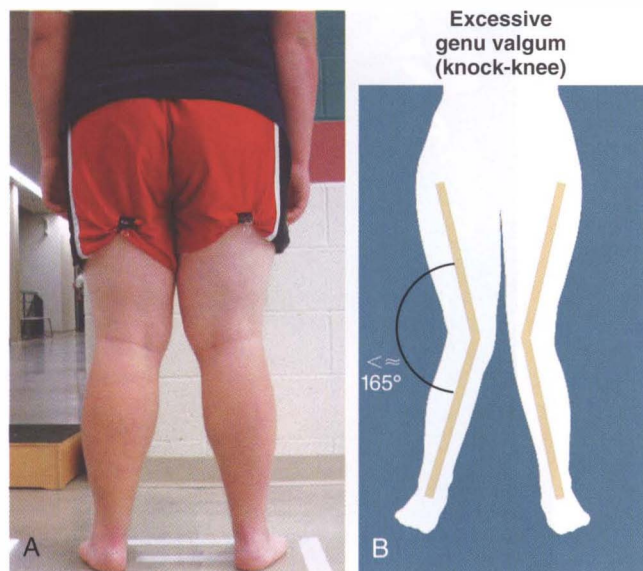


Figure 7-6. A and B, Genu valgum. Excessive frontal plane deviations. (B, From Neuman DA: *Kinesiology of the musculoskeletal system: foundations for rehabilitation*, ed 2, St Louis, 2010, Mosby.)

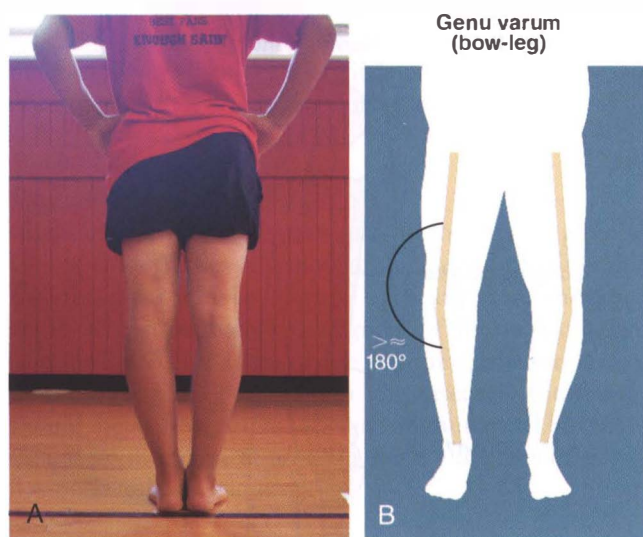


Figure 7-7. A and B, Genu varum. Excessive frontal plane deviations. (B, From Neuman DA: *Kinesiology of the musculoskeletal system: foundations for rehabilitation*, ed 2, St Louis, 2010, Mosby.)

degrees,²⁶ may contribute to a genu varum through excessive loading on the medial knee compartment that leads to a loss of medial knee joint space.

Transverse Plane

Normal Alignment

Transverse plane alignment is observed from the anterior and posterior aspects. General assessment of the entire lower extremity should be performed, followed by a more specific assessment of each region, such as the hip or knee. Rotation of the femur is assessed from the posterior



Figure 7-8. Tibial varum. A line representing the tibial shaft deviates from a vertical reference line greater than 10 degrees.

view, using the vertical creases that represent the border of the hamstrings and comparing the medial crease to the lateral crease. The distance of the vertical creases should be equal from the medial and lateral aspects of the knee, respectively. Another method would be to palpate the medial and lateral epicondyles and assess the direction of the plane that they are facing (e.g., more medially or more laterally compared to the sagittal plane). The anterior view can also be used to assess for consistency; however, an impaired alignment of the patella can be misleading. See Chapter 8 for a discussion of normal alignment of the foot and ankle in the transverse plane.

Impairments

Femoral medial rotation is a common alignment impairment observed in patients with knee pain (Figure 7-9). When femoral medial rotation is noted in standing alignment, the possibility of a structural femoral anteversion should also be considered and determined with further examination.²² The appearance of femoral medial rotation may also suggest poor performance of the hip lateral rotators or reduced extensibility of the TFL-ITB. These muscle properties can be assessed with further testing.

When the foot is directed laterally during stance, it may be the result of an acquired postural impairment, such as femoral lateral rotation, or a structural impairment, such as femoral retroversion, tibial external torsion, or foot deformity. The location of the impairment should be assessed (e.g., femur or tibia) and to determine if the impairment is acquired or structural so that treatment may be adjusted accordingly.

Tibial torsion is described as a rotation of the tibial shaft. Although we have observed individuals with

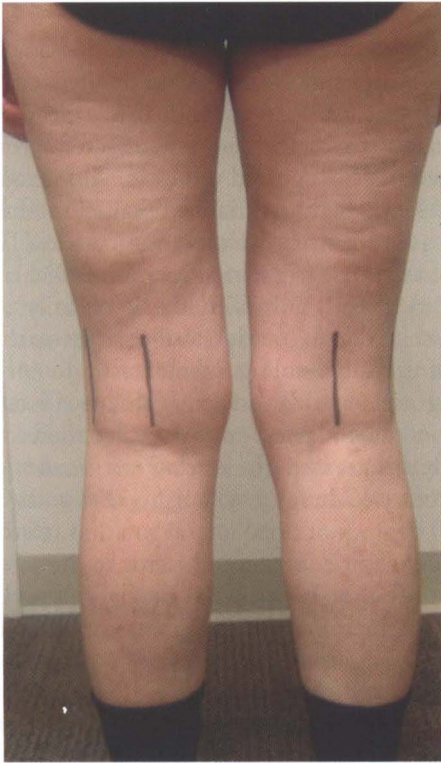


Figure 7-9. Femoral medial rotation. Note the medial and lateral hamstring creases are not an equal distance from the medial and lateral aspects of the knee, respectively. In fact, on the right lower extremity, the lateral hamstring is barely visible.



Figure 7-10. Tibial torsion on the right. Note position of the foot relative to the knee. The femur appears to be in medial rotation. However, the foot is laterally deviated, which leads the clinician to suspect torsion or tibial lateral rotation. The specific test for tibial torsion should then be performed.

internal tibial torsion, external tibial torsion is much more common. External tibial torsion is demonstrated when the distal tibia is rotated in the lateral direction greater than 20 to 40 degrees³⁵⁻³⁷ compared to the proximal tibia (Figure 7-10). External tibial torsion may be a compensation that develops when femoral anteversion is present and the individual attempts to correct a toe-in alignment. When external tibial torsion is determined to be present, the position of the foot should not be corrected. Trying to align the foot straight ahead will compromise the normal alignment of the ankle/foot and affect the ability of the individual to dorsiflex the ankle.²² Attempting this correction could also affect the knee by imposing medial rotation of the tibia on the femur.

Alignment of the Patellofemoral Joint

Normal Alignment

Patellar alignment may be viewed anteriorly. In the frontal plane, the patella should be centered in the trochlear groove, although imaging has suggested a slight lateral deviation.²⁷ In the sagittal plane, patellar alignment is represented by a Insall-Salvati ratio.³⁸ The Insall-Salvati ratio is the ratio of the patellar tendon length compared to the patellar height with the knee in 60 degrees of flexion. A normal Insall-Salvati ratio is 1 ± 0.2 . Although an estimate may be made clinically, measurements are best determined by lateral radiographs.

Impairments

Impaired patellar alignment may lead to abnormal stresses on the patellofemoral joint and surrounding soft tissues that with time may lead to peripatellar pain. The most common alignment impairments of the patella are excessive lateral or excessive superior displacement. Poor performance of the vastus medialis oblique (VMO) muscle and a short, stiff TFL-ITB are thought to contribute to lateral patellar displacement;³⁹ however, there is limited research to demonstrate this correlation.

By definition, lateral patellar tilt is present when the lateral patellar border is posterior to the medial patellar border and the lateral border cannot be elevated in the anterior direction.⁴⁰ The observation of lateral patellar tilt has been shown to be associated with a lateral patellar tilt angle greater than 10 degrees when measured by magnetic resonance imaging (MRI). Further study is needed, however, to assess the association of lateral patellar tilt and the presence of pain.

Excessive superior patellar displacement, also known as *patella alta*, is represented by an Insall-Salvati ratio greater than or equal to 1.2. The superior patellar displacement may indicate that the quadriceps are relatively more stiff than the patellar tendon. This relationship is detailed in the “Knee Extension Syndrome” section. Patella baja, or excessive inferior patellar displacement,

has an Insall-Salvati ratio less than or equal to 0.8. Patella baja may be observed as a complication after surgical procedures such as ACL reconstruction, which may be related to the scarring down of the patellar tendon after a surgical procedure.

Although patellar malalignment is believed to be a contributing factor to various knee pain problems, the clinical assessment of patellar alignment is unreliable.⁴¹ Therefore the entire clinical picture must be considered.

MOTIONS OF THE KNEE JOINT

Sagittal Plane

Knee Flexion and Extension

In the sagittal plane, the tibiofemoral joint flexes and extends about a medial-lateral axis passing transversely through the femoral condyles. The axis of rotation does not remain in one location but instead shifts and forms an evolute during the movement. The range of motion (ROM) available varies with age (Table 7-2). Passive ROM (PROM) at the tibiofemoral joint does not change significantly during the adult years^{42,43}; however, reduced extensibility of the rectus femoris and hamstring muscles has been shown to significantly contribute to joint limitations in the older individual.⁴³

Frontal Plane

In the frontal plane, the tibiofemoral joint abducts and adducts around an anterior to posterior axis. Normal values for tibial adduction and abduction relative to femur are highly variable, with reported mean total values ranging from 2 to 14 degrees.⁵³⁻⁵⁷ There is less motion available when the knee is extended, with only 2 to 6 degrees of total abduction and adduction,^{53,54} compared to when the knee is flexed, and motion can increase to 14 degrees.⁵³⁻⁵⁷ Abduction and adduction is typically a passive motion that occurs during activities such as gait.

TABLE 7-2

Knee Flexion and Extension ROM by Age

Age	Passive ROM (Degrees)		Active ROM (Degrees)	
	Extension*	Flexion	Extension	Flexion
Neonate (0-10 days)	20 ⁴⁴⁻⁴⁷	150 ^{46,47}		
3 months	10	145 ⁴⁶		
6 months	3	140 ⁴⁶		
Adults up to age 74	5	155 ^{48,49}	0	140 ^{23,49-52}

*Hyperextension is defined as greater than 5 degrees of extension.
ROM, Range of motion.

Transverse Plane

In the transverse plane, the tibiofemoral joint rotates around a vertical axis located approximately at the intercondylar eminence.⁵⁸ An individual is expected to have approximately twice the amount of lateral rotation as medial rotation.⁵⁹ Reported values for tibiofemoral rotation ROM are highly variable because of the various methods used to assess tibiofemoral rotation. With the knee flexed to 90 degrees, total rotation ROM is between 25 to 57 degrees.^{53,59-63} With the knee fully extended, there is essentially no rotation available due to the passive tension of the surrounding ligaments.

During either tibial-on-femoral knee extension or femoral-on-tibial knee extension, conjunct rotation occurs; this is termed the *screw-home mechanism*. This passive rotary-locking mechanism results in approximately 10 degrees of tibial lateral rotation relative to the femur. The major contributing factor to the screw-home mechanism is the shape of the medial femoral condyle that curves approximately 30 degrees laterally, helping to direct the tibia toward its locked position in lateral rotation.²⁶

MOTION OF THE PATELLOFEMORAL JOINT

In knee extension, the patella is slightly laterally displaced. With flexion from 0 to 30 degrees, it glides inferiorly and medially. As the knee flexes greater than 30 degrees, the patella continues to glide inferiorly, but changes to a lateral glide.^{64,65} During extension from a flexed position, the patellar motion is the reverse of flexion. These motions are so small that they are hardly noticeable to the observer when motion is normal. Tilting and rotation are also reported to occur in the patella. However, there is no consensus in the amount of patellar motion and the reliability in evaluation of position and movement is limited.

KNEE MOTION DURING GAIT

Sagittal Plane

At initial contact (heel strike), the knee flexes 5 degrees, then continues to flex to 10 to 15 degrees during the initial 15% of the gait cycle. During this time, the quadriceps are working eccentrically to provide shock absorption as the body weight is transferred to the limb. The knee reaches almost full knee extension just before heel off, and at heel off, it begins to flex again. Approximately 35 degrees of knee flexion should be noted at toe off and about 60 degrees (maximum flexion) is seen at midswing.⁶⁶ The knee then extends again to almost full knee extension just before initial contact. Children demonstrate a similar pattern; however, they tend to walk with more knee flexion. They do not get as much extension as adults during midstance or before initial contact.^{67,68}

Frontal Plane

Minimal tibial abduction/adduction may be noted during the gait cycle with a maximum of 5 degrees.^{25,69}

Transverse Plane

Generally, during gait, the tibia medially rotates from heel strike until 20 percent of gait cycle (just before midstance). The tibia then laterally rotates until toe off and medially rotates through swing.^{25,69} Normal rotation between the tibia and femur during the gait cycle should be approximately 8 to 9 degrees.^{25,69} At initial contact, the tibia is laterally rotated about 2 to 3 degrees relative to the femur. From initial contact through midstance, the tibia is medially rotated more than the femur, approaching 5 degrees of tibial medial rotation compared with the femur. During swing, the tibia is laterally rotated relative to the femur.

KNEE MOTION DURING RUNNING

Knee motion during running is similar to walking; however, the knee is relatively more flexed throughout the cycle.⁶⁶ On heel strike, the stance knee flexes up to 45 degrees as the quadriceps work eccentrically to aid shock absorption. The knee then extends during stance; however, it never reaches full extension. At midstance, the knee remains flexed approximately 25 degrees. Maximum knee flexion of 90 degrees occurs during swing phase. A similar pattern of knee motion occurs with all speeds of running; however, as speed increases, the amount of knee flexion during swing increases as high as 130 degrees.

MUSCLE ACTIONS OF THE KNEE

Extensors

The quadriceps muscle is the primary extensor of the knee joint and consists of four muscles: vastus intermedius, vastus lateralis, vastus medialis, and rectus femoris (Figure 7-11). The rectus femoris is the only one of these muscles that crosses both the hip and knee, allowing it to also act as a hip flexor.

The quadriceps angle, or Q-angle, represents the line of the resultant force of the quadriceps that tends to pull the patella superiorly and laterally relative to the patellar ligament. The Q-angle is represented by the angle between a line connecting the anterior superior iliac spine (ASIS) to the midpoint of the patella and a line connecting the tibial tubercle to the midpoint of the patella (Figure 7-12). The normal values for Q-angle are less than 10 degrees in men^{25,51,70} and less than 15 degrees in women.^{25,51,70} A Q-angle larger than normal is proposed to create excessive lateral forces on the patella through a bowstring effect that may predispose the patella to pathological changes. Q-angle can be influenced by excessive femoral anteversion, genu recurvatum, ankle/foot pronation, lateral tibial rotation, genu valgus,

patellar alignment, and tibial tubercle anomalies.^{2,70,71} The Q-angle should not be confused with the physiologic valgus of the knee.

Quadriceps muscle impairments related to knee pain may include poor performance or overrecruitment. As mentioned previously, the oblique portion of the vastus medialis (VMO) may provide an important restraint to lateral patellar displacement given the angulation of the fibers that attach to the patella. Poor performance of the VMO may contribute to excessive lateral patellar displacement.³⁹

With intensive physical training or loading through weight training or sports, the quadriceps may become relatively too stiff or short and contribute to excessive stress on the patella, patellar ligament, or tibial tubercle. This excessive pull superiorly may be associated with patella alta. In contrast, the quadriceps can become functionally weak when habitual alignment of knee hyperextension is present.

The articularis genus is a small muscle located on the anterior distal femur that inserts into the synovial membrane of the knee joint. As the knee is extended, it assists in drawing the synovial membrane upward and preventing folds of the membrane from becoming compressed within the knee joint.

Flexors

The hamstring muscles are comprised of the semimembranosus and semitendinosus muscles medially and the biceps femoris muscle laterally (see Figure 7-16). Their primary actions include knee flexion and hip extension; however, they also assist with hip medial and lateral rotation and may contribute to tibial medial and lateral rotation. The hamstrings are at risk of overuse when synergists, such as the gluteus maximus, are underused.²² For example, when the foot is fixed on the ground, the hamstrings can extend the knee by pulling the knee back to the body through its action as a hip extensor. Usually, when hamstring dominance such as this occurs, the quadriceps and gluteus maximus are not performing optimally. This movement impairment is commonly seen in individuals with a swayback alignment²² and genu recurvatum.

Movement impairments in the transverse plane may be the result of impaired hamstrings. The medial hamstrings assist in medial rotation of the hip and can become dominant and shorter in length compared to the biceps femoris. This imbalance in synergists is seen when an individual maintains excessive hip medial rotation or participates in sports or activities that tend to position or encourage hip medial rotation such as cycling. The biceps femoris assists in lateral rotation of the femur and lateral rotation of the tibia. When the primary hip lateral rotators are not performing optimally, the biceps femoris may compensate by increasing its action in an attempt to control hip lateral rotation.²² The overuse of the biceps in this way may lead to a muscle strain. The biceps femoris may also contribute to lateral rotation or

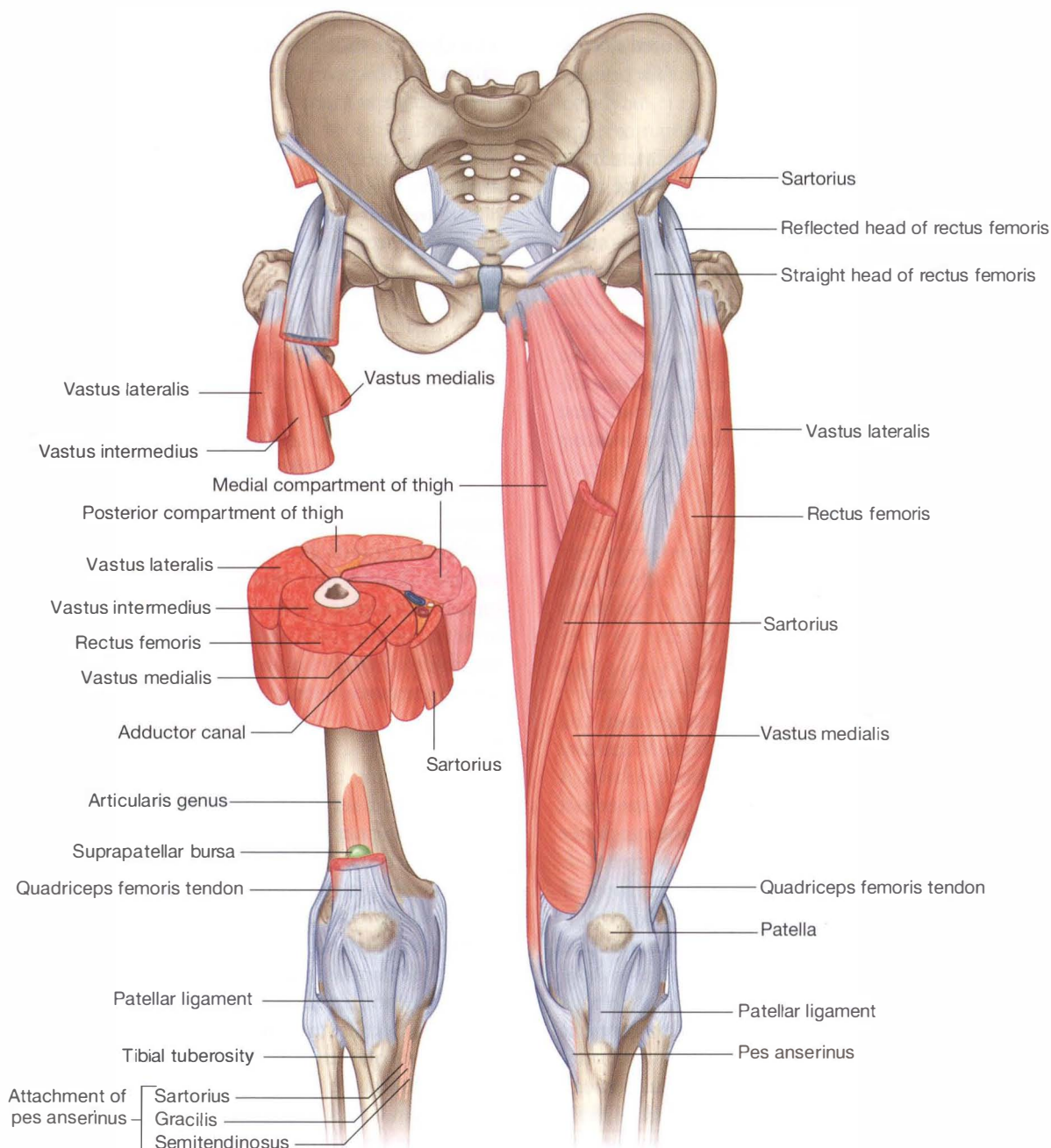


Figure 7-11. Quadricep muscles. The quadriceps can be seen here including the reflected rectus femoris (the only two joint muscle of the quadriceps), along with the vastus lateralis, vastus intermedius and vastus medialis. (From Drake RL, Vogl AW, Mitchell AWM: *Gray's anatomy for students*, ed 2, Baltimore, 2009, Churchill Livingstone.)

posterolateral displacement of the lower leg relative to the femur, given its distal attachment to the fibular head. A patient case demonstrating this phenomena is provided by Sahrman.²²

The sartorius muscle flexes, abducts, and laterally rotates the hip and also flexes the knee and rotates it medially. The gracilis acts primarily to adduct the hip and also flexes and medially rotates the knee. Both muscles insert below the medial tibial condyle into the pes anserinus along with the semitendinosus tendon. The pes

anserinus insertion may become injured with excessive tibial lateral rotation contributing to medial knee pain.

The gastrocnemius and soleus muscles are powerful ankle plantarflexors; however, the gastrocnemius is also a knee flexor (Figure 7-13). The plantaris also assists with ankle plantarflexion and knee flexion. The gastrocnemius and soleus are described in more detail in Chapter 8. Impairments in length and strength of the gastrocnemius are fairly common. Related to the knee, individuals who stand in knee hyperextension tend to develop shortness

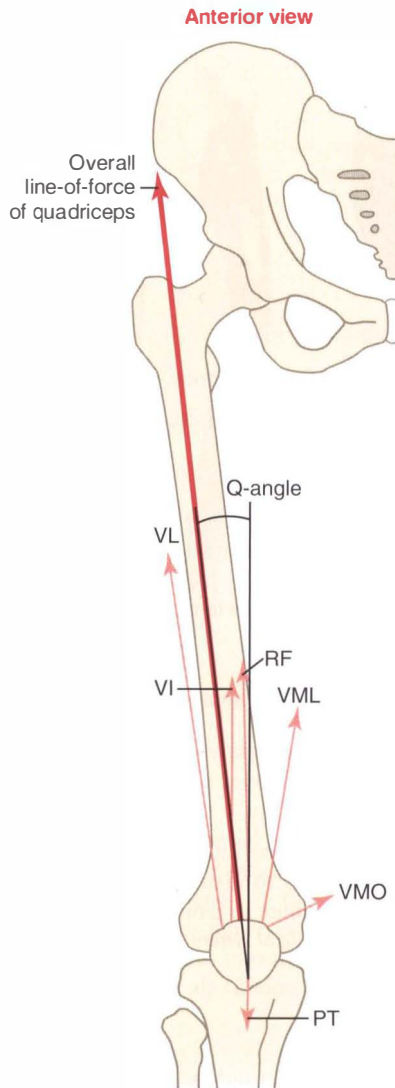


Figure 7-12. Q-angle. The overall line-of-force of the quadriceps is shown as well as the separate line-of-force of the muscles within the quadriceps. The vastus medialis is divided into its two predominant fiber groups: the obliquus and the longus. The net lateral pull exerted on the patella by the quadriceps is indicated by the Q-angle. PT, Patellar tendon; RF, rectus femoris; VI, vastus intermedius; VL, vastus lateralis; VML, vastus medialis (“longus”); VMO, vastus medialis (“obliquus”). (From Neuman DA: *Kinesiology of the musculoskeletal system: foundations for rehabilitation*, ed 2, St Louis, 2010, Mosby.)

of the gastrocnemius as a result of the alignment of relative plantarflexion. In movement impairments of the knee, poor performance of the ankle plantarflexors may be observed as a lack of push-off during gait, a delayed heel rise, or excessive dorsiflexion during foot flat.

The popliteus muscle is a knee flexor and tibial medial rotator (see Figure 7-13). The popliteus is also known as the key to the knee, because it “unlocks” the knee as it moves from the fully extended (locked) position into flexion. The popliteus unlocks the knee either by medially rotating the tibia in a non-weight-bearing activity or laterally rotating the femur in a weight-bearing activity.

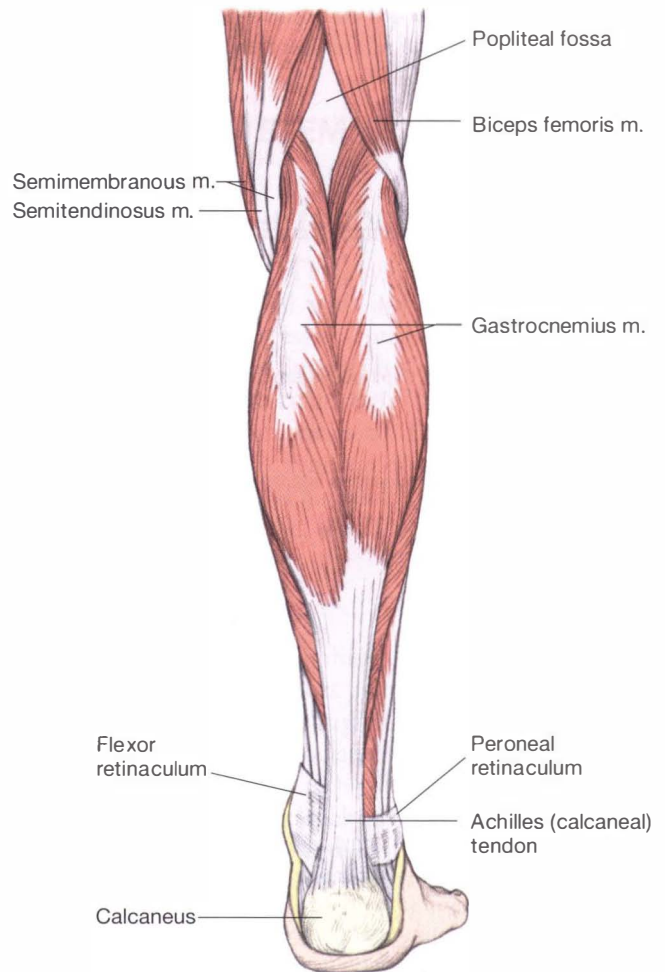


Figure 7-13. Posterior muscles of the lower leg. The gastrocnemius is cut to allow visualization of the soleus muscle. (From Mathers, et al: *Clinical anatomy principles*, St Louis, 1996, Mosby.)

The popliteus is mostly active during crouching and may help the posterior cruciate ligament (PCL) prevent anterior dislocation of the femur.^{23,26}

Other Important Hip Muscles That Can Affect the Knee

Lateral Rotators of the Hip

The primary hip lateral rotators include the deep (sometimes referred to as short or intrinsic) lateral rotators and the gluteus maximus. The intrinsic or deep lateral rotators of the hip include the piriformis, gemellus superior and inferior, obturator internus and externus, and quadratus femoris muscles (Figure 7-14). The obturator externus, however, is generally considered a secondary lateral rotator of the hip because its line of force is so close to the longitudinal axis of rotation when the hip is in the anatomical position. As primary lateral rotators of the hip, the deep lateral rotators serve to provide precise control of rotation of the femoral head in the acetabulum, thus maintaining the integrity and stability of the hip

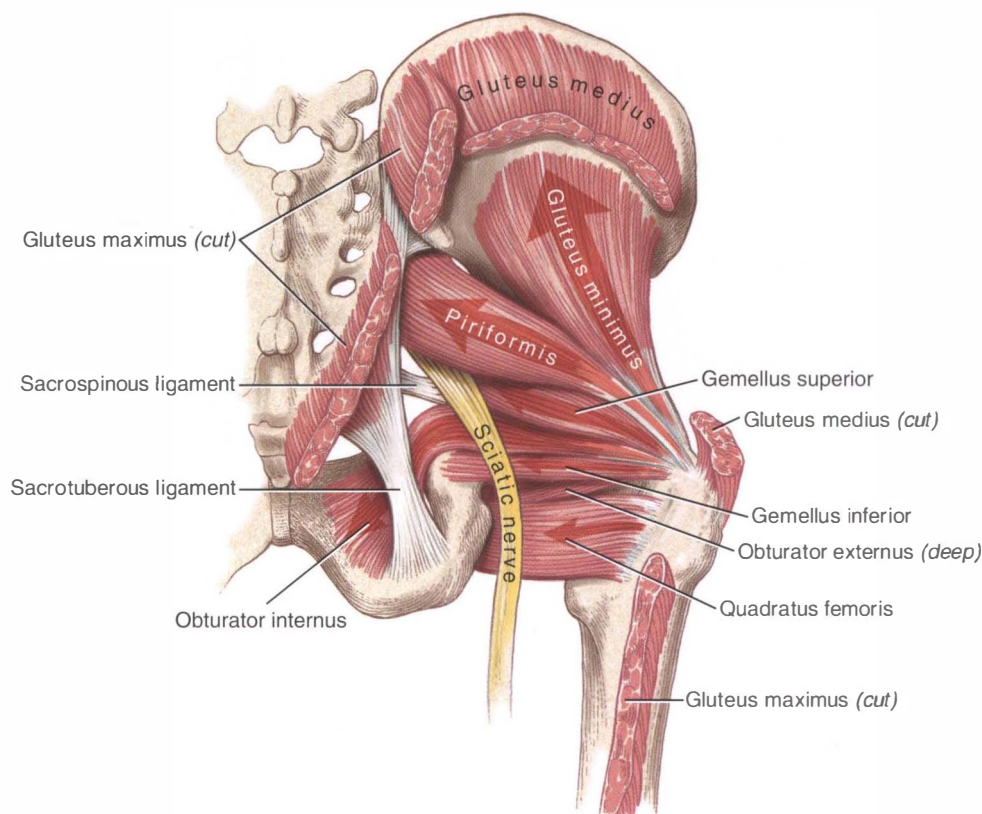


Figure 7-14. Hip lateral rotators. Some of the deep lateral rotators of the hip are depicted here—obturator internus, obturator externus and piriformis. They help to maintain control and stability of the hip joint. When lengthened or weak, they can contribute to femoral medial rotation and knee pain. (From Neuman DA: *Kinesiology of the musculoskeletal system: foundations for rehabilitation*, ed 2, St Louis, 2010, Mosby.)

similar to the way that the rotator cuff muscles provide control of the humeral head in the glenoid. In patients with knee pain syndromes, these muscles often become lengthened and weak, thus losing the precise control of the hip and allowing hip medial rotation to occur.

In addition to being a primary lateral rotator, the gluteus maximus muscle is also a primary hip extensor (Figures 7-15 and 7-16). Individuals who stand in a sway-back alignment commonly have atrophy of the gluteus maximus because their weight line is posterior to their center of mass.^{22,23} In these cases, when the gluteus maximus becomes functionally weak, the hamstrings may become the dominant hip extensors instead of the gluteus maximus.

A large portion of the gluteus maximus muscle attaches into the ITB. Therefore shortness or stiffness of the gluteus maximus can contribute to relative stiffness/flexibility issues involving the ITB. Relative stiffness/flexibility as a result of shortness or stiffness of the gluteus maximus through the ITB seems to be more common in males than females and should be suspected if the patient sits in excessive hip abduction.

The secondary lateral rotators of the hip include the sartorius, the biceps femoris, and the posterior fibers of the gluteus minimus and medius (Figure 7-16).

The posterior gluteus medius acts to abduct, extend, and laterally rotate the hip. The length and strength of the posterior gluteus medius is often affected by postural changes at the pelvis and hip. If an individual stands with the right iliac crest higher than the left or with the right hip in medial rotation, the posterior gluteus medius on the right may be lengthened and possibly weak, particularly if tested in the shortened position. Poor performance of this muscle is often a key factor in knee pain problems.

Because control of the knee is needed throughout the range of hip flexion to hip extension in activities such as sit to stand and cutting, the muscle performance of the hip lateral rotators should be tested with the hip flexed and with the hip extended. A number of the hip lateral rotators change their action when the hip is flexed. Although they are hip lateral rotators when the hip is in 0 degrees of flexion, the piriformis and portions of the gluteal muscles change to medial rotators of the femur as the hip is flexed to 90 degrees. This switch in action is due to a change in the location of the muscles' moment arms relative to the axis of rotation.^{72,73} Once identified, muscle performance deficits can then be targeted with specific exercises, with the hip flexed or hip extended. Given their likely role in providing stability of the hip,

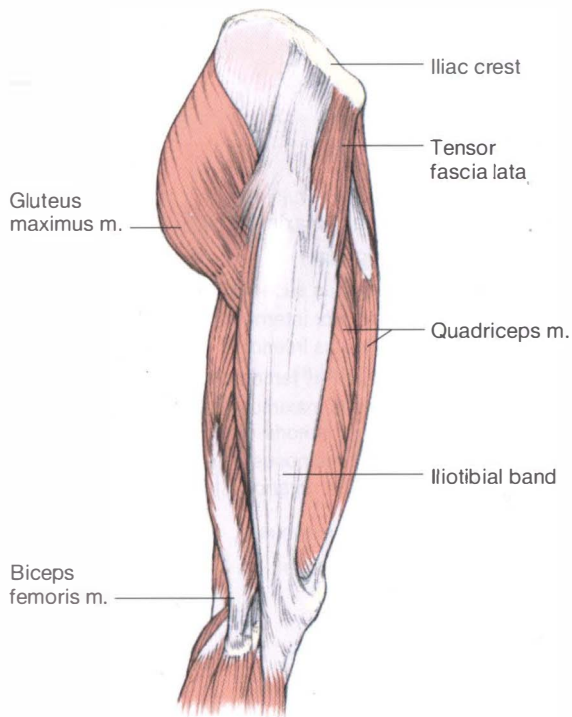


Figure 7-15. Gluteus maximus and tensor fasciae latae–iliotibial band. The TFL-ITB is a major contributor to impairments of the lower extremity. When it is too short or too dominant, it often contributes to femoral medial rotation. Also, the attachment of the TFL-ITB to the patella and the lateral tibial tuberosity may result in impairments of the patella and lateral rotation of the tibia. From this figure, also note the large contribution of the gluteus maximus into the ITB. (From Mathers LH, Chase RA, Dolph J, et al: *Clinical anatomy principles*, St Louis, 1996, Mosby.)

specific attention to the deep lateral rotators (hip flexed position) is warranted.

Medial Rotators of the Hip

The TFL-ITB is a two-joint muscle complex that flexes, abducts, and medially rotates the hip and laterally rotates the tibia through its insertion onto the lateral tibial tubercle (see Figure 7-15). The TFL-ITB also assists in stabilizing the knee when the knee is extended, although it does not actively extend the knee.^{23,26} When the TFL-ITB becomes short or too stiff, it can cause a compensatory motion such as lateral tibial rotation or valgus at the knee. The TFL-ITB can also contribute to patellar lateral glide as a result of its insertion onto the lateral patella.²²

The anterior fibers of the gluteus medius abduct, flex, and medially rotate the hip. Because the anterior fibers of the gluteus medius tend to be stronger than the posterior fibers, the imbalance often results in excessive medial rotation. The anterior gluteus minimus also abducts, flexes, and medially rotates the hip, contributing further to the potential for excessive medial rotation of the hip.²² When testing performance of the medial rotators of the hip, it is important to remember that muscle function may be increased when the hip is flexed, compared to when the

hip is extended.^{72,73} When the hip is extended, there are no primary medial rotators of the hip.²⁶

MOVEMENT SYSTEM SYNDROMES of the Knee

TIBIOFEMORAL ROTATION SYNDROME

Tibiofemoral rotation (TFR) syndrome is characterized by knee pain associated with impaired rotation of the tibiofemoral joint. Excessive rotation between the tibia and femur can be seen during tests of alignment, tests of movement, and performance of functional activities. There are two subcategories of TFR syndrome: TFR with valgus (TFRVal) syndrome and TFR with varus (TFRVar) syndrome. This text focuses on the most common TFR syndrome, TFRVal, and only briefly discusses TFRVar.

Symptoms and History

Individuals that have the diagnosis of TFR syndrome (with valgus or varus) report pain along the tibiofemoral joint line, the peripatellar regions, or at the insertion of the ITB. Pain is often associated with activities that contribute to rotation between the tibia and femur, including weight-bearing activities, such as walking and stair climbing, or non-weight-bearing activities, such as sitting with the lower leg placed in a rotated position relative to the femur. Individuals that demonstrate this movement fault may include ballet dancers, runners, equestrians, and sedentary workers. Those with OA who report instability⁷⁴ are also likely to fall into the TFR category.

TIBIOFEMORAL ROTATION WITH VALGUS SYNDROME

Individuals with TFRVal syndrome demonstrate excessive medial rotation or adduction of the femur relative to the tibia, or excessive lateral rotation or abduction of the tibia relative to the femur resulting in knee valgus. This motion has also been described as medial collapse^{2,75} or poor dynamic knee stability.^{6,76} Clinically, it appears that females are more likely to demonstrate TFRVal than men, and this observation appears to be supported in the literature as well.⁷⁶⁻⁷⁸ Although it is more common in women, TFRVal syndrome may be present in males, thus the need to take an individualized approach to examination.

Symptoms and History

Structures that may be injured in an individual with TFRVal syndrome include structures of the tibiofemoral joint, the patellofemoral joint, the ITB, and surrounding musculature. A number of studies have demonstrated an association between the movement impairment associated with TFRVal syndrome and knee injury,^{1,4,6,79-84} highlighting the importance of assessing the entire lower extremity. In a prospective study, Hewett et al⁶ reported that during the landing phase of a jump,

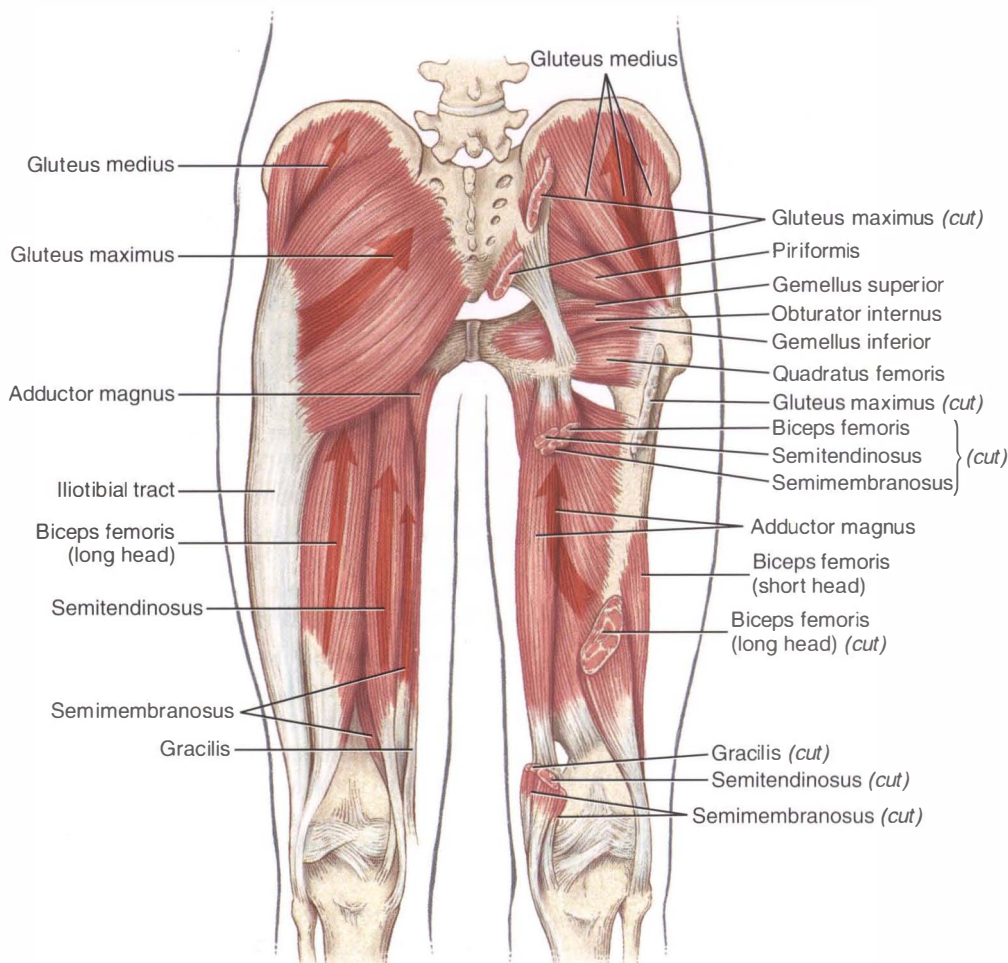


Figure 7-16. The posterior muscles of the hip. The left side highlights the gluteus maximus and hamstring muscles (long head of the biceps femoris, semitendinosus, and semimembranosus). The right side highlights the gluteus medius and five of the six short external rotators, i.e., piriformis, gemellus superior and inferior, obturator internus, and quadratus femoris. (From Neuman DA: *Kinesiology of the musculoskeletal system: foundations for rehabilitation*, ed 2, St Louis, 2010, Mosby.)

young women with a knee valgus angle greater than 8 degrees were more likely to suffer a noncontact ACL injury than those with an angle of less than 8 degrees (Figure 7-17). In addition, Hewett's group demonstrated that the risk of ACL injury is reduced with training to correct the movement impairment.^{13,85}

Overuse syndromes, such as PFPS and ITB friction syndrome, have also been associated with TFRVal. Traditional treatment of PFPS has focused on the movement and alignment of the patella^{11,86,87}; however, numerous studies have demonstrated that the alignment or movement of the tibia and femur may be associated with PFPS.^{1,3,81-84} Although repetitive knee extension-flexion has been implicated in ITB friction syndrome, a recent study demonstrated that increased hip adduction may contribute to the onset of ITB friction syndrome.⁴

An examination that includes the assessment of movement quality and tests of muscle length and

muscle performance, in addition to tests to identify injured structures, is recommended. Key tests and signs of the movement examination are described in the following sections. Tests to assess specific knee structures, such as the ligaments or meniscus, are not the focus of this text; therefore the reader is encouraged to consult other available sources.*

Key Tests and Signs

Alignment Analysis

While the patient is standing, the examiner assesses the overall posture and specific alignment of the lower extremities. Alignment is often not predictive of the movement impairment; however, alignment may contribute to the movement impairment. From the posterior

*Suggested reading: Magee DJ: *Orthopedic physical assessment*, ed 4, St Louis, 2002, Saunders.

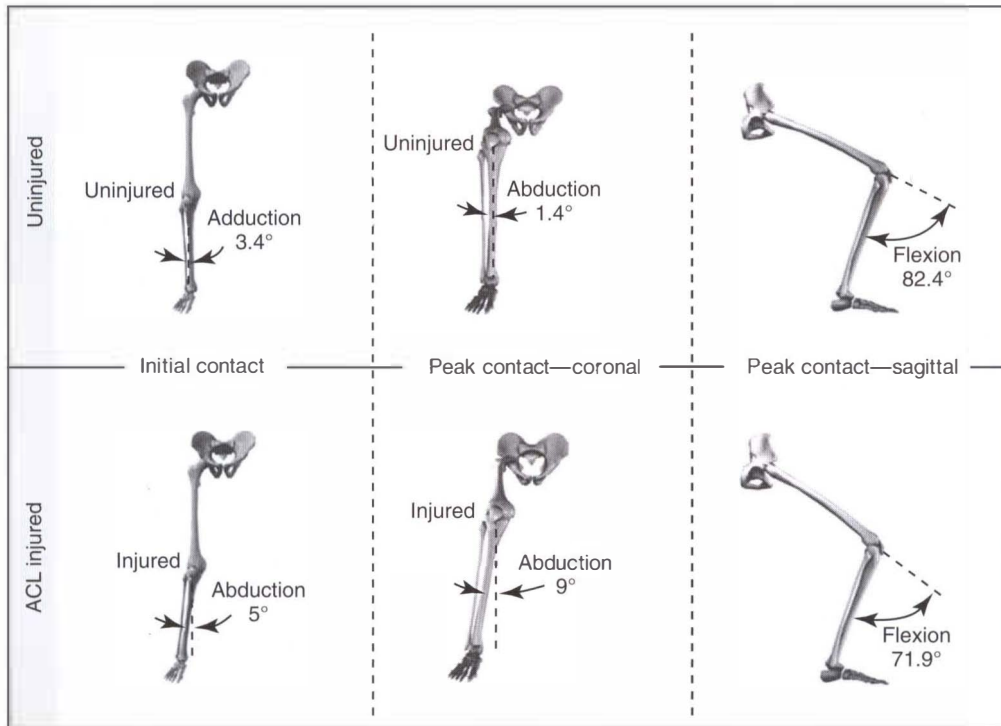


Figure 7-17. Biomechanical model depicting mean knee joint kinematics during the drop vertical jump at initial contact and maximal displacement in the ACL-injured and uninjured groups ($n = 9$ knees and $n = 390$ knees, respectively). *Left*, Coronal plane view of knee abduction angle at initial contact in the ACL-injured and uninjured groups. *Center*, Coronal plane view of maximum knee abduction angle in the ACL-injured and uninjured groups. *Right*, Sagittal plane view of maximum knee flexion angle in the ACL-injured and uninjured groups. (From Hewett TE, Myer GD, Ford KR, et al: Biomechanical measures of neuromuscular control and valgus loading of the knee predict anterior cruciate ligament injury risk in female athletes: a prospective study, *Am J Sports Med* 33:492, 2005.)

view, the patient may demonstrate medial rotation of the femur or lateral rotation of the tibia (Figure 7-18). The patient may also demonstrate knee valgus. From the lateral view, posterior pelvic tilt with hip extension and knee hyperextension might indicate poor performance of the gluteals. A lordotic posture might suggest short or stiff hip flexors and poor abdominal control. Excessive pronation or supination of the foot should also be noted.

Movement Impairments

Standing tests. Single-leg stance should be assessed by comparing both lower extremities. During single-leg stance on the involved limb, the patient will demonstrate excessive medial rotation of the involved femur. The patient may also demonstrate excessive ankle pronation. During single-leg stance on the uninvolved limb, tibial lateral rotation may be noted in the involved limb when the knee is flexed to 90 degrees (Figure 7-19). In addition to movement quality, the examiner may observe the patient's ability to maintain balance when standing on one limb. Poor stability may indicate poor proprioception, which may be a contributor to the patient's pain problem.

During hip and knee flexion in stance (partial squat), the patient will demonstrate femoral (hip) adduction/

medial rotation and knee valgus (Figure 7-20, *A*). This motion may increase or produce the patient's symptoms. When the motion is corrected (Figure 7-20, *B*), the pain typically improves, supporting the diagnosis of TFRVal syndrome.

Supine tests. When performing the two-joint hip flexor length test,⁸⁸ lateral rotation or abduction of the tibia may be observed when the involved limb is lowered into hip extension (Figure 7-21). If the patient reports pain during the test, the test is repeated with stabilization of the tibia to prevent the observed motion. If the patient's symptoms are improved, then the movement impairment of TFR is supported. Further tests would be needed to determine if the diagnosis is TFRVal syndrome or TFRVar syndrome.

Prone tests. Lateral rotation of the tibia during knee flexion in prone may be observed. If this motion is painful, then the secondary test should be performed by repeating the motion while preventing the tibial rotation. If the patient's symptoms are improved, then the movement impairment of TFR is supported. Further tests would be needed to determine if the diagnosis was TFRVal syndrome or TFRVar syndrome. During the performance of hip medial or lateral rotation, the examiner may

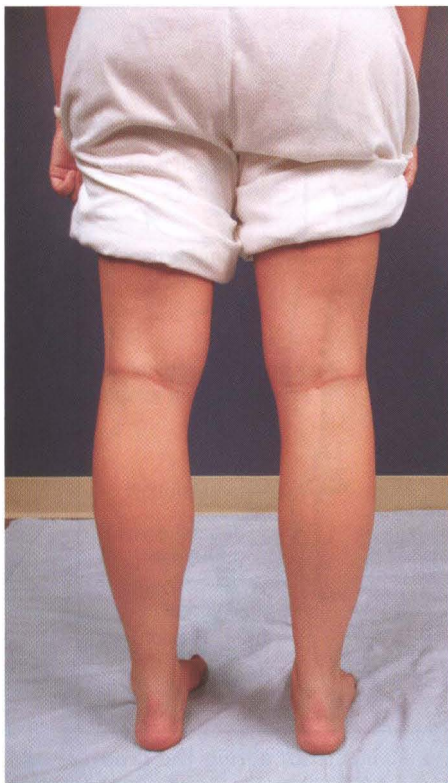


Figure 7-18. Femoral medial rotation. Note the insertion of the medial and lateral hamstrings. The medial hamstrings are more prominent, indicating femoral medial rotation. The lateral hamstring insertion is barely visible on the right lower extremity.

observe excessive rotation or gliding of the tibia relative to the femur. If hip rotation ROM is measured in this position, care should be taken to prevent motion of the tibia relative to the femur, which may inflate the value of hip rotation ROM.⁸⁹

Joint Integrity

In our experience, individuals with TFRVal syndrome often demonstrate an overall laxity in the tibiofemoral joint in the involved and uninvolved joint; however, this laxity has not been quantified. The therapist may suspect ligamentous laxity if there is excessive motion at the tibiofemoral joint while testing hip rotation. In the absence of trauma, tests for ligamentous integrity are often negative with the patient demonstrating equal motion on both limbs.

Muscle Length Impairments

A common muscle impairment includes reduced extensibility of the TFL-ITB,⁹⁰ which may contribute to a relative lateral rotation of the tibia through its attachment on the lateral tibial tubercle.

Muscle Strength/Performance Impairments

Impairments of muscle strength and performance include poor performance of the hip lateral rotators and hip



Figure 7-19. Single-leg stance observing the limb being flexed. Note the alignment of the foot. **A**, The left uninvolved foot is vertical relative to the floor. **B**, The right foot is angled away from the vertical indicating tibial lateral rotation.



Figure 7-20. Hip and knee flexion in standing. **A**, Note the femoral adduction and medial rotation. There is minimal pronation at the foot, which may contribute to excessive stresses at the knee. **B**, Secondary test of hip and knee flexion in standing. The movement impairment of femoral adduction and medial rotation was corrected.

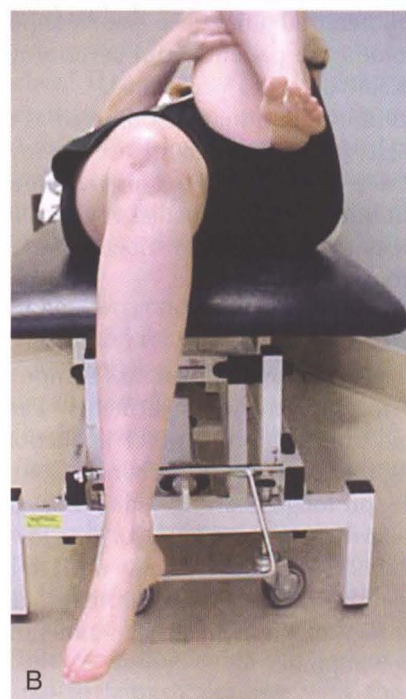


Figure 7-21. Tibial lateral rotation during two-joint hip flexor length test. **A**, Starting position of the two-joint hip flexor length test. Note position of the right tibia and foot in the sagittal plane. **B**, End position of the two-joint hip flexor length test. Note position of the right tibia and foot. Tibia is now more laterally rotated relative to the femur, secondary to the tension of the TFL-ITB as it is being stretched.

abductors.^{91,92} Tibial medial rotators may also be impaired, restricting their ability to control tibial lateral rotation, however these muscles are challenging to assess.

Functional Activities

Gait. During gait, excessive medial rotation or adduction of the femur during stance or tibial lateral rotation during swing may be observed. Excessive pronation of the foot may also be observed.

Step-up and step-down. Most patients with knee pain problems will report an increase in their symptoms with stair ambulation. A step-up and step-down test may be performed to assess the patient's preferred pattern. Patients with TFRVal syndrome will demonstrate femoral adduction and knee valgus with performance of this activity (Figure 7-22). If the movement is painful, a secondary test is performed by repeating the movement and correcting the movement impairment. Because this activity introduces significant stresses on the structures of the knee, reducing the patient's pain significantly may be difficult. If symptoms are not reduced with movement impairment modifications of either the tibiofemoral joint or the patellofemoral joint (see patellofemoral lateral glide syndrome), the patient's pain severity may be too high for the activity being performed.

Tibial lateral rotation may be observed as the patient attempts to clear the toes as they raise the involved foot to the next step (Figure 7-23). This movement impairment may indicate that the medial rotators of the tibia are not sufficiently stabilizing the tibia as the lateral hamstrings contract to flex the knee.

Other Functional Tests

Activities that aggravate the patient's symptoms should be assessed for movement impairments. Patients with TFRVal syndrome exhibit femoral adduction or knee valgus during the symptomatic activities. Common activities include prolonged sitting, squatting, and sit-to-stand. If the patient is an athlete or has low symptom irritability, higher level activities may need to be assessed to determine the movement impairment. These may include running,¹ single-leg squat,^{1,93} and various forms of jumping or hopping.^{1,76,94}

Summary of Examination Findings

TFRVal syndrome presents with the movement impairment of femoral adduction and medial rotation relative to the tibia or tibial abduction/lateral rotation relative to the femur that contributes to a knee valgus. Positions or movements associated with TFRVal syndrome are often painful, and when the movement impairments are corrected, pain is reduced.

Treatment

Primary Objectives

The primary objectives of a treatment program include the following:

1. Correct TFRVal during functional activities.
2. Improve performance of the hip lateral rotators, abductors and tibial medial rotators.
3. Increase extensibility of the TFL-ITB.
4. Address contributions of the foot if necessary.

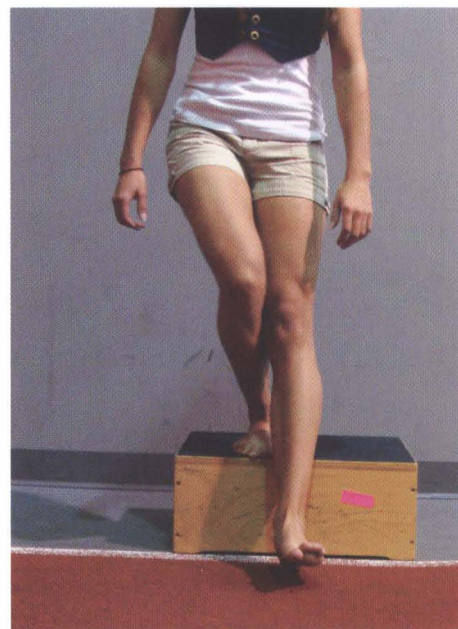


Figure 7-22. Step-down test. Note femoral adduction and knee valgus of the left stance limb.



Figure 7-23. Step-up test. Note tibial lateral rotation of the swing leg, indicating movement impairment of tibiofemoral rotation.

Corrective Exercise Program

Treatment for this classification includes educating the individual on correcting the postural habits and movements that contribute to the movement impairment and thus the pain problem. The patient is provided with a general description of the impairment: excessive rotation between the tibia and femur. Specific instruction for alignment and functional activities is provided and practiced by the patient. The patient is also instructed in exercises to address the associated muscle impairments.

Alignment. First, the patient is educated in correction of posture and functional activities. To improve alignment between the femur and tibia, the therapist must address impairments in both the sagittal and transverse planes in an effort to achieve a more neutral or ideal alignment. If hyperextension is present, the patient is instructed to unlock the knees. To align the tibia and femur in the transverse plane, the patient is asked to align knees over feet with neutral rotation of hips and tibias by decreasing medial rotation of femur and lateral rotation of tibia. To correct femoral medial rotation, the patient is instructed to contract his or her gluteals and hip lateral rotators to laterally rotate the femur. However, if structural tibial torsion or femoral anteversion is present, normal alignment will not be possible and attempts to “correct” the patient’s alignment may result in abnormal stresses to the adjacent joints. Instruction to the patient should emphasize proper alignment that accommodates for these structural impairments. For example, if the patient has tibial torsion, the appearance of a lateral foot progression angle or “turn out” should be allowed. If the patient demonstrates femoral anteversion, the appearance of medial rotation of the femur should be allowed.

Functional activities. Functional activities that contribute to the movement impairment must also be addressed. The functional activity that is most bothersome to the patient should be addressed first, followed by the activities in which the patient spends the most time such as work or school activities. This chapter covers the activities that are useful for most patients; however, the therapist is encouraged to use the principles of the MSI system to address other functional activities that may not be described here.

Gait. To control femoral adduction and medial rotation during gait, the patient is instructed to contract the “buttock muscles” of the stance limb during weight acceptance; the goal is to recruit the hip abductors and lateral rotators. This is sometimes difficult for the patient to achieve on the first visit, therefore an exercise like weight-shifting with unilateral muscle contraction may be useful to assist the patient who is learning to contract the muscles at the appropriate time. The patient should also be instructed to avoid rotating on a fixed foot when making turns.

If the patient is having significant pain in the knee, an assistive device may be suggested to decrease the forces through the affected knee. The cane should be placed in

the hand opposite the involved limb. Using the cane in the opposite hand has been shown to significantly reduce external moments⁹⁵ across the knee.

Another strategy during gait is to have the patient walk with the feet apart. This change in alignment shifts the adduction moment toward the medial knee and can decrease the pain. As with all recommended alterations in alignment or movement patterns, the change in the symptoms is the guide to the effectiveness and/or appropriateness of the recommendations.

Sit-to-stand; stand-to-sit. The patient should also be instructed to avoid femoral adduction, femoral medial rotation, and knee valgus when transitioning from a sitting position to a standing position. For proper performance of sit-to-stand, the patient is instructed to slide forward in the chair and place the feet hip width apart and aligned behind the knees. On rising, the patient should lean forward to advance the tibias anteriorly over the feet, then use the quadriceps and gluteus maximus muscles to lift the body up and forward out of chair. While performing this, the patient should keep the knee and toes aligned in the transverse plane. Common cues that are useful include “squeeze your seat and keep your knee over your second toe” and “do not let the knees come together.” If the patient has difficulty with the correction, a resistive band may be placed around the distal femurs and the patient instructed to gently push into the band to keep it taut as they rise from the chair. If the band becomes loose during the performance of the activity, the patient is provided feedback for the suboptimal performance.

Stairs. The instructions used in the previous paragraph are also useful for stairs. The patient should avoid femoral adduction, femoral medial rotation, and knee valgus while ascending and descending stairs. During stair ascent, the patient may need to shift the weight anteriorly (lean forward over the stairs) to more functionally engage the gluteals.⁹⁶

If the patient has significant pain with stairs, there are a number of methods to reduce symptoms during stair ambulation. These suggestions are useful for all patients with knee pain, despite their movement system syndrome. While ascending stairs, the patient is instructed to use a step-to pattern, leading with the uninvolved extremity and then advancing the involved extremity. As the patient improves and begins to use a step-over-step method, he or she may still be challenged in completing the step-up leading with the involved leg. The patient can use the plantarflexors of the uninvolved leg to help push-up from the lower step. The patient should also be encouraged to use the handrail to reduce the weight bearing on the involved limb.

Descending stairs is often painful for someone with knee impairments. While descending stairs, the patient may use a step-to pattern first leading with the involved extremity and then advancing the uninvolved extremity. Patients who are significantly limited may need to descend the stairs backward; however, this should be assessed

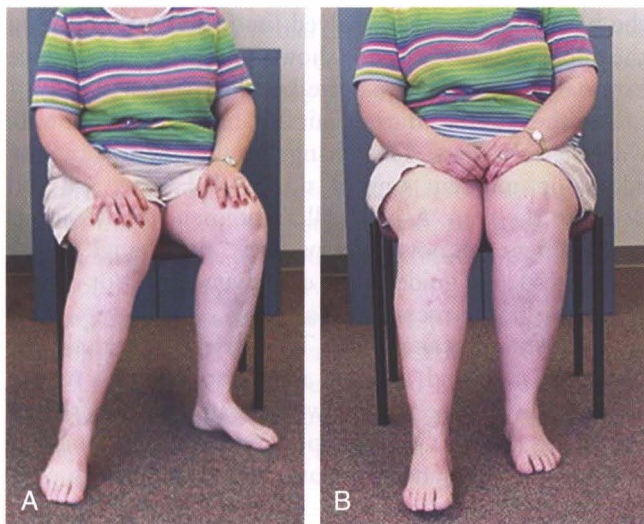


Figure 7-24. Sitting position. **A**, Patient with TFRVal syndrome and knee pain bilaterally demonstrates her working position. She is a transcriptionist and uses a foot pedal regularly. Note position of the feet relative to the knees. **B**, Working position corrected. Patient is instructed in a modified position. (From Harris-Hayes M, Sahrman SA, Norton BJ, et al: Diagnosis and management of a patient with knee pain using the movement system impairment classification system, *J Orthop Sports Phys Ther* 38(4):203-213, 2008.)

closely to be sure the patient can perform safely. As the patient improves and begins to use a step-over-step method, a useful method to reduce stress to the involved limb while descending stairs is to use the plantarflexors eccentrically to absorb some of the body weight as the body is lowered onto the lower step.

Other functional activities. Personal activities related to work, school, fitness, and leisure should also be addressed. The patient should be instructed to avoid the TFRVal movement impairment during functional activities. For example, in sitting, the patient may sit with the foot in a relatively lateral position to the knee. The patient should be instructed to modify the position so that the knee and foot are aligned in the transverse plane (Figure 7-24). An impairment may also be demonstrated in the patient's driving. Some patients change from the gas to brake pedal by keeping their heel in contact with the floorboard and rotating the tibia to move the foot, resulting in repetitive rotation between the tibia and the femur. These patients should be instructed to lift the foot from the floor as they change pedals to avoid the repetitive rotation, or they can rotate at the hip rather than the knee. After specific instruction in the performance of key activities, the patient should understand concepts that can be generalized to other activities.

Fitness activities. If the patient does not have a fitness program, then a discussion is warranted to encourage a fitness program as a goal. If the patient participates regularly in fitness, we encourage continued participation in some form of fitness, although the current program

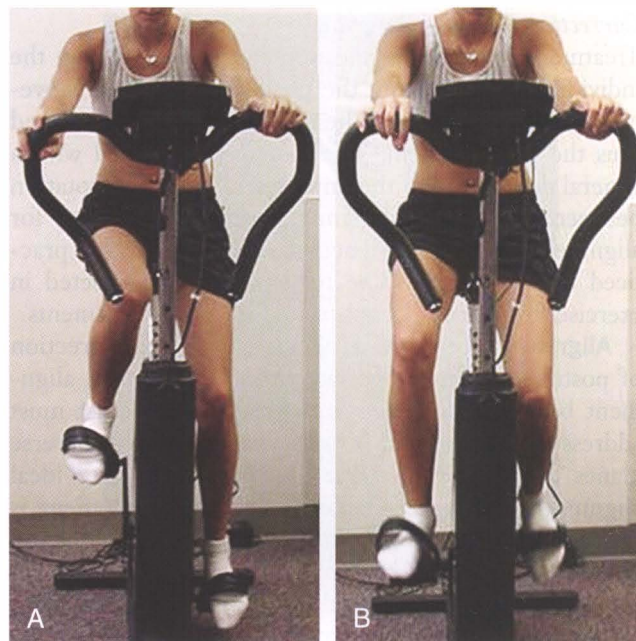


Figure 7-25. Fitness activity: Cycling. **A**, Note the valgus alignment of the right knee. **B**, Position is modified to correct for TFRVal syndrome.

may need to be modified. For example, the patient's aerobic activities may need to be modified by addressing the movement impairment (Figure 7-25) and possibly reducing the intensity. The modified intensity level should be related to the patient's stage of rehabilitation. For example, if the patient's injury is in Stage 1 for rehabilitation, then the patient may use one-leg cycling for aerobic conditioning and progress to activities in the water with the body submerged to reduce stresses to the knee. For Stage 2, the person may be instructed to use a bike or to start with a walking program while concentrating on maintaining proper tibiofemoral alignment. The intensity is then gradually increased as the patient's symptoms improve. Box 7-1 shows an example program to progress an individual back to running after injury.⁹⁷ The type of fitness equipment also needs to be considered. For example, if the patient has tibial torsion then Nordic Track or even bicycle pedals that require a fixed forward position of the feet can cause injury to the knee.

Home Exercise Program

In addition to modifying the patient's functional activities, the patient should be instructed in an exercise program to improve muscle performance and extensibility. Exercise prescription should be based on the results of the physical examination and include only exercises that address limitations specific to the patient. In addition, patients should be instructed in the appropriate response to the exercises. Appropriately, patients may feel some muscle soreness or fatigue with activities that overload the muscle. The pain will be in the muscle

BOX 7-1**How to Encourage and Promote Fitness without Injury****STAGE 1 FOR REHABILITATION**

- Use of one-leg cycling for aerobic conditioning after surgery.⁹⁷
- Water activities with the body submerged to reduce stresses on the knee.

STAGE 2 FOR REHABILITATION**Example: running**

- I. Early in the rehabilitation stages, the emphasis is placed on achieving an ideal gait pattern; speed or distance should not be emphasized. Assess gait pattern and instruct as appropriate.
- II. Interval training is recommended.
 - A. Begin with walking program and gradually mix in short bouts of running. Gradually increase the time running and decrease the time walking.
 1. Example of progression: Patient should be able to walk 30 minutes without an increase in pain or swelling to begin.
 - a. Run 1: Walk 4 minutes, run 1 minute, repeat 4 times for a total of 20 minutes
 - b. Rest day
 - c. Run 2: Walk 3 minutes, run 2 minutes, repeat 4 times for a total of 20 minutes
 - d. Rest day
 - e. Run 3: Walk 2 minutes, run 3 minutes, repeat 4 times for a total of 20 minutes
 - f. Continue to progress running appropriately. (This example will not be appropriate for all patients and must be adjusted as needed.)
 - g. Once the patient can run 1 mile without increasing pain or swelling, begin to progress to previous training levels.
 - B. It is expected that the patient may experience some generalized discomfort or swelling, particularly after surgery, with the initiation of running. If this generalized pain and swelling persists longer than 48 hours, then the running distance or intensity must be decreased. If the patient describes a stabbing pain or a pain that is consistent with tissue injury, running should be stopped and the patient reevaluated.
- III. Modify surface of training if indicated.
 - A. Instruct patient to initiate running with surfaces that reduce the ground reaction force on the lower extremities. If available, a track or chip trail would be a good surface to start. Concrete should be avoided if possible.
 - B. Running on a street with a camber may contribute to common knee problems such as ITB friction syndrome. Runners should be encouraged to either avoid the camber or alternate the direction of their run.

ITB, Iliotibial band.

regions and not in the joint. However, they should not feel an increase in their symptoms during the performance of their exercises or experience a “pressure sensation” in the knee. This should be made explicit to patients. If either pain or pressure occurs, they should review the instructions to the exercise to be sure that they are performing it correctly and try again. If they still experience pain or pressure, they should discontinue this exercise until they return for their next visit.

Exercises to improve strength and performance of the hip abductors and hip lateral rotators may be prescribed. Many of these exercises are described in detail by Sahrmann.²² Exercises to improve hip abductor and hip lateral rotator strength, listed from easiest to most difficult, include hip lateral rotator isometrics in prone, hip abduction in prone, progressive hip abduction with lateral rotation in side lying, hip lateral rotation against resistance bands in sitting, and lunges in standing while maintaining proper alignment of the knee. During the performance of these exercises, therapists should check to be sure that the patient is recruiting the correct muscles by palpating the lateral rotators and posterior gluteus medius. In addition, it is important that the patient is able to feel the contraction in the buttock region so that he or she can recreate the exercise at home. To specifically target the gluteus maximus, the patient can perform hip extension in prone with the knee flexed and progress to exercises in standing such as hip extension using resistance bands.

An exercise used to improve the motor recruitment or timing of the hip lateral rotators and abductors is weight shifting with gluteal contraction on the stance lower extremity. Once the patient has demonstrated good performance of the weight-shifting exercise, the exercise may be progressed to standing on one leg with correct alignment. Resisted activities of the opposite leg while standing on the affected leg may also be used to challenge the hip lateral rotators and abductors.

Exercises to improve the extensibility of the TFL-ITB should be prescribed. We recommend the following exercises: (1) prone knee flexion (bilateral [Figure 7-26] or unilateral), (2) prone hip lateral rotation without tibiofemoral motion, (3) two-joint hip flexor length test position, and (4) Ober test position. During the performance of these exercises, the tibiofemoral joint must be stabilized to prevent rotation. The patient is instructed to control tibial rotation by stiffening the necessary musculature at the knee. For example, while performing prone knee flexion, the patient points the foot toward the opposite limb, therefore contracting the tibial medial rotators to help stabilize the joint. If the patient is unable to control the tibial rotation, the exercises will need to be modified. Modifications might include either abducting the hip or placing a pillow under the pelvis to put the TFL-ITB on some slack. During all of these stretching exercises, the patient should have good abdominal support to avoid pelvic anterior tilt or transverse rotation.

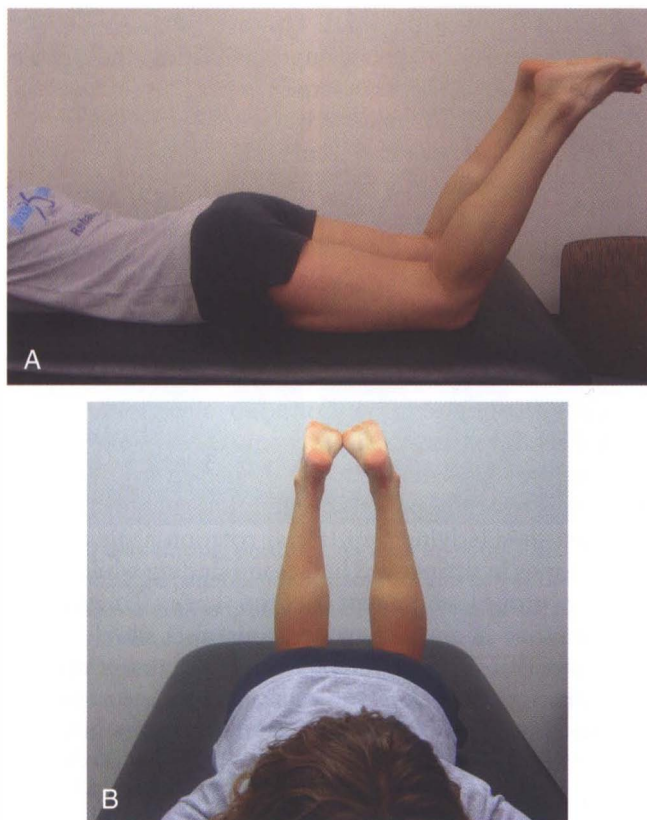


Figure 7-26. Prone knee flexion. **A**, Prone bilateral knee flexion to improve the extensibility of the TFL-ITB. **B**, To prevent tibial lateral rotation during performance of the stretch, the patient is instructed to keep the toes together and the heels in line with the tibias.

Improvement of abdominal performance may be needed. The abdominals assist in keeping the pelvis stable during activities involving the limbs. Some individuals may demonstrate poor performance of the abdominals as evidenced by increased rotation of the pelvis during functional activities such as gait or during performance of exercise (for example, pelvic rotation or tilting while lifting the leg during hip abductor strengthening). If so, he or she should be instructed in exercises to improve strength (lower abdominal progression as described by Sahrmann²²) and recruitment (encourage patient to pull in abdominals with functional activities).

Taping

If the patient has difficulty correcting the movement impairment, taping may be helpful. The posterior X taping method, developed by our colleague, Debbie Fleming-McDonnell,* has been used as a method to prevent or reduce rotation at the tibiofemoral joint (Figure 7-27). The strips of tape that move from proximal-lateral thigh around the posterior knee to the distal-medial tibia are proposed to assist in reducing femoral medial rotation and

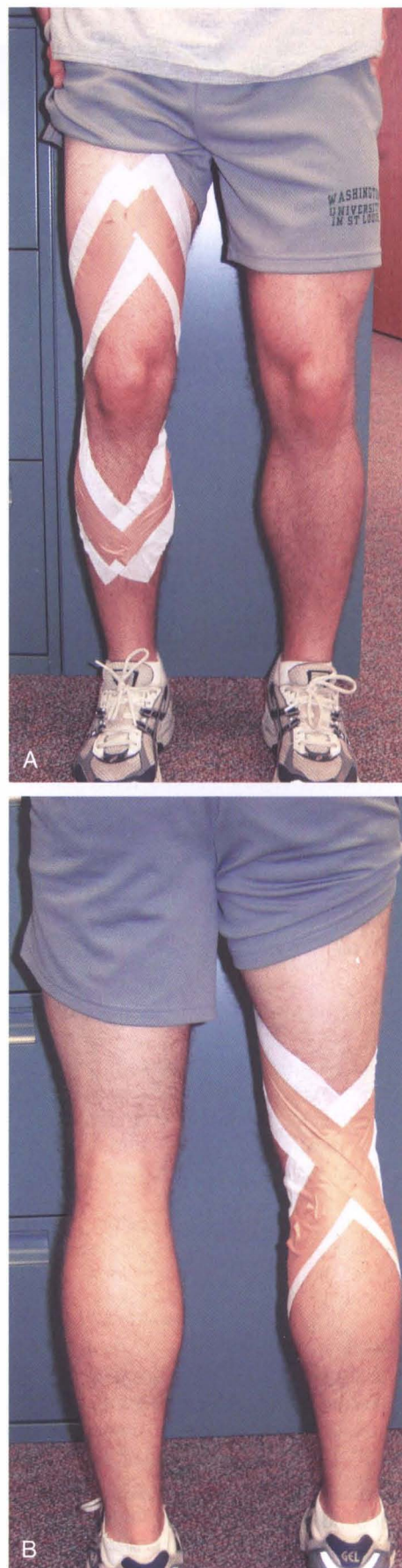


Figure 7-27. Posterior X taping method for TFRVal. **A**, Anterior view. **B**, Posterior view.

*PT, DPT, Program in Physical Therapy, Washington University School of Medicine, St Louis, Missouri.



Figure 7-28. Decision-making for orthotics. Patient may not benefit from orthotic. Note excessive femoral medial rotation and foot supination. Recommend correcting hip impairment first.

tibial lateral rotation. We often add other strips of tape for symmetry or to assist in preventing knee hyperextension in patients who tend to hyperextend.

Orthotics

Most patients improve by addressing deficits of the hip only; however, some patients may benefit from orthotics to correct pronation at the foot. A number of articles related to the use of orthotics for knee pain problems have been published; however, the findings are equivocal.⁹⁸⁻¹⁰² We believe the inconclusive findings are related to the lack of foot type classification in studies related to knee pain. We believe that some individuals may benefit from correcting impairments of the foot and others may not (Figures 7-28 and 7-29). For example, if a patient demonstrates pronation that is excessive or occurs at an inappropriate time during gait, abnormal rotation at the tibiofemoral joint may result. If pronation is suspected to contribute to the rotation at the tibiofemoral joint, an orthotic may be appropriate.¹⁰³ If, however, orthotics do not reduce excessive tibiofemoral rotation or they increase tibiofemoral rotation, they may not be indicated.

A careful assessment of the foot should be done to determine whether the rotation of the femur results in rotation at the tibiofemoral joint or motion at the foot. If excessive medial rotation of the hip occurs and the foot is stiffer than the tibiofemoral joint, whether by foot structure or by using an orthotic, tibiofemoral rotation



Figure 7-29. Decision-making for orthotics. **A**, Patient may benefit from orthotic. Note excessive femoral medial rotation and foot pronation. Hip may still be a contributor. Recommend correcting contribution of the hip with the addition of orthotics if needed. **B**, Patient may benefit from orthotic; however, correcting standing alignment by reducing hip abduction may improve alignment of the knee and foot.

will be exaggerated. Therefore the therapist must assess if the rotation at the tibiofemoral joint is increased or decreased if a pronation support is provided. When orthotics are indicated, temporary orthotics may be fabricated to assess the usefulness of the orthotic and allow the patient to test the correction before deciding to purchase a customized pair of orthotics.

Neuromuscular Training

Impairments of the neuromuscular system, such as poor balance or proprioception, may be present with any of the movement impairment syndromes. Treatment should include neuromuscular training to address impairments of proprioception and balance and the ability to accommodate to perturbations. When instructing the patient in neuromuscular training exercises, the patient should avoid motions and positions such as excessive knee valgus or femoral medial rotation. Examples of neuromuscular retraining activities are provided in Box 7-2. At time of the writing of this text, there are a number of laboratories studying this topic in patients with knee disorder.^{13,14,104,105} The reader is encouraged to review current studies.

TIBIOFEMORAL ROTATION WITH VARUS SYNDROME

Symptoms and History

Individuals with TFRVar syndrome also demonstrate excessive rotation at the tibiofemoral joint; however, it is associated with a knee varus. The patient may demonstrate a varus thrust during gait. A varus thrust has been described in individuals with injury to the posterolateral corner of the knee and recently studied in the osteoarthritic knee.⁷ Traditionally, varus thrust has been described as motion that is primarily in the frontal plane and thought to be the consequence of structural changes of the medial compartment in the osteoarthritic knee. We have observed, however, an apparent varus thrust in young individuals without radiological evidence of OA or ligamentous injury. This apparent varus thrust seems to be a result of a combination of hip medial rotation and knee hyperextension.

Structures that may be injured in an individual with TFRVar syndrome include the structures of the tibiofemoral joint, the ITB, and the surrounding musculature. The medial compartment of the tibiofemoral joint may be particularly at risk, given that it is responsible for 60% to 80% of the total load across the knee. Recent interest has been placed on the external knee adduction moment and its contributions to the load on the medial knee compartment.¹¹⁰ The external knee adduction moment is defined as the product of the ground reaction force and the perpendicular distance to the knee joint (Figure 7-30). Clinically, the alignment associated with the knee adduction moment is genu varus. The knee adduction moment has been associated with the progression of knee OA.¹¹¹ An increase in varus alignment of the knee may result in a larger moment arm of the ground reaction force and thus increase the force through the medial compartment.

Several authors have reported that using a “toe-out” gait pattern reduces the knee adduction moment and thus reduces symptoms.¹¹²⁻¹¹⁴ Two mechanisms have been proposed to explain the reduction of symptoms when a toe-out pattern is used. In their study of individuals with

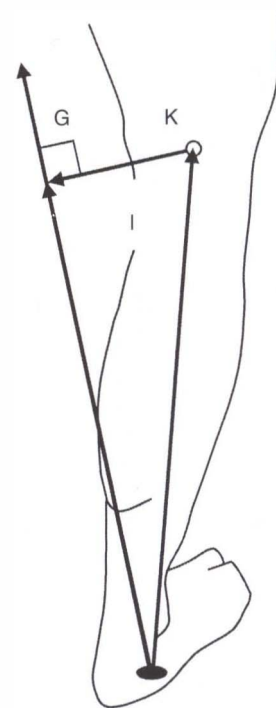


Figure 7-30. The external knee adduction moment is defined as the product of the ground reaction force and the perpendicular distance to the knee joint. G, Ground reaction force vector; I, momentum of ground reaction force; K, knee joint center. (Modified from Jenkyn TR, Hunt MA, Jones IC, et al: Toe-out gait in patients with knee osteoarthritis partially transforms external knee adduction moment into flexion moment during early stance phase of gait: a tri-planar kinetic mechanism, *J Biomech* 41(2):276-83, 2008.)

knee OA, Jenkyn et al¹¹³ demonstrated that a portion of the external knee adduction moment was transformed into a flexion moment during the early phase of stance. Chang et al¹¹⁵ provided another theory based on their interpretation of a study by Wang et al¹¹⁶: A toe-out gait pattern shifts the ground reaction force vector closer to the knee joint center. This shift results in a reduction in the moment arm of the ground reaction force and thus the external knee adduction moment.

Key Tests and Signs

Alignment Analysis

A patient with TFRVar syndrome often presents with femoral medial rotation and knee varus and may demonstrate a supinated or a fixed flat foot. The genu varus may be due to structural problems, such as OA in the medial compartment of the knee, or it may be a postural fault cause by femoral medial rotation along with knee hyperextension (Figure 7-31, A-D). The examiner should be careful not to classify by standing alignment alone. An individual may demonstrate a varus alignment in standing but demonstrate knee valgus with activities (Figure 7-31, E-F). The examiner must consider the entire movement examination and the symptom behavior to determine the appropriate diagnosis.

BOX 7-2

Neuromuscular Training

When instructing the patient in neuromuscular training exercises, it is important to remind the patient to avoid motions or alignments consistent with his or her specific movement system syndrome.

PROPRIOCEPTION/BALANCE¹⁰⁶

Activities to improve proprioception of the knee should be incorporated as soon as possible. Begin early in treatment using activities such as weight shifting, progressive increases in weight bearing on the involved LE, and then eventually unilateral stance. As the patient can take full weight on the involved knee, activities are progressed to the use of a balance board.

Progression: Activities should be progressed to prepare patient to return to daily activities, fitness routines, and work or sporting activities. As the patient progresses, proprioception can be challenged by asking the patient to stand on unstable surfaces (pillows, trampoline, or BOSU ball); perturbations can be applied by having the patient catch a ball being thrown to him while standing on one leg or by perturbing the surface on which the patient is standing.¹⁰⁵ Sliding board activities have also been shown to be beneficial to patients after surgery.¹⁰⁷

SPORT-SPECIFIC TRAINING (IF APPROPRIATE)

In preparation to return to sports, sport-specific activities should be added. The initial phases of these activities will include straight plane activities at a slow pace and then a gradual increase in the level of difficulty by increasing the intensity and patterns to include changes of direction, starts, and stops.

AGILITY EXERCISES

Emphasis is placed on proper movement.

Hopping timed

Within each level, begin with short bouts of hopping and longer rests between (15 seconds on, 30 seconds off), then increase on time and decrease off time (30 seconds on, 15 seconds off).

1. Hopping bilateral LEs with support of the UEs to decrease the amount of stress through the knee
2. Bilateral hopping without support
3. Bilateral hopping in different designs: Side-to-side, back and forth, box, V, zigzag hopping
4. Progress to same activities with unilateral LEs

Jumping from short surface, 2 inches

Emphasis should be placed on landing on both feet evenly with neutral knees over toes (avoid excessive knee valgus or femoral adduction or medial rotation). The patient should also think about landing softly, using the ankle plantarflexors and allowing the knees to flex to help absorb the landing.^{13,106}

1. Jump forward, backward, and to each side.
2. Progress by increasing the height of the surface.

Jumping up on to surface

Begin with shorter surface and increase height when appropriate.

Other plyometrics: ladder drills

NOTE: If plyometrics and resistance training are to be performed during the same visit, plyometrics should be performed before the resistance training activities.¹⁰⁶

RUNNING

See Box 7-1 for initial running program. Once the individual is able to run 1 mile without an increase in symptoms or swelling, cutting activities may begin.

1. Figure 8 running, beginning with a large "8," then gradually decreasing the size of the 8
2. Zigzag running with soft cuts, hard cuts, and cut and spin

NOTE: Care should be taken to evaluate how the patient chooses to cut. Often, particularly in patients who have suffered noncontact injuries, the patient may have adopted an inefficient cutting pattern such as planting the left foot when trying to cut to the left.

JUMPING PROGRAM

Please refer to article by Hewett et al.¹³ for description of jumping program. The following are some of the key concepts used in their program.

1. Soft landing: Use plantarflexors to assist in accepting weight
2. Knee flexion: Do not land with knee stiff (remains in extension)
3. Proper knee alignment in the frontal plane: No knee valgus

DRILLS

Once the patient can complete cutting drills without pain or swelling and demonstrates good control of the LE, variations, such as the following, can be added:

1. Drills with sport specific equipment (basketball, hockey stick, soccer ball)
2. Partner drills

BASKETBALL SPECIFIC TRAINING

Please refer to article by Louw et al.¹⁰⁸ for description of specific training for basketball.

FUNCTIONAL TESTING

Consider functional tests before the patient's return to sport. There are many functional tests available. The validity of these tests are controversial; however, each test can offer some insight in how the patient may perform in his or her specific sport. It is recommended that a battery of tests be used to assess the aspects of balance, coordination, agility, and strength. Refer to Fitzgerald et al.¹⁰⁹ for a proposed system to test patients returning to sports after non-operative treatment of ACL tear. Common test items for the knee include the following:

1. Single-leg hop for distance
2. Triple-leg hop for distance
3. Six-meter hop for time
4. Crossover hop for distance
5. Six-meter shuttle run
6. Vertical jump
7. Lateral step

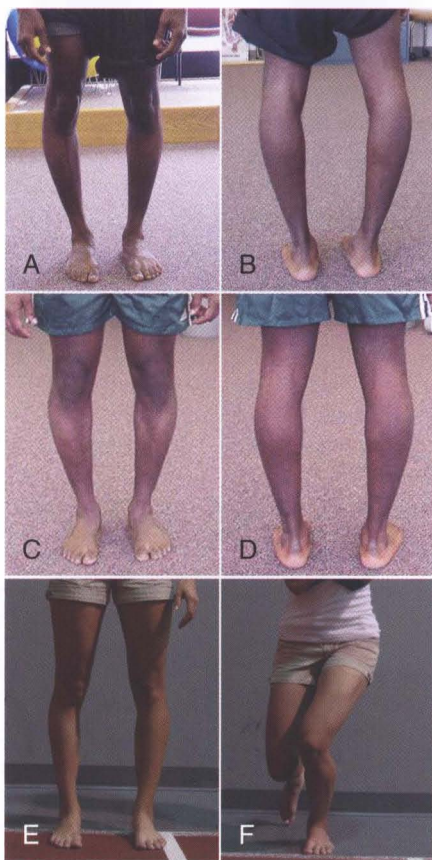


Figure 7-31. TFRVar Alignment. Patient's alignment during examination. Anterior view (A) and posterior view (B). Patient demonstrates structural faults of genu varum and tibial varum. Genu varum is increased with postural fault of femoral medial rotation and knee hyperextensions. Patient's modified alignment (same patient as A and B), anterior view (C), and posterior view (D). Patient has been instructed to correct postural faults by "unlocking his knees" and contracting the hip lateral rotators to reduce femoral medial rotation. Varus alignment in standing (E) might suggest TFRVar; however, patient demonstrates valgus positioning of the knee (F) during a single leg squat indicating that TFRVal is the likely diagnosis.

Movement Impairments

Standing tests. During single-leg stance on the involved limb, the patient will demonstrate excessive medial rotation of the involved femur with minimal to no movement at the foot. Balance may also be a factor in this syndrome, although clinically it is not as common in TFRVar syndrome as it is in TFRVal syndrome.

Supine tests. Similar to TFRVal syndrome, the patient with TFRVar syndrome may demonstrate rotation or abduction of the tibia during the performance of the two-joint hip flexor length test (see Figure 7-21).

Joint Integrity

The patient may demonstrate mild-to-moderate laxity in the fibular collateral ligament (lateral collateral ligament); however, overall laxity in the tibiofemoral joint is not typically observed in the young individual with

TFRVar syndrome. Older patients with arthritic changes may demonstrate some general joint laxity.

Muscle Length Impairments

Common muscle impairments include reduced extensibility of the TFL-ITB.⁹⁰

Muscle Strength/Performance Impairments

Impairments of muscle strength and performance include poor performance of the hip lateral rotators and possibly hip abductors.^{91,92}

Functional Activities

Gait. During gait, excessive femoral medial rotation and knee hyperextension may contribute to the apparent varus thrust during stance. Ankle dorsiflexion and foot pronation are often limited, which may increase stresses to the tibiofemoral joint.

Step-up. During a step-up, the patient does not shift the body weight forward over the foot and demonstrates a faulty movement of pulling the knee back to the body, instead of bringing the body forward over the limb. Because the foot is anchored on the floor during the step-up, hip extension performed by the hamstrings may assist with knee extension, therefore reducing the need to recruit the quadriceps to extend the knee. Gluteal muscles also have a reduced ability to extend the hip when the patient's body weight is kept in a relative posterior position.

Other Functional Tests

Activities that aggravate the patient's symptoms should be assessed for a movement impairment. Common activities include prolonged sitting, squatting, and sit-to-stand. If the patient is an athlete or has low irritability of their symptoms, higher level activities, such as single-leg squat and jumping, may need to be assessed to determine the movement impairment.

Summary of Examination Findings

TFRVar syndrome presents with the movement impairment of excessive rotation between the tibia and femur that is associated with a genu varum. Varum of the tibiofemoral joint may be secondary to structural changes in the medial joint surfaces as in OA; however, an apparent varum may be secondary to acquired impairments of femoral medial rotation and knee hyperextension. Positions or movement associated with TFRVar syndrome are often painful, and when corrected, pain is reduced.

Treatment

Primary Objectives

The primary objectives of a treatment program include the following:

1. Correct TFRVar during functional activities.
2. Improve performance of the hip lateral rotators.
3. Improve shock absorption during gait.

Corrective Exercise Program

Treatment for TFRVar syndrome is similar to the treatment for TFRVal syndrome with a few subtle differences; only the differences are discussed here.

Alignment. Instructions to correct alignment are similar to those for TFRVal syndrome. To improve alignment between the femur and tibia, the therapist must address impairments in both the sagittal and transverse planes in an effort to achieve a more neutral or ideal alignment. If hyperextension is present, the patient is instructed to unlock the knees. To align the tibia and femur in the transverse plane, the patient is asked to align knees over feet with neutral rotation of hips by decreasing medial rotation of femur. To correct femoral medial rotation, the patient is instructed to contract their gluteals and hip lateral rotators to laterally rotate the femur. As described previously, structural impairments, such as tibial varum must be noted and considered when attempting to correct alignment (see Figure 7-31).

Functional activities. Instructions to maintain proper alignment and movement strategies during functional activities are recommended. Cues to correct femoral medial rotation are the same as those provided for patients with TFRVal syndrome. Genu varum is often challenging to correct; however, cues to reduce impact on the knee joint may be useful in reducing stresses on the knee joint. For example, during gait, patients are encouraged to use a heel-to-toe gait pattern and use the rolling of the foot to provide shock absorption. In severe cases, symptoms may be reduced by instructing the patient to walk with a “toe out” pattern.¹¹²⁻¹¹⁴ If the patient is experiencing medial condyle degenerative changes, the instruction is to walk with the feet closer together and in slight lateral rotation to decrease the stress on the medial condyle.

If the patient could benefit from a cane, typically, the cane is placed in the hand opposite the involved limb. Anecdotally, however, some patients have reported decreased symptoms when the cane is placed in the ipsilateral hand. Using the cane in the ipsilateral hand may decrease the forces on the medial knee. To apply weight onto the cane, the patient shifts the body weight closer to the affected knee, thus reducing the external moment arm of the body weight and possibly the amount of force through the medial compartment of the knee.

Home Exercise Program

Exercises to improve strength and performance of the hip lateral rotators may be prescribed if the patient demonstrates excessive medial rotation. See the “Home Exercise Program” section for “Tibiofemoral Rotation with Valgus Syndrome” for a description of these exercises.

Taping/Bracing

The taping method demonstrated in Figure 7-27 is useful to prevent or reduce rotation and hyperextension at the tibiofemoral joint. In patients with advanced disease, particularly OA, an unloader brace may be useful.^{117,118}

Orthotics

Cushioned shoes and an additional cushioned insert may improve shock absorption of the lower extremity, particularly in patients with a rigid, supinated, or structurally (fixed) pronated foot.

CASE PRESENTATION

Tibiofemoral Rotation with Valgus Syndrome

Symptoms and History

A 16-year-old female soccer player is referred to physical therapy for evaluation and treatment of right knee pain. She reports right anteromedial knee pain for 2 months. Her pain began during preseason training and limited her ability to participate in practice. During practice, her pain would increase to 5/10. The pain could be sharp, particularly with cutting and kicking the soccer ball with the involved limb. Her pain improved with rest and ice. Her Knee Outcome Score–Activities of Daily Living (KOS-ADLs)¹¹⁹ is 74%, and her KOS-Sports score is 57%. Radiographs show no abnormalities of the tibiofemoral or patellofemoral joint.

Alignment Analysis

The patient is 5 feet 10 inches and weighs 150 pounds. In stance, the patient demonstrates medial rotation of the femur and greater foot progression angle (toe out) on the right. In sitting, the tibia is rotated laterally relative to the femur. There are no obvious impairments of patellar alignment.

Movement Analysis

During single-leg stance on the right, the patient demonstrates excessive medial rotation of the femur and pronation of the foot. During a partial squat, the patient demonstrates femoral adduction, knee valgus, and foot pronation. The patient reports an increase in her pain during the performance of the squat. The patient is then instructed to keep her knee in line with her toes and avoid allowing the knees to come together. She is able to correct her performance and reports that her symptoms are decreased compared to the uncorrected movement.

During knee flexion in prone, the patient demonstrates lateral rotation of the tibia and reports an increase in her symptoms at the end of the motion. With manual correction to control tibial lateral rotation, the patient reports a decrease in her symptoms compared to the uncorrected movement.

Joint Integrity

Accessory motions of the patellofemoral joint are excessive in the medial and lateral directions but equal to the uninvolved side. Accessory motions of the tibiofemoral joint are also equal bilaterally. The patient reports no change in her symptoms with the accessory motion testing.

Muscle Length Impairments

During the two-joint hip flexor length test, the patient demonstrates a short, stiff TFL on the right. As the hip is extended, the tibia rotates laterally and the patient reports an increase in her symptoms. With manual correction to control the rotation of the tibia, the patient reports a decrease in her symptoms compared to the first performance.

Muscle Strength/Performance Impairments

On the right, the hip lateral rotators are 4–/5 tested in sitting, the gluteus maximus is 4/5, the TFL is 4/5, and the posterior gluteus medius is 3+/5. While testing the posterior gluteus medius, the patient's hip flexes and medial rotates, indicating that the hip flexors are compensating for performance of the posterior gluteus medius. With cueing, she is able to correct the position but could only maintain the position against minimal pressure to the distal lower extremity.

Stiffness/Extensibility/Flexibility

The TFL-ITB is relatively more stiff than the knee joint causing compensatory lateral tibial rotation during the two-joint hip flexor length test.

Tests for Source

The patient reports tenderness with palpation along the medial and lateral joint lines, as well as the medial patellar facet. McConnell test¹²⁰ and the patellofemoral grind test^{52,120} for patellofemoral pain are negative. All ligamentous and meniscal tests are negative.

Functional Activities

During sit-to-stand and stair ambulation, the patient demonstrates femoral adduction and knee valgus. She does not report pain with sit-to-stand; however, she is instructed in correcting her movement to reduce femoral adduction and knee valgus. She is able to correct easily. With cutting activities on the right lower extremity, the patient demonstrates femoral adduction and tibial lateral rotation. The cutting maneuvers increase her symptoms. The patient attempts to correct her movement quality during the cutting maneuver; however, she is unable to correct the fault completely.

Diagnosis and Staging

The diagnosis is TFRval syndrome and the stage for rehabilitation is Stage 2. Her prognosis is good to excellent. Positive moderators include her young age, overall good health, high motivation to return to her activities, and her ability to change the simple movement impairments, such as partial squat and sit-to-stand, with instruction only. Negative moderators include her high activity level.

Treatment

The patient was seen once per week for 4 weeks, then once every other week for 2 weeks for a total of 6 visits over 8 weeks. Treatment included instruction in correct

performance of functional activities, including her sporting activities. She was also instructed in a home exercise program to improve performance of the hip abductors and hip lateral rotators and exercises to increase the extensibility of the TFL-ITB. Although she reported pain in the right knee only, she was encouraged to perform the exercises bilaterally.

During the first visit, the patient was instructed in correct performance of sit-to-stand, stair ambulation, and squatting. She was instructed to contract her gluteals to control the femoral adduction and knee valgus during the activities. She was able to make these corrections quite easily.

To improve the recruitment of the hip musculature during functional activity, the patient was instructed in the exercises, weight shifting, and single-leg stance. She was encouraged to contract her hip lateral rotators when weight was shifted onto the ipsilateral lower extremity. She was instructed to perform these exercises frequently throughout the day if possible. Daily activities, such as brushing one's teeth or speaking on the phone, provide excellent opportunities to work on weight shifting throughout the day.

To improve performance of the hip lateral rotators and hip abductors, side lying hip abduction/lateral rotation was prescribed with the hip and knee extended (level 2 Sahrman²²). The patient was instructed to perform the exercise with her back and leg against the wall. She was instructed to keep the shoulders, hips, and heels on the wall while performing the exercise. The wall provides feedback to remind her to keep her hip in the extended position and avoiding hip flexion.

To more specifically target the hip lateral rotators in hip flexion, she was instructed in lateral rotation in sitting with the feet together.²² An elastic exercise band was placed around the distal end of the femurs to provide resistance to the hip lateral rotators. These exercises were to be performed once a day, in 3 sets, each set to fatigue. The repetitions depend on her ability to perform the exercise correctly.

Knee flexion in prone was prescribed to improve the extensibility of the TFL-ITB. To prevent tibial lateral rotation, the patient was instructed to flex both knees while keeping her feet together during the exercise.

Although the patient could easily correct her movement impairments during functional activities, it was unlikely that she could correct her movement strategies entirely during her soccer practice, so the patient's knee was taped with the method shown in Figure 7-27. She was instructed to keep the tape in place up to 3 days, as long as she did not develop skin irritation.

At her second visit, 1 week later, the patient reported 50% compliance with the exercises and 70% compliance with the functional activity corrections. She stated that with the tape, she was able to participate in the entire soccer practice. She still had an increase in symptoms, that only increased to a 2/10 maximum. In a subsequent practice after she had removed the tape, she was unable

to participate in the entire practice. She demonstrated correct performance of the exercises, therefore the exercises were progressed. Sidelying hip abduction/lateral rotation was progressed to level 3.²² She was also given prone hip extension with the knee flexed. She was instructed to place pillows under her abdomen while performing prone hip extension, to allow for adequate motion, which was restricted by her short TFL-ITB.

Also, at her second visit, some of her soccer drills were addressed. Recommendations were provided in correcting the movement impairments of hip adduction and tibial lateral rotation during her activities. The patient was taped again.

At 1 month, the patient was able to participate in her practices without a significant increase in her pain and the patient was progressed to Stage 3. Taping was discontinued, and exercises were progressed. The strength and recruitment of her hip musculature improved, thus her program was progressed to exercises in weight bearing. She was given resisted shuffles using an elastic band around the distal femurs. Resisted hip extension and hip abduction in standing were given, using an elastic band for resistance.

Sports-specific drills were practiced while encouraging proper alignment of the knees. Neuromuscular training was also incorporated. The patient was encouraged to incorporate these activities into her regular soccer warm-ups.

Outcome

The patient was seen for a total of 6 visits over 8 weeks. At the time of her last visit, 2 months after her initial visit, the patient reported that she was playing soccer pain-free and continued to use the training drills during her soccer practice. Function was also improved as demonstrated by improved scores: KOS-ADLs is 100% and KOS-Sports is 100%.

TIBIOFEMORAL HYPOMOBILITY SYNDROME

The movement impairment of tibiofemoral hypomobility (TFHypo) syndrome is associated with a limitation in the physiologic motion of the knee. The limitation may result from degenerative changes in the joint or from the effects of prolonged immobilization. OA of the knee may contribute to TFHypo syndrome, although not all individuals with OA have TFHypo syndrome. The diagnosis of tibiofemoral rotation should be considered if a patient has radiographic evidence of OA but no limitation in knee ROM.

Symptoms and History

Individuals with the diagnosis of TFHypo syndrome report knee pain located deep in the joint and often describe their pain as vague. Symptoms are typically increased with weight-bearing activities, such as walking,

standing, and stair ambulation, and are relieved with rest. Reports of stiffness after prolonged periods of rest are common. The most common diagnoses used by a referring physician include OA and knee contracture.

Key Tests and Signs

Alignment Analysis

During assessment of standing alignment, the patient often demonstrates knee flexion; however, individuals with OA may demonstrate genu varum or genu valgus. The knee joint may also appear to be enlarged or show signs of inflammation/swelling. In addition to assessing knee alignment, alignment of the hip and foot should also be assessed.

Movement Impairments

Standing tests. During single-leg stance on the involved limb, the patient may demonstrate poor hip and trunk control, which is evidenced by pelvic tilt or trunk lateral bending. This is often described as a positive Trendelenburg sign¹²¹ or a gluteus medius limp when severe (notable lateral trunk flexion over involved side). The patient may also demonstrate poor balance requiring upper extremity support for performance.

Sitting. During sitting knee extension, the patient may demonstrate decreased knee extension ROM. Careful observation of this movement is recommended. Some patients demonstrate co-contraction of the lower extremity muscles, particularly quadriceps and hamstrings, while attempting to extend the knee. If co-contraction is occurring, the limb moves slowly and the patient appears to be using a great deal of effort. If co-contraction is suspected, a cue to reduce effort of the activity often results in ease of the motion and a reduction in symptoms. Passively extending the patient's knee while the patient is sitting in a chair with a backrest will provide information about hamstring length and stiffness.

Joint Integrity

Patients with TFHypo syndrome demonstrate a reduction of ROM in flexion and extension. Limitations in knee ROM may be due to impaired arthrokinematics and/or reduced muscle extensibility, therefore assessment of joint flexibility, accessory motions, and muscle extensibility is recommended. Often, end-range of motion is painful. Patients with TFHypo syndrome associated with OA may report a decrease in their end-range pain with repeated passive motion. Patients with osteoarthritic changes of the joint may demonstrate a capsular pattern, defined as a loss in flexion ROM that is greater than the loss of extension.¹²² Recently, however, the validity of using this pattern to detect individuals with OA has been called into question.^{123,124}

Muscle Length Impairments

Decreased extensibility of the hip flexors, hamstrings, and ankle plantarflexors may also be associated with the TFHypo syndrome.

Muscle Strength/Performance Impairments

Common muscle impairments include poor performance of the gluteal musculature, hip lateral rotators, gastrocnemius, and quadriceps. As described previously, co-contraction of the quadriceps and hamstrings may be visible during exercise or performance of functional activities. Co-contraction has been shown to increase joint contact pressures that may result in increased injury to the joint surfaces.^{125,126}

Functional Activities

Gait. Patients with TFHypo syndrome demonstrate reduced knee ROM throughout their functional activities. During ambulation, there is a reduction of knee excursion in both flexion and extension. Often the knee is maintained in flexion throughout the entire gait cycle. The patient may also demonstrate a decreased stride length and decreased push-off.

Stairs. While descending stairs, the patient may demonstrate reduced knee flexion excursion on the stance limb. This reduced excursion is not solely the result of reduced joint flexibility but may be an impaired movement strategy caused by muscle co-contraction. The patient demonstrates co-contraction of the lower extremity muscles¹²⁷ that often results in an increase in symptoms and effort. Follow-up instruction to “let go” of the musculature often results in an improvement in symptoms.

Sit-to-stand. Reduced knee flexion is also seen as the patient moves from a sitting position to standing. Sufficient knee flexion is required to move the tibia anteriorly to bring the patient’s center of mass (COM) over their feet. When the anterior movement of the tibia is reduced, the patient compensates with increased hip and trunk flexion to advance their COM anteriorly.

Summary of Examination Findings

Patients with TFHypo syndrome present with a physiologic limitation of knee motion, typically in knee flexion and knee extension. They also demonstrate a limitation of knee joint excursion during functional activities such as gait and stair ambulation. The observed limitation in ROM may be due to limitations in joint flexibility and muscle extensibility or an impaired motor recruitment pattern.

Treatment

Treatment for this syndrome includes first educating the individual on correcting the postural habits and movements that may be contributing to the movement impairment.

Primary Objectives

The primary objectives of a treatment program include the following:

1. Improve knee flexion and extension ROM.
2. Improve muscle performance of gluteals, hip lateral rotators, quadriceps, and gastrocnemius, similar to TFRVal or TFRVar category.

3. Improve aerobic conditioning without an increase in pain or swelling.
4. Educate in performance of functional activities.
5. Caution against repetitive rotation of the knee with the foot fixed.
6. Consider forces created by compression, particularly in knees that are malaligned.
7. Use of an assistive device if necessary during gait to decrease the compressive stresses to the involved knee.

Corrective Exercise Program

The patient is instructed in functional activities and an exercise program to address the associated movement impairments. All patients should be encouraged to participate in regular fitness activities to maintain current weight or reduce weight if the patient is overweight or obese.

Alignment. It is often difficult for patients with TFHypo syndrome to change alignment immediately; however, correct alignment should be encouraged.

Functional activities. In the early stages of rehabilitation, compensatory modifications may be needed to accommodate the lack of ROM or to prevent increased pain. As the patient’s ROM and pain improves, the performance of functional activities should focus on teaching the components of ideal motion. If it is determined that the limitation in ROM is structurally fixed, then compensatory techniques should be provided.

Gait. During gait, the patient is instructed to use a “rolling” heel-to-toe gait pattern. This modification’s intent is to improve the shock absorption contribution of the foot and encourage improved push-off. If the patient is experiencing severe pain or demonstrates a significant malalignment, such as genu varum, an assistive device should be recommended to redistribute the forces on the affected knee. See the information on the use of a cane in the “Functional Activities” section for “Tibiofemoral Rotation with Varus Syndrome.”

Sit-to-stand; stand-to-sit. To rise from a sitting position to standing, the patient should be instructed to slide forward to the edge of the chair. Once at the front of the chair, the patient should position the feet about hip-width apart and slightly posterior to the knees. If knee flexion is significantly limited, the patient may keep the affected knee comfortably extended while placing the unaffected foot appropriately. The patient is instructed to lean forward at the hips to be sure his or her center of mass is moved forward over his or her base of support. The patient is also encouraged to contract the quadriceps and gluteals and avoid femoral adduction when rising from the chair.

When transitioning from standing to a sitting position, the patient is instructed again to contract the gluteals and quadriceps and slowly lower themselves into the chair. Individuals with significant limitations or pain may need to begin practicing these movements with a higher seat surface and use their upper extremities on the

armrests to assist with pushing up from the seat and lowering into the seat. Performance of sit-to-stand may be progressed by reducing the use of the upper extremities and lowering the height of the seat.

Stairs

Patients with TFHypo syndrome often have a high severity of symptoms with stair ambulation. Please see the “Treatment” section in the “Tibiofemoral Rotation with Valgus Syndrome” section for methods to reduce symptoms with stair ambulation. If the patient demonstrates co-contraction during the stair descent, cues to “let go” or relax their musculature often results in a reduction of symptoms.

Other functional activities. Activities the patient performs throughout the day that may contribute to the patient’s symptoms should be addressed. For example, patients often report increased stiffness and pain after prolonged sitting. They should be instructed to decrease the amount of time that the knee is maintained in one position. They can accomplish this by rising from the chair every 20 to 30 minutes and walking or flexing and extending the knee if the situation will not allow rising from their chair, such as during a business meeting or class.

Fitness activities. Fitness activities should be addressed as soon as possible. The appropriate level of activity demand should be assessed. In the early rehabilitation stages, the patient should begin with non-weight-bearing or reduced weight-bearing activities such as swimming, water exercises, and stationary biking without resistance. As the patient improves, weight bearing should be gradually increased. Using a StairMaster or elliptical cross-trainer can serve as a good transition to walking. While initiating strengthening exercises, it is safer for the patient to begin with high repetitions of relatively low resistance; high levels of resistance are not encouraged because of the high levels of compressive forces through the joint.

Home Exercise Program

The patient should be provided with a home exercise program and instruction on the appropriate response to exercise. Specific exercises should be provided to increase ROM and improve lower extremity muscle strength and muscle extensibility.

Exercises to improve muscle performance, including strengthening and motor recruitment of the hip musculature, are described in detail in the treatment description of TFRVal syndrome. Patients with TFHypo syndrome may also benefit from strengthening of the gastrocnemius muscle, beginning with elastic band resistance and progressing to weight-bearing heel raises. Other muscles that should be considered are the abdominals and the quadriceps, if appropriate.

Historically, quadriceps strengthening has been recommended for patients with knee OA, based on the theory that the quadriceps provide shock absorption at the

knee. A recent trial involving patients with knee OA demonstrated that pain can be decreased with the implementation of a strengthening program.¹²⁸ However, epidemiological studies specific to knee OA have shown that increased quadriceps strength can actually accelerate the progression of OA in knees with malalignment^{16,18,20} or laxity.²⁰ One must consider the compressive forces that the quadriceps can add to a joint before administering aggressive quadriceps strengthening activities. We recommend that therapeutic exercises to hypertrophy the quadriceps be avoided in patients with malalignment or laxity of the knees. However, the functional performance of the quadriceps may be enhanced through proper performance of functional activities such as sit-to-stand, stand-to-sit, step-up and step-down, and partial wall squats.

Exercises to improve the extensibility of the hip flexors, gastrocnemius, and hamstrings are also prescribed.²² To improve the extensibility of the hip flexors, the following exercises may be provided: hip and knee extension in supine (heel slide) with the opposite hip held passively flexed to the chest, knee flexion in prone, and hip lateral rotation in prone to specifically stretch the TFL-ITB. To improve the extensibility of the gastrocnemius, the patient may be instructed to perform ankle dorsiflexion in sitting with the knee extended or ankle dorsiflexion in standing. Hamstring extensibility may be increased with knee extension in sitting (see Figure 7-40).

Other Interventions

Accessory and physiologic mobilizations may be used to reduce pain and increase ROM. If the patient is having pain at rest, a distraction mobilization can be taught to the patient for independent use at home. A trial of gentle distraction should be performed to determine if this technique will be appropriate. For the home technique, the patient sits with the knees at 90 degrees, with the lower leg dangling. A small pillow or rolled-up towel is used to elevate the thigh so that the foot is off the floor. A small weight or shoe, approximately 1 to 2 pounds, is applied to the distal limb (Figure 7-32). Patient allows the leg to dangle up to 10 minutes to help relieve discomfort. This may be performed as often as needed to relieve pain.

Bracing may be considered for patients who continue to have symptoms that are limiting their function. Braces range from the simple neoprene sleeve thought to provide warmth and possible improvement in proprioception to customized unloader braces to redistribute forces in the knee. If prescribing a brace, the therapist must consider the patient’s goals and motivation, as well as the anthropomorphic characteristics for adequate fit. We recommend a trial of a relatively inexpensive, easy-to-apply brace first. If symptoms are not affected, then a custom brace might be considered.

Finally, neuromuscular training may also improve function of the lower extremity. Activities in Box 7-2 may need to be modified for the patient’s skill level. A program

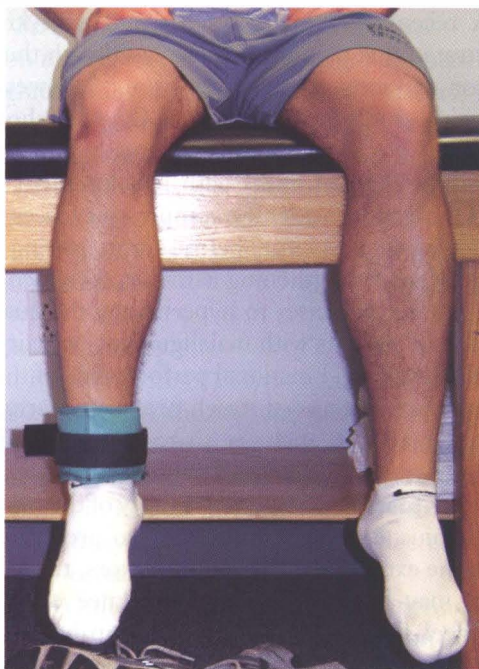


Figure 7-32. Home program for distraction mobilization to reduce pain. Patient is instructed to place light weight or heavy shoe, approximately 1 to 2 pounds, to the distal limb. Patient allows the leg to dangle up to 10 minutes to help relieve discomfort. This may be performed as often as needed to relieve pain.

developed for nonoperative ACL has been modified for use in the older individual and has preliminary evidence indicating success.¹⁰⁴

KNEE EXTENSION SYNDROME

Knee extension (Kext) syndrome is described as knee pain associated with quadriceps dominance or stiffness that results in an excessive pull on the patella, patellar tendon, or tibial tubercle. This movement system syndrome may be associated with poor performance of the hip extensors. The Kext syndrome has a subcategory of patellar superior glide (KextSG). Although both conditions are a result of quadriceps stiffness, the structures that are involved are related to the location of relative stiffness/flexibility. In KextSG syndrome, the patellar tendon and surrounding retinacula are relatively more flexible than the quadriceps, therefore when the quadriceps contracts, the patellar is displaced superiorly in the trochlear groove. Excessive stresses may be placed on the patellofemoral joint or patella tendon as the patella is pulled superiorly. In Kext syndrome, the patella is thought to be relatively stable and therefore the strain may be placed on the structures superior to the patella. Because the movement impairments of the two conditions are similar, they are described concurrently; movement impairment of Kext syndrome is described and information specific to KextSG syndrome is highlighted.

Symptoms and History

Patients with Kext syndrome report symptoms superior to the patella in structures such as the quadriceps or quadriceps tendon. In contrast, patients with KextSG syndrome report symptoms in the peripatellar region or the infrapatellar region and may involve the patellofemoral joint structures or the patellar tendon and the patellar tendon attachment sites, including the patellar inferior pole and tibial tuberosity. In patients with either syndrome, symptoms are aggravated with activities that require repetitive or forceful knee extension such as jumping. Patients are often athletes such as runners, football linemen, and volleyball players. Common diagnoses used by referring physicians include patellar tendinopathy (often called *jumper's knee*), quadriceps strain, and Osgood-Schlatter disease.

One impairment that might be associated with KextSG syndrome is patella alta. Researchers have identified a clear association between patella alta and increased lateral displacement and lateral tilt of the patella, particularly with a quadriceps contraction.¹²⁹⁻¹³¹ Such patellar instability can occur with patella alta because the patella rests superior to the femoral lateral condyle, which typically prevents excessive lateral patellar glide.

In addition, patella alta may also be associated with anterior knee pain or chondromalacia in the absence of patellar instability.¹³²⁻¹³⁶ One potential mechanism underlying the anterior knee pain associated with patella alta is a decrease in contact area between the patella and the femur, which has been demonstrated by Ward and his colleagues.^{137,138} Because physical stress to biological tissue is defined as the force per unit area, any decrease in the size of the contact area at a particular joint would increase the stress on that joint, potentially leading to degenerative changes and pain.

Current evidence for the treatment of patella alta is limited to surgical intervention.^{131,134,136} In this chapter, we provide a conservative treatment approach for patella alta as related to the diagnosis of knee extension.

Key Tests and Signs

Alignment Analysis

The patient with Kext syndrome or KextSG syndrome may demonstrate a swayback posture with a posterior pelvic tilt. Overdevelopment of the quadriceps musculature may be apparent. In addition, patients with KextSG syndrome often demonstrate patella alta as described by Insall³⁸ (Figure 7-33).

Movement Impairments

Standing tests. During hip and knee flexion in stance (partial squat), the patient with Kext syndrome often shifts the body weight posteriorly, keeping the tibia perpendicular to the floor (Figure 7-34). The secondary test for this movement is to instruct the patient to shift the body weight anteriorly and allow the tibia to advance



Figure 7-33. Patella alta demonstrated. Insall-Salvati ratio measured clinically: 1.67.

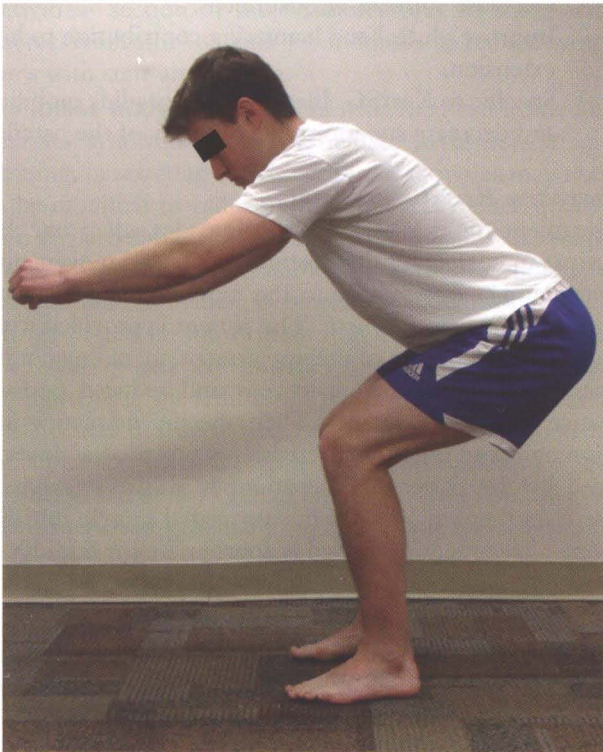


Figure 7-34. Movement test item—squat. The patient with knee extension often shifts the body weight posteriorly, keeping their tibia perpendicular to the floor. If patient reports pain with this movement, perform the secondary test.

forward over the foot (Figure 7-35). If symptoms are reduced, Kext syndrome should be suspected. If KextSG syndrome is suspected (pain located peripatellar or inferior to the patella), the partial squat test may be repeated as the examiner places an inferior glide on the patella. If symptoms are decreased compared to the primary test, KextSG syndrome is supported.

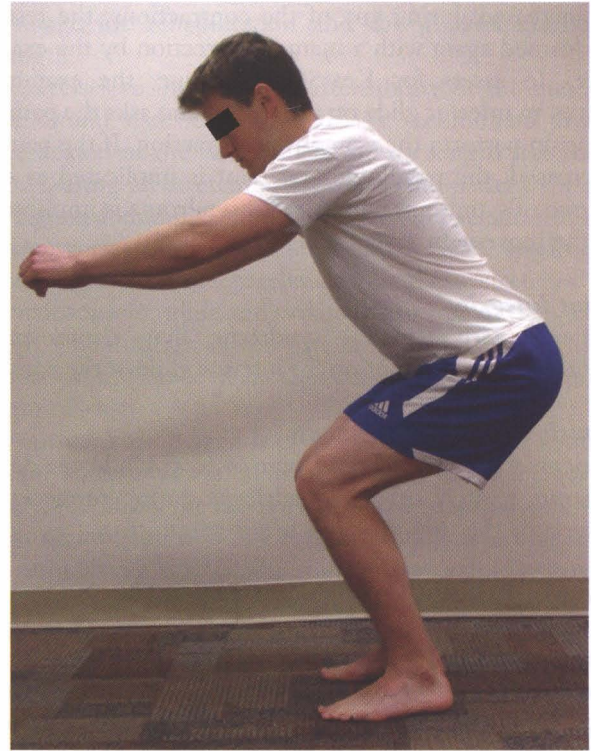


Figure 7-35. Secondary test: Instruct the patient to shift his or her body weight anteriorly and allow the tibia to advance forward over the foot.

Supine tests. While performing the two-joint hip flexor length test,⁸⁸ knee extension may be observed when the involved limb is lowered into hip extension. If the knee extension persists when the hip is brought into abduction, rectus femoris stiffness is implicated. If the patient reports pain during the test, the test may be repeated while the examiner places an inferior glide on the patella. If symptoms decrease, then KextSG syndrome is supported. The patient with Kext (without superior glide) will likely report an increase in symptoms if an inferior glide is placed on the patella, which would place additional stress on the structures superior to the patella.

Prone tests. During knee flexion in prone, patients with KextSG or Kext syndrome will demonstrate a short or stiff rectus femoris and may report pain at the end of their motion. For symptoms in the peripatellar or inferior patellar region, an inferior glide is placed on the patella during the test. A decrease in symptoms with this secondary test supports KextSG syndrome as the diagnosis. Similar to the two-joint hip flexor length test, an increase in symptoms with the inferior glide would implicate Kext syndrome (without superior glide) as the diagnosis.

Sitting tests. The McConnell test¹²⁰ for patellofemoral pain may be modified to confirm KextSG syndrome. In sitting, the patient performs an isometric quadriceps contraction against resistance at 120, 90, 60, 30, and 0 degrees of knee flexion. If the patient's pain is produced

or increased during any of the contractions, the test is performed again with a manual correction by the examiner. To assess for KextSG syndrome, the examiner places an inferior glide on the patella and asks the patient to again perform the isometric contraction. If the pain is decreased, the patellofemoral joint is implicated as the source of symptoms and KextSG syndrome is implicated as the movement system diagnosis.

Joint Integrity

Patients with KextSG syndrome may demonstrate reduced accessory motion for inferior glide of the patella.

Muscle Length Impairments

Patients with KextSG syndrome or Kext syndrome demonstrate a short or stiff quadriceps during prone knee flexion or the two-joint hip flexor length tests.

Muscle Strength/Performance Impairments

Patients with KextSG syndrome or Kext syndrome often demonstrate poor performance of the gluteus maximus and hamstrings. Quadriceps musculature may compensate for the reduced performance of the hip extensors. The imbalance between the quadriceps and the hip extensors may result in an increased demand on the quadriceps to perform activities that involve extension of the lower extremity.

Stiffness, extensibility, or flexibility. The quadriceps may be short or have increased stiffness due to hypertrophy. In patients with KextSG syndrome, the quadriceps are relatively more stiff than the patellar tendon and the surrounding patellar retinacula and therefore the patella is pulled superiorly excessively. This relative stiffness/flexibility may be observed in a number of tests such as the two-joint hip flexor length test and prone knee flexion.

Functional Activities

During assessment of movements, such as walking and running, patients with Kext syndrome and KextSG syndrome demonstrate decreased knee flexion excursion, particularly between heel strike and foot flat. Reduced knee flexion excursion may also be seen while landing from a jump. While landing from a jump, the knees should flex to assist in absorbing the forces associated with the landing. Patients with Kext or KextSG syndrome often lack this knee flexion and land with a stiff knee, which may be the result of the inability of the quadriceps to elongate appropriately during the landing.

Similar to the partial squat test described earlier, the patient keeps the body weight shifted posteriorly during a step-up or squatting activity. This position may reduce the contribution of the hip extensors and increase the need for quadriceps participation. The increased quadriceps participation may result in an increased load on the patellofemoral joint or peripatellar structures.

Summary of Examination Findings

Kext and KextSG syndromes presents with stiffness of the quadriceps musculature often associated with quadriceps hypertrophy and activities that require repetitive knee extension. The two syndromes differ primarily in location of the structures in which the relative stiffness/flexibility is occurring, thus setting up those structures for injury. KextSG syndrome, the more common of the two, occurs because the quadriceps muscles pull the patella superiorly, resulting in injury in the peripatellar or infrapatellar region. Pain can be reduced by stabilizing the patella in an inferior direction during the aggravating activities. Kext syndrome is less common and often presents as a strain to the quadriceps musculature or the quadriceps tendon.

Treatment

Primary Objectives

The primary objectives of a treatment program for Kext syndrome and KextSG syndrome include the following:

1. Decrease stiffness of quadriceps.
2. Improve gluteal and hamstring contribution to hip extension.
3. Specific to KextSG: Increase inferior glide mobility and decrease superior glide mobility of the patella.

Corrective Exercise Program

Treatment for this classification includes educating the patient in correcting the postural habits and movements that may be contributing to the movement impairment and thus the pain problem. The patient is provided with a general description of the impairment, including dominance/stiffness of the quadriceps and reduced performance of the hip extensors. Then, specific instruction for alignment and functional activities is provided and practiced by the patient. The patient is also instructed in exercises that will address the associated muscle impairments. Treatment described is appropriate for both Kext syndrome and KextSG syndrome, unless otherwise noted.

Functional activities. Functional activities that contribute to the movement impairment must be addressed. The functional activity that is most bothersome to the patient should be addressed first, followed by the activities in which the patient spends the most time such as work or school activities. In this chapter, we cover those activities that are useful for most patients; however, the therapist is encouraged to use the principles of the movement system to address functional activities that may not be described in this chapter.

Sitting. If the patient reports increased symptoms during sitting, he or she should be instructed to reduce the amount of knee flexion while sitting. As symptoms improve, the patient may gradually increase the amount of flexion. If superior patellar glide is contributing, the patient may be instructed to perform a manual inferior glide to the patella to decrease symptoms and to decrease quadriceps stiffness.

Gait. During gait, the patient is encouraged to improve push-off. The patient may also benefit from cues to shift their body weight slightly forward.

Sit-to-stand. To rise from a sitting position to standing, the patient should be instructed to slide forward to the edge of the chair. Once at the front of the chair, the patient should position the feet about hip-width apart and slightly posterior to the knees. The patient is instructed to flex forward at the hips to shift the COM over their feet. The patient should then contract his or her gluteals when rising from the chair while making sure the tibia advances forward over the foot.

Stairs. Similar to rising from a chair, the patient should be instructed in flexing at the hip and shifting the tibia anteriorly to bring the center of mass over the foot. As the patient rises up the step, he or she should use the gluteals to lift the body weight up and forward to ascend stairs. If the patient is unable to ascend or descend stairs without an increase in symptoms, compensatory methods may need to be provided. Please see the “Functional Activities” section in the “Tibiofemoral Rotation with Valgus Syndrome” section for methods to reduce symptoms with stair ambulation.

Fitness activities. Patients with Kext syndrome and KextSG syndrome often participate in fitness, weight training, or sporting activities. These activities may need to be modified to reduce symptoms and reduce quadriceps hypertrophy. If the person participates in weight training, quadriceps strengthening activities should be reduced, and activities to target the gluteals and hamstrings should be substituted. It is important to remember that when a muscle hypertrophies through strengthening, the stiffness of the muscles also increases.

The patient’s aerobic activities may be modified by reducing the intensity to a level appropriate for the patient’s stage for rehabilitation. The intensity is then increased gradually as the patient’s symptoms improve.

If the patient participates in jumping activities on a regular basis, jumping activities should be addressed. The patient should be instructed in achieving sufficient knee flexion during landing and to perform a soft landing. The patient should begin to practice the new strategy at low intensity levels, including small jumps and low impact landing. As the patient improves, the technique may be progressed to higher intensity jumps and landings if symptoms are not aggravated.

Home Exercise Program

Exercises to improve the performance of the gluteus maximus include prone hip extension with the knee flexed, weight shifting, standing on one leg, hip extension in standing with resistance, lunges, and squats. Care should be taken not to increase the patient’s knee symptoms with any of these exercises, particularly lunges and squats, which will incorporate quadriceps participation. The appropriate level of exercise depends on

the stage for rehabilitation and the gluteus maximus strength.

Exercises to improve the extensibility of the quadriceps should also be prescribed. We recommend prone knee flexion or the two-joint hip flexor length test position. During all stretching exercises, the patient should have good abdominal support to avoid pelvic anterior tilt or transverse rotation. Patients with KextSG syndrome need to stabilize the patella during these stretches to prevent superior glide and isolate the stretch to the quadriceps. Stabilization of the patella may be accomplished by manual assistance of another person or through taping (Figure 7-36).

If prone knee flexion is prescribed, the patient should flex the knee only as far as he or she can without increased pain. In addition, the therapist needs to be sure the movement of the patella is not restricted by pressure against the supporting surface. In some cases, a folded towel needs to be placed under the thigh so the patella is able to move inferiorly during knee flexion.

Other Interventions

Taping and patellar mobilization may be useful in patients with KextSG syndrome. We have developed a method to reduce the pull of the quadriceps on the patellar tendon and tibial tubercle (see Figure 7-36). Patients who participate in activities that involve repetitive jumping should be taught to reinforce the taping technique, because the

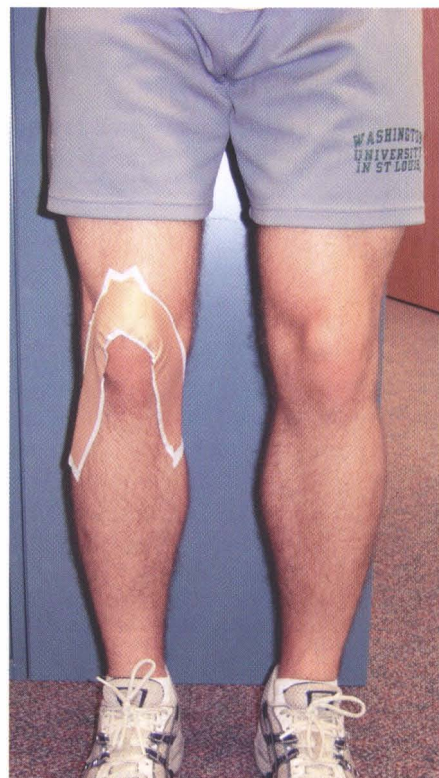


Figure 7-36. Horseshoe taping technique: To assist stabilization of the patella in patients with knee extension with patellar superior glide (KextSG) syndrome.

taping may loosen with the repetitive jumping stresses. Patellar inferior glides and mobilization with movement may be used to help improve the patellar positioning. Based on the concept proposed by Mulligan,¹³⁹ a mobilization for KextSG syndrome was developed. While in the sitting position, the patient performs knee extension and flexion. During the eccentric flexion phase, the patient performs a manual inferior glide of the patella.

CASE PRESENTATION

Knee Extension with Patellar Superior Glide Syndrome

Symptoms and History

A 28-year-old male triathlete is referred to physical therapy for evaluation and treatment of left knee pain. He reports left knee pain for 5 months that was located immediately posterior to the patella. His pain began after a recent marathon. He stated that he had no pain during or after the race. He took the recommended rest after the marathon, then approximately 3 weeks after the marathon, he began to increase his running mileage in preparation for his next triathlon. After running a set of intervals, he noticed a sharp pain behind the left kneecap. He had used ibuprofen and ice with minimal relief. At the time of the examination, the patient rated his pain as a 2/10 at rest that increased to 6/10 with running. His symptoms do not appear to increase with cycling or swimming. His KOS-ADL¹¹⁹ score is 76%, and KOS-Sports score is 71%. No imaging was performed.

Alignment/Appearance

The patient is 6 feet 3 inches and weighs 210 pounds with a fit appearance. In stance, the patient's alignment was unremarkable.

Movement Analysis

Standing

During a partial squat, the patient reports an increase in knee pain. No movement faults are noted. For the secondary test, the partial squat is repeated while the examiner placed a manual patellar glide in the medial direction. The patient reports an increase in knee pain similar to the previous test. The examiner asks the patient to repeat the test while the examiner placed a manual glide in the inferior direction. The patient reports no pain with the test.

Prone

During knee flexion in prone, the patient reports an increase in pain that was resolved with the addition of a patellar inferior glide.

Joint Integrity

Accessory motions of the patellofemoral joint were limited in the inferior direction. The patient reports no change in symptoms with the accessory motions.

Muscle Length Impairments

During the two-joint hip flexor length test, the patient demonstrated a short rectus femoris on the left. As the hip was extended, the knee extended and the patient reports an increase in his symptoms. With a manual glide of the patella in the inferior direction, the patient reports a decrease in his pain compared to the first performance. Hamstrings are short and stiff.

Muscle Strength/Performance Impairments

Using manual muscle testing, the left hip lateral rotators are 4+/5, the gluteus maximus is 4-/5, the iliopsoas is 4/5, and the posterior gluteus medius is 4+/5. Hamstring and quadriceps are strong (5/5); however, the patient reports an increase in his pain when resistance is applied to the quadriceps.

Stiffness/Extensibility/Flexibility

The rectus femoris was relatively more stiff than the patellofemoral joint causing superior glide of the patella during rectus femoris length tests.

Tests for Source

The patient reported tenderness with palpation along the medial and lateral patellar facets. There was no tenderness along the tibiofemoral joint line. The McConnell test¹²⁰ and the patellofemoral grind test^{52,120} for patellofemoral pain were positive. During the McConnell test, the patient reported pain when resistance is applied with the knee in 60 degrees of flexion. This pain is alleviated with a manual inferior glide. All ligamentous and meniscal tests were negative.

Functional Activities

The patient reports an increase in his symptoms during a stair ascent. As he pushed off of the step with the involved limb, he kept his trunk vertical and did not flex forward at the hip. Cues to lean forward and use his gluteals to push up to the next step resulted in decreased symptoms with the step. Gait was unremarkable. During landing from a jump, he demonstrates reduced knee flexion excursion, giving a stiff knee appearance.

Diagnosis and Staging

The diagnosis is KextSG syndrome, and the stage for rehabilitation is Stage 2. His prognosis is good to excellent. Positive moderators include his young age, overall good health, high motivation to return to his activities, and his ability to change the movement impairments with instruction only. Negative moderators include his high activity level.

Treatment

The patient was seen once per week for 2 weeks, then once every other week for 2 weeks for a total of 4 visits over 7 weeks. Treatment included instruction in

correct performance of functional activities, including his sporting activities. He was also instructed in a home exercise program to improve performance of the hip extensors and hip lateral rotators as well as exercises to increase the extensibility of the rectus femoris and hamstrings.

During the first visit, the patient was instructed in shifting his COM forward over the feet during functional activities such as sit-to-stand and ascending stairs. This was accomplished by leaning forward and dorsiflexing the ankle to advance his tibia anteriorly over the foot. He was then instructed to use his gluteals while extending the lower extremity to raise his body weight up to the next step.

To improve performance of the hip lateral rotators and posterior gluteus medius, sidelying hip abduction/lateral rotation with the hip and knee extended was prescribed. To improve gluteus maximus performance, prone hip extension with the knee flexed was prescribed. To accommodate rectus femoris stiffness, he performed this exercise with pillows under his hips to allow greater hip motion. He was instructed to perform the exercises one time per day. He was instructed to perform 3 sets, each set to fatigue. The repetitions depended on his ability to perform the exercise correctly. He was also instructed to stop all of the exercises that he was using to increase quadriceps strength such as resisted knee extension, lunges and squats. He was encouraged instead to substitute gluteal strengthening activities such as hip extension.

To improve extensibility of the rectus femoris, the two-joint hip flexor test position was used as a stretching technique. He was instructed to extend the hip toward the surface of the mat. Once the hip was in the final position, the patient was instructed to flex the knee. The patient was unable to perform the stretch without an increase in symptoms, so the examiner applied the taping method in Figure 7-36 to assist. With the tape applied, the patient could perform the stretch without discomfort behind the patella. He also reported feeling a good stretch in the quadriceps muscles. An alternative stretch, knee flexion in prone, was provided for the times that he could not be taped. He was instructed to flex the knee through the ROM that did not increase his pain.

Regarding his fitness program, the patient was encouraged to continue with cycling and swimming according to his training schedule. For the running component, he was encouraged to avoid interval training that involved sprints for 2 weeks. During these 2 weeks, the distance he runs should be limited to a distance that does not increase his symptoms by more than 2 points. For example, if he rated his pain at rest as 2/10 and increased to 5/10 after the run, he should reduce his distance during the next run. He was encouraged to continue using ice as needed.

The patient was also instructed in how to apply the tape appropriately. He was instructed to at minimum

wear the tape during stretching and during his runs. He was encouraged to wear the tape throughout the day if possible.

At his second visit, 1 week later, the patient reported 80% compliance with the exercises and 70% compliance with the functional activity corrections. He reported that his worst pain in the last week was 2/10 after sitting for a prolonged time at a conference. He stated that the tape was helpful and discovered that he could run longer distances if the tape was in place. He demonstrated correct performance of the exercises, therefore the exercises were progressed. Sidelying hip abduction/lateral rotation and prone hip extension were progressed to standing hip abduction/lateral rotation and standing hip extension using resistance. The patient's gym had a pulley resistance system, so he was instructed in the proper performance of the exercises using the pulley system.

He demonstrated proper performance of the two-joint hip flexor length stretch; however, he reported that he had some difficulty finding an appropriate place to perform the stretch. He would like to be able to perform the stretch before and after runs outside. He was instructed in a method to perform the stretch in a half-kneeling position (Figure 7-37). He was encouraged to maintain proper trunk alignment during performance of the stretch.

On review of functional activities, such as sit-to-stand and stair ambulation, the patient was able to demonstrate the activities independently. He reported that he no

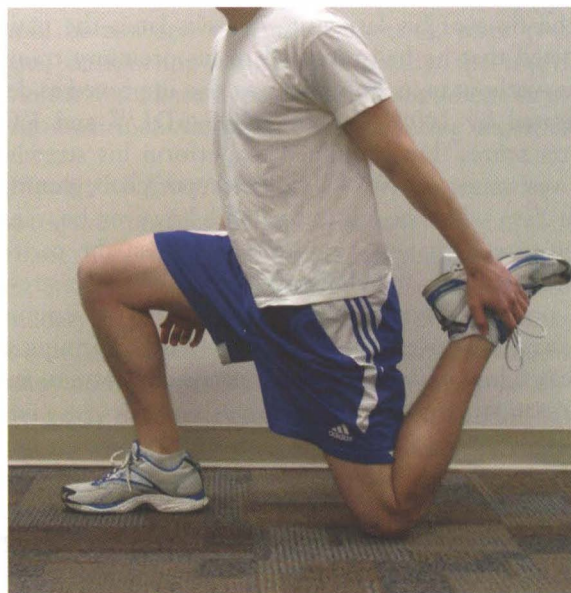


Figure 7-37. The two-joint hip flexor length stretch in half-kneeling position. May be performed in Stage 3 of rehabilitation. The patient is instructed to use the ground to prevent superior glide of the patella while performing the stretch. For patient comfort, this stretch should not be performed on a hard surface. The patient is instructed to maintain proper trunk alignment by using abdominal contraction to prevent lumbar extension and to avoid leaning forward.

longer had pain with stairs, although he was surprised when he had an increase in pain after prolonged sitting. With follow-up questioning, the patient revealed that he did not wear the tape on the day of the conference because he felt it was not needed. To address this relative stiffness/flexibility, the patient was instructed in a self-mobilization using inferior glide of the patella during knee flexion. He was instructed to perform this as often as he could throughout the day, particularly during the days he was sitting for a prolonged period of time.

At 5 weeks, the patient reported that he had no pain at rest or with his training runs. He stated that he had not used tape in the last 2 weeks and felt ready to begin interval training again. He demonstrated independence in his home program and functional activities. He was instructed in how to progress his resistance training for the hip musculature and encouraged to continue performing the stretches on a consistent basis. The strengthening and stretching routine that he typically performed before his injury was reviewed and suggestions were provided. For example, during his hamstring stretch, he demonstrated increased lumbar flexion. He was instructed to avoid lumbar flexion to isolate the stretch to the hamstrings and to avoid unnecessary stress to the lumbar spine.

The examiner agreed that he could initiate his interval training. The patient was encouraged to apply tape during the first few sessions. If he had no increase in symptoms, then he could try a session without tape.

Outcome

At the time of his last visit, 7 weeks later, the patient reported that he had returned to his preinjury training status without tape. Function was also improved as demonstrated by 100% on both KOS-ADL¹¹⁹ and KOS-Sports scores. He continued to perform his stretching and resistance activities. He also reported beginning a yoga class, which he felt was helpful; however, he wanted to be sure if that was appropriate. Given the patient's inherent stiffness and high activity level, a regular stretching program would be appropriate. The examiner reviewed the poses that the patient was performing and educated him on how to modify particular poses to avoid increased stress to the joints.

KNEE HYPEREXTENSION SYNDROME

Knee hyperextension (Khext) syndrome is described as knee pain associated with an impaired knee extensor mechanism. Dominance of the hamstrings and poor performance of gluteus maximus and quadriceps muscles result in hyperextension of the knee placing excessive stresses on the knee. Differentiating Khext syndrome from TFR syndrome can be a challenge; therefore tests to rule out TFR syndrome should be performed before providing the Khext syndrome diagnosis.

Symptoms and History

Patients report pain located in the peripatellar region or tibiofemoral joint that is aggravated during prolonged standing or with activities that involve rapid knee extension such as swimming or kicking during martial arts. Race walkers also demonstrate Khext syndrome as they repetitively hyperextend their knee to maintain prolonged foot contact during their sport. Common diagnoses used by referring physicians include patellofemoral pain syndrome and fat pad syndrome, also called *Hoffa's disease*.¹⁴⁰

The articles that are available related to Khext syndrome are limited to describing the effect of knee alignment on structures of the knee. Loudon et al¹⁴¹ provided a thorough review of the relationship of knee hyperextension alignment and tissue injury. Extension of the knee is not limited by bony anatomy, thus the soft tissues of the posterior knee are primarily responsible for the resistance needed to prevent the knee from further extension. Based on the anatomy and principles of biomechanics, a reasonable assumption is that prolonged knee hyperextension during standing or repetitive hyperextension during gait could result in increased tensile stresses on the ACL and the soft tissues of the posterior knee, as well as compressive stresses on the anterior structures such as the fat pad.¹⁴¹

There are a few studies that demonstrate a direct association between knee hyperextension and injury. In a prospective study of female soccer players, Myer et al¹⁴² reported that knee hyperextension alignment increases the odds of sustaining an ACL injury by fivefold. In a case-control study, Loudon et al¹⁴³ used conditional stepwise logistic regression to find a significant correlation between knee hyperextension alignment and ACL injury. There is also evidence that women with hyperextension of the knee may have reduced knee joint position sense that may reduce the individual's ability to control end-range knee extension movements.¹⁴⁴

Although knee hyperextension alignment is implicated in knee injury and pain, an individual with Khext syndrome can demonstrate signs of hyperextension during other tests such as gait and stair ambulation. The diagnosis of Khext syndrome should not be given based on alignment alone.

Key Tests and Signs

Alignment Analysis

Individuals with Khext syndrome often demonstrate knee extension greater than 5 degrees in standing (Figure 7-38). They may also demonstrate a swayback posture with a posterior pelvic tilt and ankle plantarflexion. Correction of the standing alignment may result in a decrease in the patient's symptoms.

Movement Impairments

Standing tests. During single-leg stance on the involved limb, the patient may demonstrate an increase



Figure 7-38. Knee hyperextension alignment. Note knee extension greater than 5 degrees and ankle plantarflexion.

in knee hyperextension. If medial rotation of the hip is noted during this test, then a tibiofemoral rotation diagnosis should be considered.

Joint Integrity

Patients in this category may demonstrate a general joint hypermobility as assessed by the Beighton index¹⁴⁵; however, this is not a requirement. Some patients appear to have general laxity of the ligaments, yet their Beighton index is relatively low. The patient may demonstrate knee extension PROM that is greater than 10 degrees; however, in acute flare-ups of the condition, the patient may actually demonstrate a reduction in knee extension compared to the uninvolved side. This is thought to be a protective mechanism to reduce stresses to the injured structures.

Muscle Length Impairments

The patient may have a short or stiff gastrocnemius; however, these limitations are not seen in all patients with Khext syndrome. Hamstring shortness is often associated with this syndrome.

Muscle Strength/Performance Impairments

Impairments of muscle strength and performance include poor performance of gluteus maximus and quadriceps. The gluteus maximus often tests weak during manual muscle testing (MMT) and demonstrates delayed recruitment during activities such as prone hip extension with the knee extended. The gluteus maximus should contract

early in the motion of limb movement during prone hip extension. A notable delay in gluteus maximus contraction may indicate that the hamstrings are acting as the primary hip extensors for the hip movement. The quadriceps often tests strong during a MMT; however, the patient may display poor functional use of the quadriceps during activities such as a step-up or sit-to-stand as evidenced by the patient pulling his or her knees back to the body.

Functional Activities

Gait. During gait, the patient may demonstrate hyperextension from heel strike through late stance. The patient may also demonstrate a prolonged foot flat, keeping their heel in contact with the floor longer than expected. Noyes et al¹⁴⁶ described this gait pattern in patients with posterolateral ligament complex injuries; however, this pattern has been observed in symptomatic patients without documented ligamentous injury.

Step-up. During a step-up, the patient demonstrates a faulty movement of pulling the knee back to the body, instead of shifting the body forward over the limb. This motion is achieved by using the hamstrings more than the quadriceps and gluteus maximus to extend the hip and the knee. Because the foot is anchored on the floor, hip extension performed by the hamstrings results in knee extension and therefore reduces the need to recruit the quadriceps to extend the knee.

Other Functional Tests

Activities that tend to exacerbate the patient's symptoms should be assessed such as sit-to-stand, work requirements, or sporting activities. Typically, the individual demonstrates a knee hyperextension alignment or movement impairment during these aggravating activities.

Summary of Examination Findings

Khext syndrome presents with the movement impairment of knee hyperextension during alignment, movement tests, and functional activities. A special note related to secondary tests for Khext syndrome is that patients with this syndrome often have a chronic condition that does not always modify immediately with secondary tests. The patient may need to try modifications for a period of time to see the effect. For example, the patient may report no change in symptoms with correction of standing alignment; however, if standing alignment is modified while at work, symptoms may improve dramatically.

Differentiating between Khext syndrome and tibiofemoral rotation syndrome can be challenging. If signs for both Khext syndrome and tibiofemoral rotation syndrome are observed, the therapist should follow treatment guidelines for tibiofemoral rotation syndrome, which provides treatment related to the rotation component and also addresses the hyperextension component. Khext syndrome should be reserved for those displaying the movement impairment in the sagittal plane only.

Treatment

Primary Objectives

The primary objectives of a treatment program include the following:

1. Decrease hyperextension of the knee during functional activities.
2. Improve muscle performance of the gluteus maximus and quadriceps.
3. Decrease overrecruitment or dominance of the hamstrings.

Corrective Exercise Program

Treatment for this syndrome includes educating the individual in correcting the postural habits and movements contributing to the movement impairment and thus the pain problem. The patient is provided with a general description of the impairment and specific instruction for alignment and functional activities. Then the functional activities are practiced by the patient. The patient is also instructed in exercises that will address the associated muscle impairments.

Alignment. First, the patient is educated in correction of posture and functional activities. To improve alignment between the femur and tibia, the patient is instructed to relax or unlock the knees to reduce hyperextension of the knee. If the patient stands in a posterior pelvic tilt, this should also be corrected. A mirror is useful during correction of the alignment. Patients often report that their position of hyperextension feels “normal,” and the correction feels as if their knees are too flexed as in a partial squat. The mirror reinforces the proper alignment of the knee.

Functional activities

Gait. During ambulation, the patient is encouraged to use a proper heel-to-toe gait pattern and to land softly on the heel at heel strike. The patient is also instructed to avoid knee hyperextension and hip hyperextension during the stance phase of gait cycle. Most patients with knee hyperextension have a delayed heel rise at push-off; therefore a helpful cue is to ask the patient to lift the heel a little earlier than usual. Another useful cue, as described by Noyes et al,¹⁴⁶ is to walk with the knee slightly flexed.

Sit-to-stand/stairs. During sit-to-stand and stairs, the patient is instructed to use the quadriceps and gluteus maximus to lift the body up and forward and to avoid pulling the knee(s) back to meet the body. The final position of the knee should be a neutral position not hyperextended. If the patient is unable to ascend or descend stairs without an increase in symptoms, compensatory methods may need to be provided. Please see the “Functional Activities” section the “Tibiofemoral Rotation with Valgus Syndrome” section for methods to reduce symptoms with stair ambulation.

Standing. Patients with Khex syndrome often report increased symptoms with prolonged standing. They should be instructed in correcting their alignment during

stance and to reduce the amount of time that they stand in one position. They should be encouraged to change their activities as often as possible, including sitting, walking and leaning into a support surface. If they are in a situation that does not allow them to change their activity, weight shifting provides some temporary reduction in stresses on the knee.

Fitness activities. If the patient does not have a fitness program, then a discussion is warranted to encourage a fitness program as a goal. If the person participates regularly in a fitness program, modification may be necessary. The patient's aerobic activities may need to be modified by addressing the movement impairment and by reducing the intensity. The intensity level of the aerobic activity should be related to the patient's stage for rehabilitation. For example, if the patient is a speed walker and the injury is Stage 1 for rehabilitation, the patient may be instructed to use a bike, walk in a pool, or start with a slower walking pace or shorter walking distance. The intensity is then gradually increased. As the patient's symptoms improve, the patient should begin to increase the walking distance and then increase the speed.

Home Exercise Program

Exercises to improve strength and performance of the gluteus maximus and quadriceps may be prescribed. To improve gluteus maximus performance, exercises, such as prone hip extension with the knee flexed, weight shifting, single-leg stance, and resisted hip extension, are prescribed. When performing prone hip extension with the knee flexed, the patient should have at least one pillow under the abdomen so that the exercise is performed from some hip flexion to neutral and not into hip hyperextension. Functional activities that can be used as exercise to improve gluteus maximus and quadriceps performance include sit-to-stand, wall sits, step-up/step-downs, lunges, and squats. Abdominal muscle exercises may also be appropriate if the patient demonstrates poor trunk and/or pelvic control.

Sitting knee extension with ankle dorsiflexion is an exercise that can be performed easily throughout the day to improve the extensibility of the hamstrings and gastrocnemius. The gastrocnemius can be stretched with prolonged passive ankle dorsiflexion in standing, and the hamstrings can be stretched with prolonged knee extension in the sitting position (see Figure 7-40). To properly stretch the hamstrings, be sure that the spine does not flex.

Taping

Taping may be useful in patients with knee hyperextension. The posterior X taping demonstrated in Figure 7-27 to treat TFRVal syndrome will also assist with preventing Khex syndrome. If the fat pad is very irritable, it may be helpful to try the unloading taping technique proposed by McConnell (Figure 7-39).



Figure 7-39. Taping technique. Unloading taping technique proposed by Jenny McConnell. This taping method is proposed to reduce stress on the source of symptoms, the fat pad.

Neuromuscular Training

Neuromuscular training to improve proprioception, balance, and the ability to accommodate to perturbations is important (see Box 7-2). During neuromuscular training, the patient is instructed to limit the amount of knee hyperextension.

CASE PRESENTATION

Knee Hyperextension Syndrome

Symptoms and History

A 35-year-old female is referred to physical therapy for evaluation and treatment of left knee pain. She reports two previous bouts of similar pain that resolved fairly quickly without intervention. However, this episode began approximately 3 weeks ago and has not improved. The pain is located in the posterior aspect of her knee and just inferior to the patella deep in the joint. She has participated in competitive race walking for the past 3 years. Initially, her pain would only occur during races or when training, but the pain progressed to occurring with daily walking and stair ambulation. Her pain forced her to stop race walking approximately 2½ weeks ago, and she is very anxious to return to this activity. Her pain rating at the time of the initial visit was 3/10 with daily activities and increases to 6/10 if attempting to race walk. She describes her pain as a deep aching in the posterior

knee that becomes sharper when race walking. Nothing seems to give her relief except taking Ibuprofen. Her KOS-ADL¹⁹ score is 51%, and KOS-Sports score is 40%. Radiographs show no abnormalities of the tibio-femoral or patellofemoral joint. She also states that she has a 2-year-old daughter who she tends to carry on her left hip. She was working part-time as a business consultant.

Alignment Analysis

The patient is 5 feet 6 inches and weighs 135 pounds. In stance, the patient demonstrated tibial varum and genu recurvatum bilaterally; however, both faults were greater on the left compared to the right. She had a flat lumbar spine, posterior pelvic tilt, and hip joint hyperextension with a mild swayback alignment.

Movement Analysis

During single-leg stance on the left, the patient demonstrates increased knee hyperextension. The patient did not report an increase in pain, although she does express a feeling of instability compared to standing on the unininvolved limb. The patient also demonstrates a pelvic lateral tilt (Trendelenburg sign) during single-leg stance bilaterally; however, she demonstrated more tilt during single-leg stance on the left than on the right.

During a step-up onto a 12-inch stool, the patient kept her COM posterior to her base of support and snapped her knee back to her body using her hamstrings. She reported a mild increase in symptoms during this test. She was cued to lean forward to bring her COM over her foot, and to think about using her quadriceps and gluteals as she stepped up. She performed the step-up correctly by following the cues provided. She reported that her symptoms did not increase with the corrected method.

Joint Integrity

Knee extension PROM tested in supine is 15 degrees on the left and 10 degrees on the right. The patient's tibiofemoral joints are mildly lax compared to normal, which was noted particularly during prone hip rotation testing, during which the leg motion was particularly evident.

Muscle Length Impairments

Hamstring length is tested and found to be short bilaterally with 70 degrees passive straight leg raise. Gastrocnemius length was also short bilaterally, measuring 10 degrees ankle dorsiflexion with the knees flexed and 0 degrees with the knees extended.

Muscle Strength/Performance Impairments

On the left side, the gluteus maximus MMT reveals a grade of 4/5 and shows a delayed onset compared to the hamstrings during hip extension with the knee extended. The left quadriceps MMT grade is 5/5, although poor

functional performance is suspected. For example, during a wall squat the left quadriceps fatigued more readily than the right, with notable muscle quivering after only 10 seconds. The posterior gluteus medius MMT grade is 4-/5 bilaterally.

Tests for Source

The patient reports tenderness with palpation distal to the inferior pole of the patella in the region of the fat pad on the left. Mild tenderness is also noted on the posterolateral aspect of the knee. All ligamentous and meniscal tests are negative.

Functional Activities

During sit-to-stand and stair ambulation, the patient demonstrates the tendency to pull her knees back to the body using her hamstrings, rather than keep her COM over her feet and use her quadriceps to extend her knees. Increased symptoms are elicited on the left after completing one flight of stairs. The patient is cued to lean forward and to get her shoulders over her feet while concentrating on not hyperextending her knees. Although she has some difficulty performing the stair ambulation correctly with these cues, the patient reports no aggravation of her symptoms. Gait deficits noted are knee hyperextension from heel strike through terminal stance with a delayed heel rise bilaterally. When cued to decrease the knee hyperextension and attempt an earlier heel rise, the patient has trouble trying to change her gait pattern and becomes a little frustrated. A bilateral hip drop is also noted during gait.

Diagnosis and Staging

The diagnosis is Khext syndrome. The stage for rehabilitation is Stage 2. Her prognosis is good to excellent. Positive moderators include her fairly young age, overall good health, and high motivation to return to her activities. Negative moderators include her difficulty making corrections during alignment and functional activities and her anxiety about wanting to return to race walking, a sport that encourages knee hyperextension by demanding that one foot be in contact with the ground at all times.

Treatment

The patient was seen twice per week for 2 weeks secondary to taping needs, then decreased to once per week for 4 weeks for a total of 8 visits over 6 weeks. Treatment included instruction in correct performance of functional activities, including speed walking. She was also instructed in a home exercise program to improve performance of the hip abductors, gluteus maximus, and quadriceps, along with exercises to increase the extensibility of the hamstrings, gastrocnemius, and soleus muscles. Although she reported pain only in the left knee, she was encouraged to perform the exercises bilaterally.

During the first visit, the patient was instructed to correct her standing alignment of knee hyperextension

by relaxing her knees. A mirror was needed for visual feedback of her alignment. Her tendency at first was to excessively flex her knees, and she found it very difficult and tiresome to maintain normal alignment. Therefore it was decided to perform the posterior X taping technique to provide an external source of feedback to her when she would start to hyperextend her knees (see Figure 7-27). The patient was instructed to keep the tape on for 1 to 3 days if tolerated and to check her skin carefully when the tape was removed. Assuming there would be no skin reactions, the plan was for her to return at the end of the week to be re-taped.

She was instructed to try alternating the hip she used for carrying her child, instead of always holding her on the left. Holding her child on the left hip resulted in prolonged positioning of hip adduction and pelvic lateral tilt. This prolonged positioning may have contributed to her hip weakness and increased knee hyperextension on the left. The patient was instructed in performance of sit-to-stand, attempting to get her shoulders over her feet and prevent hyperextending her knees when completing the standing maneuver. This task was easier for her to correct than gait or stair climbing during the first session.

To improve the functional performance of the quadriceps, the patient was instructed in a wall squat exercise. She assumed a position of about 45 degrees hip and knee flexion and was instructed to start by maintaining the position for 15 seconds and to perform 5 repetitions. Each day she was to try to add 5 seconds onto her hold time during the first week. She was also cued to avoid hyperextending her knees when returning from the squat position to the hip and knee extended position.

To begin to improve the performance of her gluteus maximus, the patient was instructed to forward bend by hip flexion only with knees flexed and practice returning by contracting her gluteals to lift her upper body. She was also given the exercise of prone hip extension over 3 or 4 pillows to help place her in enough hip flexion so that her knee could stay relaxed in flexion as she extended her hip using her gluteus maximus. She was instructed to perform the exercise one time per day. She was instructed to perform 3 sets, each set to fatigue. The repetitions depended on her ability to perform the exercise correctly.

To improve the recruitment of the posterior gluteus medius, the patient was instructed in weight shifting. She was instructed to avoid pelvic tilting and knee hyperextension as she shifted. The patient had difficulty maintaining the appropriate pelvic position, so she was encouraged to place her hands on her ASIS to monitor the pelvic alignment. She was then able to perform the activity correctly. She was also encouraged to maintain the trunk in a neutral position and avoid sidebending. She was instructed to perform this exercise frequently throughout the day, if possible.

To address her limitations in hamstring extensibility, she was instructed to sit on the edge of a chair with one leg extended and to lean forward from her hips keeping her spine straight until she felt an appropriate stretch to her hamstrings. Because her knee would easily assume a hyperextended position, the patient had to make a conscious effort to keep the knee relaxed in slight flexion during the stretch (Figure 7-40). While stretching her hamstrings, she was also instructed to try to dorsiflex her ankle without toe extension to provide an additional stretch to her gastrocnemius. The patient was instructed in the typical standing wall stretch for the gastrocnemius as well.

At her second visit, she reported 75% compliance with the exercises and about 50% compliance with the functional activity corrections, which were still hard for her. She stated that the tape behind her knees was definitely helpful in relearning how to stand properly. She was able to wear the tape for 2 days and had no skin reaction, so she requested to have the tape applied again at that visit. Her symptoms had decreased to 2/10, and she reported less pain with stair ambulation.

She demonstrated correct performance of the exercises, therefore the exercises were progressed. With the wall squat, she was now able to sustain the position for 30 seconds before fatiguing. This exercise was progressed by having her place her right foot slightly in front of her left, forcing her to increase the load to her left quadriceps. Her weight shifting was progressed to single-leg stance with light upper extremity support and using all the previous cues. An additional exercise was given to her for the posterior gluteus medius. She was instructed in the side lying hip abduction/lateral rotation exercise. Two to three pillows were placed between her legs and her top leg was aligned in 10 to 20 degrees of hip and knee flexion. When the patient attempted to abduct her hip off the pillows, she reported feeling muscles working in her posterior thigh so it was determined that she was substituting with her hamstrings. With much verbal and manual cueing and specific palpation of her posterior gluteus medius, she was able to perform this exercise correctly. The patient was encouraged to start with five repetitions and progress toward ten, only if she could feel the muscle recruitment in the correct location. Because she was performing her prone hip extension exercise correctly, she was encouraged to add more repetitions.

The patient was re-taped and her gait deviations were addressed with the tape applied. The main cues given to her were to lean forward slightly while walking, take smaller strides and lift her heel earlier at terminal stance. Her attempts at these corrections were better than at her first visit, although she felt very awkward. The patient was instructed to continue with the other exercises, trying to be diligent about her hamstring stretching throughout the day.

At the fifth visit during the third week, taping was discontinued because the patient felt she was now able to

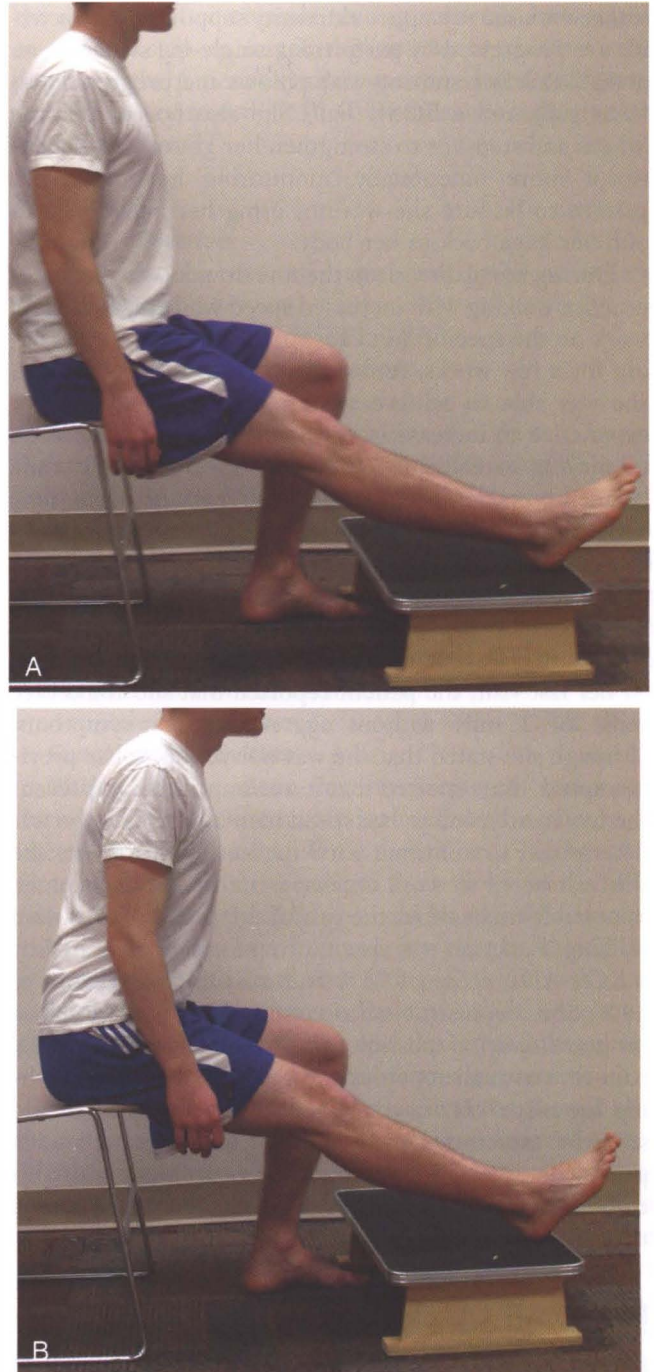


Figure 7-40. Hamstring stretching. Proper performance of hamstring stretch provided to the patient. **A**, The patient sits on the edge of a chair with one leg extended. **B**, The patient then leans forward from the hips, keeping the spine straight until an appropriate stretch is felt.

control the knee hyperextension on her own. The patient reported 0/10 symptoms at that time with walking and with stair ambulation. She admitted to trying to race walk for a short distance but developed low level symptoms so she decided she was not quite ready. At this visit, she was progressed to level 3 of the posterior gluteus medius progression. She was now able to perform single-leg

stance without any upper extremity support, so the activity was progressed by performing single-leg stance on an unstable surface starting with pillows and progressing to foam pads and a BOSU ball. She also began standing lunges and step-ups to strengthen her gluteals and quadriceps more functionally, monitoring her movement pattern to be sure she was not using her hamstrings to pull her knee back to her body.

During her sixth visit in the fourth week, she began to practice walking with increased speed while trying to still work on the specific gait cues she had now been practicing for a few weeks. As long as she did not go too fast, she was able to achieve some corrections and did not experience an increase in symptoms. She was progressed to playing catch with a weighted medicine ball while balancing on one leg on the BOSU ball. Also, she now added 5 pound weights in each hand while performing her lunges and step-ups.

Outcome

The patient was seen for a total of 8 visits over 6 weeks. At her last visit, the patient reported that she could race walk for 1 mile without aggravating her symptoms, although she stated that she was not yet up to her previous speed. She reported that it was impossible to prevent the hyperextension as her speed increased. Since she was determined to continue participation in this sport, she was instructed to work on her gait corrections as much as possible throughout the rest of the day, when not race walking. Function was also improved as demonstrated by a KOS-ADL score of 93% and a KOS-Sports score of 84%. She was instructed to continue her home exercise program daily, if possible, even when she was totally pain-free with all activities and to think of it like “brushing her teeth.” It was explained to her that if she would stop the exercises, her pain would likely return after a period of time. The patient had no problem with this commitment, and she was discharged from physical therapy.

PATELLAR LATERAL GLIDE SYNDROME

Patellar lateral glide (PLG) syndrome is described as knee pain as a result of an impaired patellar relationship within the trochlear groove. Patients with PLG syndrome have an imbalance between the vastus medialis oblique (VMO) and the vastus lateralis (VL) muscles that may place excessive compressive forces in the lateral patellofemoral joint and tensile forces on the medial joint structures. Shortness or stiffness of the TFL-ITB complex may also contribute to a lateral pull on the patella. A similar syndrome has been described by McConnell.⁸⁷

Symptoms and History

Patients with PLG report peripatellar or retropatellar pain with activities such as stairs, running and squatting.

They may also report an increase in symptoms with prolonged knee flexion when sitting, often called *movie goers syndrome*. PLG rarely occurs in isolation and is often a secondary diagnosis associated with a primary diagnosis of tibiofemoral rotation or knee hyperextension. Common diagnoses used by referring physicians include patellofemoral pain syndrome and patellar chondromalacia.

There is a large body of literature related to the relationship of the VMO and patellofemoral pain; however, the relationship has not been clearly established. A number of authors have reported that patients with patellofemoral pain demonstrate poor performance of the VMO when compared to those without symptoms.¹⁴⁷⁻¹⁵¹ There are, however, others that report there is no difference in VMO performance between those with and without patellofemoral pain.¹⁵²⁻¹⁵⁵ The inconsistent findings demonstrate a need for classification by movement impairment. Subjects with patellofemoral pain are often included in these studies based on pain location; the movement impairment associated with the pain complaint is not considered. Patients with TFRVal syndrome and patients with PLG syndrome may report a similar pain in the peripatellar region, although they may display dissimilar movement impairments. A relationship between VMO performance and patellofemoral pain may exist in individuals with PLG syndrome but may not exist in individuals with TFRVal syndrome. Classification by movement impairments may assist in clarifying the research findings.

Clinical trials of treatment that incorporate VMO strengthening have demonstrated positive results¹⁰²; however, the isolated treatment effects of VMO strengthening are not known. Often these clinical trials include additional treatments, such as stretching and taping, therefore it is difficult to determine the effectiveness of VMO strengthening alone. Recently, authors have demonstrated that increasing the VMO force can decrease the pressure on the lateral patellofemoral joint articular cartilage.¹⁵⁶

Key Tests and Signs

Alignment Analysis

The patient with PLG syndrome may demonstrate a lateral patellar tilt or lateral patellar glide.

Movement Impairments

Standing tests. During hip and knee flexion in stance (partial squat), the patient may report an increase in their symptoms; however, a movement impairment may not be apparent. A secondary test is performed by asking the patient to repeat the movement while the examiner places a medial glide on the patella. If symptoms are decreased compared to the primary test, PLG is supported.

Supine tests. Patients with PLG syndrome may report an increase in symptoms during the performance of the two-joint hip flexor length test.⁸⁸ The test is then repeated while the examiner places a medial glide on the

patella. If symptoms decrease, then PLG syndrome is supported. Symptoms may also be decreased by abducting the hip, therefore reducing the stretch on the TFL-ITB.

Prone tests. During knee flexion in prone, patients with PLG syndrome may report pain at the end of their motion. Decreased symptoms when a medial glide is placed on the patella supports the diagnosis of PLG syndrome. Similar to the two-joint hip flexor test, placing the hip into abduction reduces the stretch on the TFL-ITB, which may result in a decrease in the patient's symptoms.

Sitting tests. During knee extension in sitting, the examiner may observe sudden lateral movement of the patella near the end of the knee motion, a motion often referred to as a positive J-sign. This excessive lateral patellar motion may also be seen during an isometric quadriceps contraction.

A McConnell test¹²⁰ for patellofemoral pain may be performed to assess for PLG syndrome. In sitting, the patient performs an isometric quadriceps contraction against the therapist's resistance at 120, 90, 60, 30, and 0 degrees of knee flexion. If the patient's pain is produced or increased during any of the contractions, the test is performed again with a manual correction by the examiner. To prevent patellar lateral glide, the examiner places a medial glide on the patella and the resisted test is repeated. If the pain is decreased, the patellofemoral joint is implicated as the source of symptoms and PLG syndrome is implicated as the movement impairment.

Joint Integrity

Patients with PLG syndrome may demonstrate reduced accessory motion for medial glide of the patella.

Muscle Length Impairments

Patients may demonstrate short and/or stiff TFL-ITB and lateral patellar retinaculum. Though not common, sometimes a short and/or stiff gluteus maximus with attachment to the ITB may contribute to the lateral pull of the patella.

Muscle Strength and Performance Impairments

Although weakness of the VMO may contribute to PLG, clinical testing specific to the VMO is not possible. Other characteristics of muscle performance such as muscle timing or endurance have also been suspected to contribute to PLG. Muscle timing and endurance are also difficult to observe clinically. Laboratory measurements, such as electromyography (EMG), may assist in identifying an imbalance in the timing of contraction between the VMO and VL; however, EMG is often not practical in the clinic.

Functional Activities

During performance of functional activities, observation of the movement impairment of PLG syndrome is often difficult; however, secondary tests can be used to support

the diagnosis. For example, during activities such as sit-to-stand or step-up, a medial glide may be placed on the patella. If the patient's symptoms are reduced compared to the primary test, then PLG syndrome is supported as the diagnosis.

Treatment

Primary Objectives

The primary objectives of a treatment program include the following:

1. Decrease stiffness of TFL-ITB.
2. Improve quadriceps function.

Corrective Exercise Program

Treatment for PLG syndrome includes educating the individual in correcting the postural habits and movements that may be contributing to the movement impairment and thus the pain problems. The patient is provided with a general description of the impairment and specific instruction for alignment and functional activities. The activities are then practiced by the patient. The patient is also instructed in exercises that will address the associated muscle impairments.

Functional Activities

Sitting. If a patient reports increased symptoms during sitting, the instruction is to reduce the amount of knee flexion while sitting. If the patient has a stiff or short gluteus maximus contributing to the stiffness of the ITB, resulting in PLG, the thighs should be slightly abducted initially. As symptoms improve, the thighs should be gradually adducted until the sitting position is normal and does not cause symptoms. Patients should be encouraged to get out of their chair and flex/extend their knee every 30 minutes to reduce the amount of time the knee is maintained in a flexed position. Patients should also limit the amount of time spent with their legs crossed.

Sit-to-stand. To rise from a sitting position to standing, the patient should be instructed to slide forward to the edge of the chair. Once at the front of the chair, the patient should position the feet about hip-width apart and slightly posterior to the knees. The patient is instructed to contract the quadriceps when rising from the chair. If this motion is painful, the patient may use the hands to assist by pushing up from the armrests of the chair.

Stair ambulation. Similar to rising from a chair, the patient should be instructed to use the quadriceps and gluteals to ascend the stairs. If the patient is unable to ascend or descend stairs without an increase in symptoms, compensatory methods may need to be provided. Please see the "Functional Activities" section in the "Tibiofemoral Rotation with Valgus Syndrome" section for methods to reduce symptoms with stair ambulation.

Fitness activities. Recommendations related to fitness are provided in the "Functional Activities" section in the "Tibiofemoral Rotation with Valgus Syndrome" section.

Home Exercise Program

The patient should be provided with a home exercise program and instruction on the appropriate response to exercise. Exercises specific to PLG syndrome to improve the performance of the quadriceps may be prescribed. We recommend the use of functional activities to improve quadriceps performance. Those exercises, in the order of difficulty beginning with least aggressive, are sit-to-stand transfers, step-ups, lateral step-ups, squats, lunges, and step-downs. Ekstrom et al¹⁵⁷ demonstrated that lunges and lateral step-ups produced greater EMG activity in the VMO compared to other rehabilitation exercises. Bio-feedback to improve timing or recruitment of the VMO may be a useful intervention^{102,158,159}; however, more clinical studies are needed. In addition, we recommend avoiding open-chain resisted activities in the range of 0 to 45 degrees of flexion and closed-chain activities in the range of 60 to 90 degrees, since these ranges are thought to result in increased stresses to the patellofemoral joint.¹⁶⁰

Exercises to improve the extensibility of the TFL-ITB should also be prescribed. We recommend prone knee flexion (either unilateral or bilateral) or stretching in the two joint-hip flexor length test position. During prone knee flexion, the patient should initially perform with the involved hip in abduction to reduce the pull of the ITB. As symptoms improve, the amount of hip abduction is reduced.

The two-joint hip flexor stretch position may be used as the patient's symptoms improve. As the involved limb is lowered into extension, the hip should be allowed to abduct. Once the hip is in extension, the hip can then be adducted to add the stretch to the TFL-ITB. Assuming normal anatomy of the femoral lateral condyle, the patella will be secured within the trochlear groove prior to adding the stretch of the TFL-ITB.

Patients must not feel pressure or pain in the location of their symptoms during the stretches. If the symptoms occur, the patella is most likely being mobilized and the stretch will not be effective. Patients with PLG syndrome may need to stabilize the patella during these stretches. Stabilization of the patella may be accomplished by manual assistance of another person or through taping (Figure 7-41). During all stretching exercises, be sure that the patient has good abdominal support to avoid pelvic anterior tilt or rotation. Strengthening the muscles that are antagonists of the TFL-ITB, such as the posterior gluteus medius and gluteus maximus, may also help to improve TFL-ITB extensibility.

Other Interventions

Taping and patellar mobilization may be useful in patients with PLG syndrome. Taping to reduce patellar lateral glide as proposed by McConnell⁸⁷ has had clinical success (see Figure 7-41). The evidence consistently supports that taping helps to reduce symptoms,^{87,161-165} although the mechanism behind the symptom reduction has not



Figure 7-41. Taping technique. Taping to reduce patellar lateral glide as proposed by McConnell.⁸⁷ The patella is pushed medially by the tester and strips of tape are placed along the patella, anchored around the medial hamstring muscle bulk.

been determined. Many believe that tape is applied to either change the alignment of the patella or improve the performance of the VMO; however, the literature is mixed.^{161,166-172} Although the mechanism is not clear, taping is a safe and relatively convenient intervention that has had clinical success.

Patellar mobilizations in the medial direction may be used to help improve the extensibility of the lateral structures such as the patellar retinaculum and ITB. If the patient is in Stage 1 of rehabilitation, gentle mobilizations may be performed to reduce pain and to initiate mobility in the medial direction. As the patient's symptoms subside, aggressive grades of mobilization should be used to increase extensibility. Patients may be instructed in self-mobilizations to perform along with their home exercise program.

KNEE IMPAIRMENT

Thus far, the focus of this chapter is on the identification and treatment of specific movement system syndromes for the knee. However, patients are commonly referred to physical therapy for rehabilitation of the knee after a surgical procedure or after an acute, traumatic knee injury. When a patient presents to therapy after either a

surgical procedure or an acute knee injury, identification of a specific movement system syndrome using a thorough examination may not be possible because of pain, physician-imposed restrictions, or both. In such cases, the physical therapist must recognize the potential pathoanatomical structure(s) involved, perform a limited problem-centered examination to identify specific impairments, and provide treatment that is congruent with the stage for rehabilitation determined according to the guidelines outlined in Chapter 2.

In general, patients for which a movement system syndrome cannot be determined are classified as having a knee impairment, which is a broad term that encompasses a wide array of structural impairments or injuries. An exhaustive discussion of the potential knee injuries a physical therapist might treat and the surgical procedures after which a patient may be referred to physical therapy is beyond the scope of this text. However, to provide optimal care for the patient, the physical therapist must have a thorough understanding of the possible structures of the knee implicated for a particular injury and be familiar with common surgical procedures used by referring physicians. See the Chapter 7 Appendix for additional information regarding specific tissue properties of the structures of the knee, as well as treatment guidelines for each stage of rehabilitation.

Because the knee impairment classification is relatively nonspecific, the physical therapist should provide a source diagnosis, if possible, to guide treatment. Recall from Chapter 2 that if a movement system diagnosis cannot be determined, the diagnosis made by the physical therapist is based on the pathoanatomical structure involved, as identified by the physician; the procedure performed, if any; and the stage for rehabilitation. For example, if a patient presents to physical therapy 3 days after an ACL reconstruction, the diagnosis made by the physical therapist would likely be as follows: ACL tear, status/post ACL reconstruction, Stage 1. If the specific pathoanatomical structure cannot be determined or has not been specified by the physician, the classification of knee impairment should be used to identify the region of the body that is impaired, with an appropriate stage for rehabilitation.

As the patient progresses with physical therapy after an acute injury or surgical procedure, the physical therapist should attend to any underlying movement impairments that either develop or are identified with a more thorough examination. If a movement system syndrome can be determined, the physical therapist should use this diagnosis, with the appropriate stage for rehabilitation, to guide treatment relative to specific movement impairments. If no underlying movement impairment can be determined, the physical therapist should continue to progress treatment as tolerated according to the stage for rehabilitation associated with the source diagnosis provided.^{173,174}

CONCLUSION

This chapter offers the reader the diagnostic framework to effectively evaluate and treat chronic, acute, and post-surgical knee pain. By specifically identifying movement impairments and considering the tissue characteristics of pathoanatomical structures in the knee, the physical therapist can be more readily prepared to provide optimal treatment and education to patients who present with knee pain than attempting to develop a program without identifying an underlying syndrome.

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CHAPTER 7

APPENDIX



Tibiofemoral Rotation Syndrome

The principal movement impairment in tibiofemoral rotation (TFR) syndrome is knee joint pain associated with impaired rotation of the tibiofemoral joint (lateral rotation of the tibia and/or medial rotation of the femur). Correction of impairment often decreases symptoms. The subcategories of TFR syndrome are TFR with valgus (TFRVal) syndrome: Valgus knee during static/dynamic activities and TFR with varus (TFRVar) syndrome: Varus knee during static/dynamic activities.

Symptoms and History

- Pain along knee joint line or peripatellar pain
- Pain associated with weight-bearing activities (running) or non-weight-bearing activities (sitting)
- History of early stages of OA/DJD
- Often seen in individuals participating in activities requiring LR of the tibia such as ballet dancers, soccer players, equestrians, skaters, and swimmers (breast stroke)
- In ITB friction syndrome, diffuse pain is located over region of the lateral epicondyle of femur. Often aggravated with running downhill or cycling

Common Referring Diagnoses

- MCL sprain (acute, grade 1, or chronic)
- Patellofemoral joint dysfunction
- Hamstring tendinopathy or strain
- ITB friction syndrome
- Popliteus tendinopathy or muscle strain
- Pes anserine bursitis or tendinopathy
- Meniscal injury

Key Tests and Signs for Movement Impairment

Alignment Analysis

Standing

- LR of tibia or MR of femur
 - TFRVar: Varus knee, supinated foot; knee hyperextension may be present
 - TFRVal: Valgus knee, pronated foot, oblique popliteal crease

Movement Impairment Analysis

- Step-down, squat, or single-leg hop: TFR or knee valgus
 - If painful, correction decreases symptoms
- Gait: Observe MR of femur on stance or LR of tibia during swing
 - Varus: May demonstrate a varus thrust
- Single-leg stance: Observe MR of femur on stance leg on involved side
Observe LR of tibia during knee flexion of non-weight-bearing leg on involved side
- Prone knee flexion: Observe LR of tibia
- Prone hip rotation: Excessive rotation or gliding of tibia relative to femur

Aggravating or Frequent Functional Activity

- Observe MR of femur or LR of tibia during activity
 - If painful, correction decreases symptoms

Muscle Length

- Hip flexor length test: Short TFL-ITB.
 - May observe rotation of tibia as hip is extended in midline
 - May have pain in neutral hip position
 - Decreased pain with manual correction of tibial rotation

Muscle Strength/Performance Impairments

- Weak posterior gluteus medius
- Weak intrinsic hip LR. Observe LR of tibia with performance
- Weak TFL

ACL, Anterior cruciate ligament; AVN, avascular necrosis; DJD, degenerative joint disease; FCL, fibular collateral ligament; ITB, iliotibial band; LCL, lateral collateral ligament; LR, lateral rotation; MCL, medial collateral ligament; MR, medial rotation; OA, osteoarthritis; PCL, posterior cruciate ligament; RA, rheumatoid arthritis; ROM, range of motion; SCFE, slipped capital femoral epiphysis; TCL, tibial collateral ligament; TFL, tensor fascia latae; TFL-ITB, tensor fascia latae-iliotibial band.

Source of Signs and Symptoms

Tibiofemoral Joint Involvement

- Palpation: Positive pain along joint line
- Meniscal tests: May experience mild tenderness with meniscal tests that involve rotation

Patellofemoral Pain

- Palpation: Positive pain along facets of patella and femoral condyles

ITB Friction Syndrome (ITB FS)

- Palpation: Positive pain along the insertion of ITB over the lateral epicondyle
- Hip flexor length test: Resisted knee extension may increase lateral knee pain
- Noble test: Positive

Meniscus

- Suggestive history
- Locking of knee
- Two positive provocative tests¹
 - McMurray's
 - Joint line palpation (significant pain)
 - Apley's
 - Bohler's
 - Steinman's
 - Payr's

ACL

- Suggestive history
- Positive anterior drawer test
- Positive Lachman's test

PCL

- Suggestive history
- Positive sag sign
- Positive posterior drawer

TCL (MCL)

- Suggestive history
- Positive valgus test

FCL (LCL)

- Suggestive history
- Positive varus test

Associated Signs or Contributing Factors

Joint Integrity

- May have excessive tibiofemoral rotation ROM

Muscle Length

- Short gastrocnemius
- Active or passive dorsiflexion with the knee extended
- May be painful and may observe tibial LR

Muscle Strength/Performance Impairments

- Poor functional performance of quads in stairs and sit-to-stand
- May have poor abdominal control

Structural Variations

- Femoral antetorsion
- Genu recurvatum
- Genu valgus
- Tibial torsion
- Tibial varum in frontal or sagittal plane
- "Hypermobility syndrome" = increased general laxity

Differential Diagnosis

Movement Diagnosis

- Patellar lateral glide
- Tibiofemoral accessory hypermobility
- Low back syndrome
- Femoral syndrome
- Hip extension/knee extension

Potential Diagnoses Requiring Referral Suggested by Signs and Symptoms

Musculoskeletal

- Meniscal injury
- Internal derangement
- OA/DJD
- MCL sprain (grade 2 or 3)
- LCL sprain
- Posterolateral corner injury
- Acute or recurrent patellar dislocation or subluxation
- Fracture
- Sinding-Larsen-Johansson disease
- AVN of knee
- Osteochondritis dissecans: Baker's cyst
- SCFE
- AVN of hip
- Legg-Calvé-Perthes disease
- L3-L5 radiculopathy

Other

- RA
- Gout
- Lyme disease
- Neoplasm

Treatment

Emphasis of treatment is decreasing excessive rotation between the tibia on the femur.

Patient Education

The goal of patient education is correction of impaired postural habits and movements.

I. Alignment

A. Improve alignment between femur and tibia.

1. Relax/unlock knees to reduce knee hyperextension if present.
2. Ideally, align knees over feet with neutral rotation of hips and tibias by decreasing MR of femur and LR of tibia.
3. NOTE: If structural tibial torsion or femoral anteversion or retroversion is present, ideal alignment will not be possible. Instruct patient in proper alignment that accommodates these structural impairments. For example, if the person has the following:
 - a. Tibial torsion: Allow appearance lateral deviation of the foot or "turn out" of the tibia and the foot.
 - b. Femoral anteversion (torsion): Allow the appearance of MR of femur.

B. Valgus: Individuals often stand with foot aligned laterally to the hip. The individual may or may not be able to correct entirely. Must accommodate for structural variations such as structural valgus, excessive soft tissue of thigh.

II. Functional activities that contribute to the movement impairment must be addressed.

A. Gait

1. Avoid hip MR and knee hyperextension during stance phase of gait cycle.
2. Encourage proper heel-to-toe gait pattern (common fault is decreased push-off).
 - a. If patient has the impairment of hyperextension, cue the patient to "lift the heel" to discourage recruitment of the hamstrings.
 - b. If patient demonstrates MR of the femur without hyperextension, cue the patient to contract the gluteal muscles to control femoral MR. If the patient has difficulty contracting the gluteals on command an exercise such as weight shifting may be useful to teach proper contraction. Gait can then be attempted to see if contraction ability improves.
 - c. TFRVar: In severe cases, the patient may be instructed to walk with a slight toe-out gait. Instruct the patient to rotate laterally at the hip and avoid lateral rotation at the tibiofemoral joint.
 - d. Patient may require an assistive device to decrease the forces through the affected knee.

- (1) Cane is used in the opposite hand of the impaired lower extremity.

- (2) EXCEPTION: If patient has a varus alignment and using the cane in the opposite hand does not reduce symptoms, the cane may be placed on the same side of the affected knee. Observe gait to determine if desired effect of reducing varus alignment is being achieved. Also use the patient's pain response to determine the proper side of cane placement.

B. Sit-to-stand; stand-to-sit

1. Slide forward in chair.
2. Feet hip-width apart and aligned behind knees.
3. Use quadriceps and gluteus maximus muscles to lift body up and forward out of chair.
 - a. Ensure that the tibia advances over the foot with performance (shifts weight forward).
 - b. Avoid hip MR.
 - c. Avoid pulling knees back to meet body.

C. Stairs

1. Instruct in use of rail to decrease weight bearing on the involved limb.
2. Ascending stairs.
 - a. Use quadriceps and gluteus maximus muscles to lift body up and forward.
 - (1) Ensure that the tibia advances over the foot with performance (shifts weight forward).
 - b. Avoid hip MR.
 - c. Avoid pulling knee back to meet body.
3. Descending stairs.
 - a. Avoid hip MR.
 - b. If difficult to perform without pain during initial visit, may need to instruct in step-to pattern leading with the involved extremity.
 - c. If significantly limited, patient may need to descend stairs backward.

D. Personal activities (work, school, leisure activities)

1. Address activities that patients are performing throughout the day that may contribute to the movement impairment. These may include prolonged sitting, driving, and getting in and out of a car.
2. Address fitness activities early to maintain patient's routine. Modifications or alternative activities may need to be provided. Modify intensity of activities to decrease stress to injured tissues.
 - a. Running
 - (1) Interval training is recommended.
 - (a) Begin with walking program and gradually mix in short bouts of running. Gradually increase the

- time running and decrease the time walking.
- (2) Modify surface of training if indicated.
 - (a) Instruct patient to initiate running with surfaces that reduce the ground reaction force on the lower extremities. A track or chip trail is better than asphalt, and asphalt is better than concrete. Concrete should be avoided if possible.
 - (b) Running on a street with a camber may contribute to common knee problems such as ITB friction syndrome. Runners should be encouraged to either avoid the camber or alternate the direction of their run.
 - (3) Modify activities that may encourage TFL-ITB recruitment over gluteus medius/maximus recruitment.
 - (a) Biking: Use of toe clips can encourage overrecruitment of the TFL-ITB. Patient should be encouraged to focus more on the pushing phase of the cycle and less on the pulling phase.
 - (b) Running: Patients often run with their body weight shifted posteriorly (referred to as *chasing their center of gravity*). Cue the patient to shift body weight slightly forward to encourage better recruitment of the gluteal muscles. Sometimes, use of a small incline will assist patients in shifting the weight forward.

Home Exercise Program

Patients should be instructed that they should not feel an increase in their symptoms during the performance of their exercises. In addition to monitoring for symptoms, they should not experience a “pressure” in the knee during exercises. If either pain or pressure occurs, they should review the instructions to the exercise to be sure that they are performing it correctly and try again. If they still experience pain or pressure, they should discontinue this exercise until they return for their next visit.

I. Improve muscle performance

A. Intrinsic hip lateral rotators and posterior gluteus medius muscles

1. Strengthening: Progressing from easiest to most difficult.
 - a. Prone hip lateral rotation isometrics (prone foot pushes).
 - b. Prone hip abduction.
 - c. Sidelying hip abduction with lateral rotation (level 1, 2, or 3).
 - (1) Monitor to be sure patient feels the contraction in the “seat” region; the

therapist must palpate to be sure that the patient is recruiting the correct muscles. Common cues for improve performance of the hip lateral rotators include the following:

- (a) Positioning: The pelvis may be rotated posteriorly too far. Ask the patient to roll the pelvis anteriorly.
 - (b) Positioning: Place a pillow between the knees.
 - (c) Spin the thigh around an axis longitudinally through the femur.
 - (d) CAUTION: Do not use foot as a guide for lateral rotation of the hip.
- d. Hip lateral rotation against resistance.
 - (1) Sitting: Ligaments of the knee are most lax when the knee is in 90 degrees of flexion. This exercise should be monitored closely to be sure the patient is able to stabilize the tibia while performing this exercise.
 - (2) Standing.
 - e. Lunges.
 - (1) Perform with lower extremity in good alignment; initially without weight or resistance.
 - (2) Progression.
 - (a) Resisted: Using an elastic band around proximal thigh, the therapist pulls in the direction of MR and adduction.
 - (b) Patients can hold weights in their hands.

2. Recruitment.

a. Weight shifting with gluteal squeeze on the stance lower extremity.

- (1) Progress to standing on one leg with correct alignment.
- (2) Progress to resisted activities of the opposite leg while standing on the affected leg.

B. Gluteus maximus muscles

1. Prone hip extension with the knee flexed.
 - a. Positioning: Patient's that have short hip flexors with require a pillow under the pelvis.
 - b. Patient must be able to control the tibial positioning during prone knee flexion to begin this exercise.
2. Lunges, squats.

C. Abdominal muscles (if appropriate)

1. Strengthening: Lower abdominal progression as described by Sahrman.²
2. Recruitment: Encourage patient to pull in abdominals with functional activities.

D. Quadriceps muscle

1. Functional activities.

- a. Sit to stand, stand to sit, step-ups/step-downs as tolerated.
- b. Lunges, wall sits as tolerated.

SPECIAL NOTE: Knees with Malalignment or Excessive Varus or Valgus

It is thought that the quadriceps muscles provide some shock absorption to the knee; however, recent studies show that increased quadriceps activity can actually increase the progression of OA in knees with malalignment. One must consider the compression forces that the quadriceps can add to a joint before administering quadriceps strengthening activities. Quadriceps performance should be enhanced only through the proper performance of functional activities, and therapeutic exercises to hypertrophy the quadriceps should be avoided in patients with malalignment of the knees.

II. Improve extensibility

- A. TFL-ITB and rectus femoris muscles (listed in the order of least aggressive to most aggressive)
 - 1. During all stretching exercises, be sure that the patient has good abdominal support to avoid pelvic anterior tilt or rotation.
 - a. Prone bilateral knee flexion: With knees and feet together, flex both knees at the same time, monitor tibial position and avoid LR of tibia.
 - 2. May need to begin with femurs in an abducted position and gradually adduct the hips as the patient improves.
 - 3. Prone hip lateral rotation: Monitor tibial position and avoid LR of tibia.
 - 4. Hip flexor length test position: Allow the hip to abduct as it extends, then actively adduct with the tibia in neutral (foot pointing forward or slightly inward).
 - 5. Ober test position: Hip in LR and tibia in neutral to slight MR (level 3 of posterior gluteus medius progression).
- B. Gastrocnemius and hamstring muscles
 - 1. Active sitting knee extension with dorsiflexion in neutral hip rotation.
 - 2. Hamstring muscles: Prolonged passive stretches in supine.
 - 3. Gastrocnemius muscles: Standing runners stretch.

- a. Patients with excessive pronation must have their arch supported during this stretch (shoes on).

III. Other

A. Taping

- 1. Posterior knee X taping may be helpful.
 - a. To control rotation during taping, the patient should be positioned so that the lower extremity is in the desired position before applying the tape. The patient is asked to contract the gluteal muscles to laterally rotate the thigh.
 - b. ITB friction syndrome: Tape placed along the ITB to support the tissue.

B. Bracing

- 1. Although bracing may not be the first choice in treatment for this patient population, it may be an option for patients who are not achieving adequate pain control with their activities.
 - a. One theoretical benefit of bracing is that it can increase proprioception of the knee.³⁻⁵
 - b. Unloader bracing has seemed to be beneficial in patients with OA and malalignment.^{6,7} Must consider patient goals, motivation, and anthropomorphics.

C. Orthotics

- 1. Temporary orthotics may be tried to determine if they will be helpful; then custom orthotics may be ordered if indicated.
 - a. Valgus.
 - (1) For pronation that is flexible: Orthotics to assist in controlling motion at the foot.
 - b. Varus.
 - (1) For a rigid supinated foot: Cushioned insert to improve shock absorption.

D. Pain control

- 1. Modalities.
 - a. Ice as often as needed.
- 2. Modify activities to reduce stress to injured tissues.
 - a. Daily activities.
 - b. Fitness activities.

E. Neuromuscular training (see Box 7-2)

NOTES

Tibiofemoral Hypomobility Syndrome

The principal movement impairment in tibiofemoral hypomobility (TFHypo) syndrome is associated with a limitation in the physiological motion of the knee. This limitation may result from degenerative changes in the joint or the effects of prolonged immobilization. In type I TFHypo syndrome, the potential for recovery of ROM is good; whereas the potential for recovery in type II TFHypo syndrome is poor.

Symptoms and History

- Pain with weight bearing (gait, standing, stairs), that decreases with rest
- Pain deep in joint and often described as vague
- Gradual onset

Degeneration

- May complain of stiffness, especially after periods of rest
- History of remote trauma or surgery to the knee
- Narrowing of joint space seen on standing radiographs
- Typically seen in older adults >55 years old

Immobilization

- History of recent trauma or surgery
- Knee ROM has not progressed as expected (slow recovery)

Common Referring Diagnosis

- OA/DJD
- Knee pain
- Patellofemoral joint dysfunction
- Knee contracture

Key Tests and Signs for Movement Impairment

Alignment Analysis

- *Both conditions* may have enlarged joint or signs of mild inflammation.

Movement Impairment Analysis

- Step-down test: Includes pain and impaired movement associated with lack of knee flexion.
- Gait: Antalgic gait. Ambulates with a flexed knee; decreased stride length.

Aggravating or Frequent Functional Activity

- Observe limitation of knee ROM during activity.

Joint Integrity

- ROM: Decreased PROM flexion and/or extension. Includes pain at end ROM tested passively.

Degeneration

- Repeated passive end-range flexion and extension should decrease pain or improve symptoms.
- May have PROM loss in capsular pattern (flexion greater than extension).

Source of Signs and Symptoms**Joint Involvement**

- Palpation: Positive pain along joint line

Meniscal Tests

- May experience mild tenderness with meniscal tests that involve rotation

Associated Signs or Contributing Factors

- *Both conditions* may stand in knee flexion.

Muscle Length

- Short gastrocnemius
- Short hip flexors
- Short hamstrings

Muscle Strength/Performance Impairments

- Manual muscle test: Weakness
 - Gluteus maximus
 - Gastrocnemius
 - Gluteus medius/hip intrinsic LRs
- Poor functional performance of quadriceps in stairs and sit-to-stand

Structural Variations

- May have genu varus or genu valgus deformity

Movement Impairments

- Gait: Decreased use of plantarflexors from loading response to preswing to control/advance tibia
- Visible quadriceps atrophy

Differential Diagnosis**Movement Diagnosis**

- Tibiofemoral rotation

Potential Diagnosis Requiring Referral Suggested by Signs and Symptoms**Musculoskeletal**

- Fracture
- AVN of knee
- Meniscal dysfunction
- Ligamentous injury (grades 2 and 3)
- Rapidly increasing varus deformity
- AVN of hip
- OA of hip
- L3-L5 radiculopathy
- Spinal stenosis

Other

- Baker's cyst
- Neoplasm
- RA
- Gout
- Lyme disease
- Peripheral vascular disease
- Popliteal artery occlusion

Treatment

Type I Tibiofemoral Hypomobility Syndrome

The potential for recovery of ROM is good in patients with type I TFHypo syndrome. These individuals demonstrate a limitation in ROM; however, duration of limitation is not long. End-feel to PROM may be stiff; however, some extensibility is noted. The therapist should monitor progression of ROM over time to determine if the classification of type I is appropriate. If ROM does not improve in 3 to 4 weeks and all treatment strategies have been investigated, type II should be considered.

Treatment emphasis is on improving ROM, strength, and conditioning, without increasing pain and swelling. In the treatment of the knee with degeneration, consider that rotation may be contributing to the symptoms.

Patient Education

The goal of patient education is correction of impaired postural habits and movements.

- I. Alignment
 - A. Correct standing alignment as appropriate.
 - B. If structural impairment is present, ideal alignment may not be possible.
- II. Functional activities that contribute to the movement impairment must be addressed.
 - A. Gait
 1. Avoid hip MR during stance phase of gait cycle.
 2. Encourage a “rolling” heel-to-toe gait pattern (common fault is decreased push-off).
 - a. This is to improve the shock absorption value of the foot, as well as encourage proper gait pattern.
 - b. Patient may require an assistive device to decrease the forces through the affected knee.
 - (1) Cane is used in the opposite hand of the impaired lower extremity.
 - (2) EXCEPTION: If patient has a varus alignment and using the cane in the opposite hand does not reduce symptoms, the cane may be placed on the same side of the affected knee. Observe gait to determine if the desired effect of reducing varus alignment is being achieved. Also, use the patient’s pain response to determine the proper side of cane placement.
 - B. Sit-to-stand; stand-to-sit
 1. Slide forward in chair.
 2. Feet hip-width apart and aligned behind knees.
 3. Use quadriceps and gluteus maximus muscles to lift body up and forward out of chair.
 - a. Ensure that the tibia advances over the foot with performance (shifts weight forward).

4. Avoid hip MR.
5. Avoid pulling knees back to push against chair behind them.

C. Stairs

1. Instruct in use of rail to decrease weight bearing on the involved limb.
2. Ascending stairs.
 - a. Use quadriceps and gluteus maximus muscles to lift body up and forward.
 - (1) Ensure that the tibia advances over the foot with performance (shifts weight forward).
 - b. Avoid hip MR.
 - c. Avoid pulling knee back to meet body.
3. Descending stairs.
 - a. Avoid hip MR.
 - b. If difficult to perform without pain during initial visit, may need to instruct in step-to pattern leading with the involved extremity.
 - c. If significantly limited, patient may need to descend stairs backward.

D. Personal activities (work, school, leisure activities)

1. Address activities that patients are performing throughout the day that may contribute to the movement impairment, including prolonged sitting, driving, and getting in and out of a car.
2. Fitness activities.
 - a. Address fitness early to maintain patient’s routine. Modifications or alternative activities may need to be provided.
 - (a) Degeneration: While initiating exercises, it is safer to begin with high repetitions of relatively low weight.
 - b. Modify intensity of activities to decrease stress to injured tissues.
 - (a) Reduce weight bearing during initial phases and gradually increase weight bearing as tolerated by the patient.
 - (i) Swimming, stationary biking
 - (ii) Stair master, elliptical
 - (iii) Treadmill

III. Education

- A. Degeneration: Arthritis and joint protection education
 1. Risk factors for progression of OA.
 - a. Previous injury to the meniscus or ligament.
 - b. Manual labor with prolonged positioning of knee flexion.
 - c. Obesity.
 - d. Laxity of the knee.
 - e. Malalignment of the knee.

Home Exercise Program

Degeneration

Patients should be instructed that they should not feel an increase in their symptoms during the performance of their exercises. In addition to monitoring for their symptoms, they should not experience a “pressure” in their knee during their exercises. If either pain or pressure occurs, they should review the instructions to the exercise to be sure that they are performing it correctly and try again. If they still experience pain or pressure, they should discontinue this exercise until they return for their next visit.

Immobilization

Patients should be instructed that they will experience some discomfort (often described as pain or pressure) with their exercises to improve ROM. Patients should be encouraged to continue with the exercises as tolerated. Pain medications should be timed so that they are at maximum level during exercises.

I. Improve muscle performance

A. Intrinsic hip lateral rotators and posterior gluteus medius muscle

1. Strengthening

- a. Prone hip lateral rotation isometrics (prone foot pushes).
- b. Prone hip abduction.
- c. Sidelying hip abduction with lateral rotation (level 1, 2, or 3).

(1) Monitor to be sure patient feels the contraction in the “seat” region; the therapist must palpate to be sure that the patient is recruiting the correct muscles. Common cues for improve performance of the hip lateral rotators include the following:

- (a) Positioning: The pelvis may be rotated posteriorly too far. Ask the patient to roll the pelvis anteriorly.
- (b) Positioning: Place a pillow between the knees.
- (c) Spin the thigh around an axis longitudinally through the femur.
- (d) CAUTION: Do not use foot as a guide for lateral rotation of the hip.

d. Lunges.

- (1) Perform with lower extremity is good alignment; initially without weight or resistance.
- (2) Progression.
 - (a) Resisted: Using an elastic band around proximal thigh, the therapist pulls in the direction of medial rotation and adduction.
 - (b) Patients can hold weights in their hands.

2. Recruitment

- a. Weight shifting with gluteal squeeze on the stance lower extremity
 - (1) Progress to standing on 1 leg with correct alignment
 - (2) Progress to resisted activities of the opposite leg while standing on the affected leg

B. Gluteus maximus muscle

1. Prone hip extension with the knee flexed
 - a. Positioning: Patient's that have short hip flexors with require a pillow under the pelvis.
 - b. Patient must be able to control the tibial positioning during prone knee flexion in order to begin this exercise.
2. Lunges, squats
 - a. CAUTION: Aggressive exercise. Must be sure patient is able to perform without difficulty

C. Gastrocnemius muscle

1. Elastic band resistance
2. Standing heel raises, bilateral to unilateral

D. Abdominal muscles (if appropriate)

1. Strengthening: Lower abdominal progression as described by Sahrmann²
2. Recruitment: Encourage patient to pull in abdominals with functional activities

E. Quadriceps muscle

1. Strengthen with functional activities only
 - a. Sit to stand, stand to sit, step-ups/step-downs as tolerated.

Knees with Degenerative Changes and Malalignment, Excessive Varus or Valgus

It is thought that the quadriceps muscles provide some shock absorption to the knee; however, recent studies show that increased quadriceps strength can actually increase the progression of OA in knees that have malalignment. One must consider the compression forces that the quadriceps can add to a joint before administering quadriceps strengthening activities. The quadriceps performance should be enhanced only through the proper performance of functional activities, and therapeutic exercises to hypertrophy the quadriceps should be avoided in patients with malalignment of the knees.

II. Improve extensibility

A. Hip flexors (listed in the order of least aggressive to most aggressive)

1. During all stretching exercises, be sure that the patient has good abdominal support to avoid pelvic anterior tilt or rotation.
2. Supine hip and knee extension (heel slide).
3. Prone bilateral knee flexion: With knees and feet together, flex both knees at the same time; monitor tibial position, avoid LR of tibia.

- a. May need to begin with femurs in and abducted position and gradually adduct the hips as the patient improves.
- 4. Prone hip lateral rotation: Monitor tibial position, avoid LR of tibia.
- B. Gastrocnemius and hamstrings muscles
 - 1. Active sitting knee extension with dorsiflexion in neutral hip rotation.
- III. Other
 - A. Mobilization
 - 1. Accessory mobilization
 - a. If patient is having pain at rest (e.g., in non-weight-bearing positions such as supine), distraction mobilization can be taught to the patient. A trial of gentle distraction should be performed to determine if this technique will be appropriate.
 - (1) Home program: Patient in sitting position with the foot dangling (a towel may be placed under the distal thigh to raise the thigh). A lightweight shoe may be applied (1 lb). Patient allows the leg to dangle up to 10 minutes to help relieve discomfort. This may be performed as often as needed to relieve pain.
 - (2) CAUTION: This activity is used only to relieve pain at rest.
 - b. Joint mobilization.
 - (1) Pain relief: Oscillatory I, II; sustained I, II.
 - (2) Increasing ROM: Oscillatory III, IV; sustained III.
 - 2. Physiological mobilization
 - a. Assisted active ROM.
 - (1) Supine hip and knee flexion (heel slides).
 - (a) A towel or sheet may be used by the patient to provide gentle overpressure.
 - (2) Sitting knee flexion/extension.
 - (3) Prone knee flexion as previously described.
 - (4) Stationary biking.
 - b. Passive ROM.
 - (1) Knee extension: Supine or prone.
 - (2) Proprioceptive neuromuscular facilitation (PNF) techniques, such as contract/relax and hold/relax, may be useful.

- B. Edema and pain control
 - 1. Modalities
 - a. Ice (if tolerated)
 - b. Compression wrap for swelling
 - c. Ultrasound
 - d. Moist heat pack
 - e. Electrical stimulation
 - C. Bracing
 - 1. Degeneration
 - a. Bracing should be considered for patients who continue to have symptoms that are functionally limiting.
 - b. Unloader bracing has seemed to be beneficial in patients with OA and malalignment.^{6,7} Must consider patient goals, motivation, and anthropomorphics.
 - 2. Immobilization
 - a. Dynamic splinting/bracing may be used to provide a low load, long duration stretch.
 - D. Neuromuscular training (see Box 7-2)

Type II Tibiofemoral Hypomobility Syndrome

The potential for recovery of ROM is poor in patients with type II TFHypo syndrome. These individuals may report a long duration of loss of ROM, either through immobilization or long-standing OA. End-feel to PROM to the joint are very stiff, with the soft tissues demonstrating very little extensibility. When in doubt, it is best to classify the individual with type I for a trial period and assess the patient's progress appropriately. Emphasis is on educating the patient in modifications of functional activities to accommodate for loss of ROM.

- I. Treatment concepts are similar to the treatment of type I TFHypo syndrome; however, modifications must be made for the limited ROM of the knee.
 - A. Emphasis of treatment should be placed on functional activities specific to the patient. See treatment suggestions for type I TFHypo syndrome for specifics.
 - B. Proper footwear to provide shock absorption and proper support to the foot.
 - C. Independence in home exercise program to maintain current ROM of the knee.
 - D. Independence in home exercise program to maintain proper movement/alignment of the adjacent joints such as the hip, back, and ankle/foot.
 - E. If limitation significantly affects functional activities, an occupational therapy consult may be advised to address more specific modifications.

NOTES

Knee Extension Syndrome and Knee Extension with Patellar Superior Glide Syndrome

The principal movement impairment in knee extension (Kext) syndrome is knee pain associated with dominance of quadriceps muscles that results in excessive pull on the patella, patellar tendon/ligament, or tibial tubercle. The Kext syndrome has a subcategory of patellar superior glide (KextSG).

Symptoms and History

- Pain with activities that require repeated knee extension
- Associated with large quadriceps musculature
- Often present in runners, football linemen, and volleyball players
 - Kext: Pain located in suprapatellar region
 - KextSG: Pain located in infrapatellar or peripatellar region

Common Referring Diagnoses

- Jumper's knee
- Osgood-Schlatter disease
- Patellofemoral joint dysfunction
- Patellar tendonitis
- Anterior knee pain
- Chondromalacia patella
- Plica syndrome
- Quadriceps strain

Key Tests and Signs for Movement Impairment

Alignment Analysis

Standing

- Swayback, posterior pelvic tilt
- KextSG: Patella alta

Movement Impairment Analysis

- Step-up: May increase peripatellar pain
 - Observe: Does not shift body weight over the foot
 - Kext: Pain decreases when shifts body weight anteriorly (allows the tibia to move anteriorly over the foot)
 - KextSG: Pain decreases with inferior glide provided manually on the patella

Aggravating or Frequent Functional Activity

- Observe limited knee flexion excursion during activity, even though PROM is not limited (landing from a jump), demonstrates reduced knee flexion excursion

Muscle Length

- Short and/or stiff quadriceps

Muscle Strength/Performance Impairments

- Weak gluteus maximus

Source of Signs and Symptoms**Kext**

- Quadriceps strain
 - Resisted tests: Quads will be painful with resistance, however may test strong
- Palpation: Tenderness of quadriceps tendon or superior patellar facet

KextSG

- Patellofemoral pain
 - Palpation: Positive pain along patellar facets and/or femoral condyles
- Patellar tendinopathy
 - Palpation: Tenderness of infrapatellar tendon, fat pad, or peripatellar region
- Tibial tuberosity
 - Appearance: Enlarged

Associated Signs or Contributing Factors**Muscle Performance**

- Poor muscle performance of gluteus maximus
- Overuse of quadriceps

Structural Variations

- Enlarged tibial tubercle

Differential Diagnosis**Movement Diagnosis**

- Tibiofemoral rotation
- Patellar lateral glide

Potential Diagnosis Requiring Referral Suggested by Signs and Symptoms**Musculoskeletal**

- Fracture
- Osgood-Schlatter disease
- Sinding-Larsen-Johansson disease
- AVN of knee
- Osteochondritis dissecans
- SCFE
- AVN of Hip
- Legg-Calvé-Perthes disease
- L3-L5 radiculopathy
- Baker's cyst

Other

- RA
- Gout
- Lyme disease
- Neoplasm

Treatment

Treatment emphasis in Kext syndrome is on decreasing the activity of the quadriceps while improving the performance of the hip extensors. In KextSG syndrome, treatment emphasis is similar to Kext syndrome; however, methods to stabilize the patellar glide may need to be implemented.

Patient Education

The following treatment is appropriate for both Kext and KextSG syndromes unless otherwise noted. The goal of patient education is correction of impaired postural habits and movements.

I. Alignment

A. Correct alignment as appropriate

II. Functional activities that contribute to the movement impairment must be addressed.

A. Gait

1. Encourage proper heel-to-toe gait pattern (common fault is decreased push-off).
2. Cue the patient to push off with the toes. Patient may also benefit from cues to shift weight slightly forward.

B. Sit-to-stand; stand-to-sit

1. Slide forward in chair.
2. Feet hip-width apart and aligned behind knees.
3. Use quadriceps and gluteus maximus muscles to lift body up and forward out of chair.
 - a. Ensure that the tibia advances over the foot with performance (shifts weight forward).

C. Sitting

1. Patient should avoid prolonged periods of increased knee flexion (≥ 90 degrees).
 - a. Take standing/walking breaks every 30 minutes.
 - b. When unable to take breaks, use sitting knee extension to decrease time spent in knee flexion.
 - c. Patients with short rectus femoris muscles may need to sit with the knee in relatively less flexion initially. As symptoms improve, they should be instructed to gradually flex the knee until they are at a normal position.

D. Stairs

1. Instruct in use of rail to decrease weight bearing on the involved limb.
2. Ascending stairs.
 - a. Emphasize the use of the gluteus maximus muscle to lift body up and forward.
 - (1) Ensure that the tibia advances over the foot with performance (shifts weight forward).
3. Descending stairs.
 - (1) If difficult to perform without pain during initial visit, may need to instruct

in step-to pattern, leading with the involved extremity.

- b. If significantly limited, patient may need to descend stairs backward.

E. Personal activities (work, school, leisure activities)

1. Address activities that patients perform throughout the day that may contribute to the movement impairment. These may include prolonged standing or sitting.

2. Fitness activities.

- a. Address fitness early to maintain patient's routine. Modifications or alternative activities may need to be provided.

- b. Modify intensity of activities to decrease stress to injured tissues.

(1) Running

- (a) Interval training is recommended.

- i. Begin with walking program and gradually mix in short bouts of running. Gradually increase the time running and decrease the time walking.

- (b) Modify surface of training if indicated.

- ii. Instruct patient to initiate running with surfaces that reduce the ground reaction force on the lower extremities. A track or chip trail is better than asphalt and asphalt is better than concrete. Concrete should be avoided if possible.

- (c) Modify strength training.

- i. Patients should be discouraged from performing resistance activities to increase the hypertrophy of the quadriceps muscles.

- (d) Modify activities to encourage gluteus medius/maximus muscle recruitment.

- i. Biking: Patient should be encouraged to focus more on the pushing phase of the cycle (extension of hip = gluts) and less on the pulling phase (knee flexion = hams).

- ii. Running: Patients often run with their body weight shifted posteriorly (referred to as *chasing their center of gravity* in Sahrmann²). Cue the patient to shift body weight slightly forward to encourage better recruitment of the gluteal muscles. Sometimes, use of a small incline will assist the patient in shifting the weight forward.

Home Exercise Program

The patient should be instructed that they should not feel an increase in their symptoms during the performance of their exercises. If this occurs, they should review the instructions to the exercise to be sure that they are performing it correctly and try again. If they still experience pain, they should discontinue this exercise until they return for their next visit.

I. Improve muscle performance

A. Gluteus maximus muscle

1. Prone hip extension with the knee flexed.
 - a. Patient may require a pillow under the pelvis if short hip flexors.
2. Weight shifting with gluteal squeeze on the stance lower extremity.
 - a. Progress to standing on 1 leg with correct alignment.
 - b. Progress to resisted activities of the opposite leg while standing on the affected leg.
3. Lunges, squats.
 - a. CAUTION: In patients who have knee extension, the quadriceps muscles place excessive pull on the patellar tendon and tibial tubercle. Quadriceps strengthening would be contraindicated in these patients.

II. Improve extensibility

A. Quadriceps muscles (listed in the order of least aggressive to most aggressive)

1. During all stretching exercises, be sure that the patient has good abdominal support to avoid pelvic anterior tilt or rotation.
 - a. KextSG: During performance of exercises that stretch the quadriceps, patellar taping to reduce patellar glide may be required if the patient cannot perform the exercises without an increase in symptoms.

b. Prone knee flexion.

- (1) May need to begin with pillows under pelvis if patient also has short hip flexors.
- (2) Perform within range that does not increase symptoms.

c. Prone hip lateral rotation.

- d. Hip flexor length test position: Instruct the patient to flex the knee while the hip is in neutral rotation and neutral hip abduction/adduction.

III. Other

A. Taping or bracing

1. KextSG
 - a. Horseshoe taping to discourage superior glide.
 - b. Cho-pat strap across the patellar tendon.
2. Patellar joint mobilization
 - a. KextSG
 - (1) Inferior glides to patella.
 - a. Initially may need to perform least aggressive grades (I and II) but should be able to progress to more aggressive grades quickly. Grades III and IV are usually tolerated well. Patient may be instructed in proper performance for home exercise program.
 - (2) Mobilization with movement.
 - b. Sitting knee flexion: The patient allows the knee to flex from the fully extended position. As the knee flexes, the patient performs an inferior glide of the patella.
3. Pain control
 - a. Modalities.
 - (1) Ice as often as needed.
4. Neuromuscular training (see Box 7-2)

Knee Hyperextension Syndrome

The principal movement impairment in knee hyperextension (Khex) syndrome is knee pain associated with impaired knee extensor mechanism. Dominance of hamstrings and poor functional performance of gluteus maximus and quadriceps muscles result in hyperextension of the knee placing excessive stresses on the structures of the knee.

Symptoms and History

- Pain located peripatellar, joint line, or posterior knee pain; especially with activities that require repetitive knee extension
- Often present in activities that require rapid knee extension: Swimming (freestyle or breaststroke), kickboxing, martial arts
- Race walkers (prolonged foot flat)
- Increased pain at end-range extension positioning such as standing

Common Referring Diagnoses

- Patellofemoral joint dysfunction
- Fat pad syndrome
- Anterior knee pain
- Chondromalacia patella
- Plica syndrome
- Baker's cyst

Key Tests and Signs for Movement Impairment

Alignment Analysis

Standing

- Knee extension >5 degrees
- Posterior pelvic tilt
- Ankle plantarflexion

Movement Impairment Analysis

- Single-leg stance: Hyperextension of the knee on the stance limb
- Step-up: May increase pain
 - Observe: Does not shift body weight over the foot and demonstrates faulty movement of knee back to body
 - Hyperextension of knee may occur at final phase of step-up

Aggravating or Frequent Functional Activity

- Observe hyperextension of the knee during activity
 - If painful, correction decreases symptoms

Gait

- Excessive knee hyperextension during gait; may occur at heel strike through just prior to heel off; may have hard heel strike

Joint Integrity

- PROM: Knee extension >10 degrees; however, acute flare-ups of pain may demonstrate reduced knee extension

Muscle Strength

- Prone hip extension
 - Poor muscle performance of gluteus maximus
 - Overuse of hamstrings

Source of Signs and Symptoms

- Fat pad
 - Palpation: Tenderness of fat pad.
- Patellofemoral pain
 - Palpation: Positive pain along facets of patella and femoral condyles.
- Posterior structures of the knee
 - Palpation: Tenderness posterior knee

Associated Signs or Contributing Factors**Muscle Performance**

- Poor performance of quadriceps
- Poor performance of abdominals

Muscle Length/Joint ROM

- Short gastrocnemius

Structural Variations

- “Hypermobility syndrome” = increased general laxity
- 6/9 positive on Beighton’s scale⁸

Differential Diagnosis**Movement Diagnosis**

- Tibiofemoral rotation
- Patellar lateral glide

Potential Diagnosis Requiring Referral Suggested by Signs and Symptoms**Musculoskeletal**

- Fracture
- Jumper’s knee
- Osgood-Schlatter disease
- Sinding-Larsen-Johansson disease
- AVN of knee
- Osteochondritis dissecans
- SCFE
- AVN of Hip
- Legg-Calvé-Perthes disease
- L3-L5 radiculopathy

Other

- RA
- Gout
- Lyme disease
- Neoplasm
- Baker’s cyst

Treatment

Treatment emphasis in knee hyperextension syndrome is to decrease hyperextension of the knee.

Patient Education

The goal of patient education is correction of impaired postural habits and movements.

I. Alignment

A. Improve alignment between femur and tibia.

1. Relax/unlock knees to reduce hyperextension of knee.
- a. Improve alignment of pelvis if applicable.

II. Functional activities that contribute to the movement impairment must be addressed

A. Gait

1. Encourage proper heel-to-toe gait pattern.

a. Knee hyperextension.

- (1) Avoid knee hyperextension during stance phase of gait cycle.
- (2) Cue the patient to "lift the heel" to discourage overrecruitment of the hamstrings.
- (3) Cue to land softly on the heel at heel strike.

B. Sit-to-stand; stand-to-sit

1. Slide forward in chair.
2. Feet hip-width apart and aligned behind knees.
3. Use quadriceps and gluteus maximus muscles to lift body up and forward out of chair.
 - a. Ensure that the tibia advances over the foot with performance.
4. Avoid pulling knees back to meet body; final position of knee should be relaxed knee (not hyperextension).

C. Stairs

1. Instruct in use of rail to decrease weight bearing on the involved limb.
2. Ascending stairs.
 - a. Use quadriceps and gluteus maximus muscles to lift body up and forward.
 - (1) Ensure that the tibia advances over the foot with performance.
 - b. Avoid pulling knee back to meet body.
3. Descending stairs.
 - a. If patient is unable to perform without pain during initial visit, may need to instruct in step-to pattern leading with the involved extremity.
 - b. If significantly limited, patient may need to descend stairs backward.

D. Personal activities (work, school, leisure activities)

1. Address activities that patients perform throughout the day that may contribute to the movement impairment. These may include prolonged standing.

2. Fitness activities.

- a. Address fitness early to maintain patient's routine. Modifications or alternative activities may need to be provided.
- b. Modify intensity of activities to decrease stress to injured tissues.

(1) Running

(a) Interval training is recommended.

- i. Begin with walking program and gradually mix in short bouts of running. Gradually increase the time running and decrease the time walking.

(b) Modify surface of training if indicated.

- i. Instruct patient to initiate running with surfaces that reduce the ground reaction force on the lower extremities. A track or chip trail is better than asphalt and asphalt is better than concrete. Concrete should be avoided if possible.
- ii. Running on a street with a camber may contribute to common knee problems such as ITB friction syndrome. Runners should be encouraged to either avoid the camber or alternate the direction of their run.

c. Modify activities to encourage gluteus medius/maximus muscle recruitment.

(1) Biking: Patients should be encouraged to focus more on the pushing phase of the cycle (extension of hip = gluts) and less on the pulling phase (knee flexion = hams).

(2) Running: Patients often run with their body weight shifted posteriorly (referred to as *chasing the center of gravity* in Sahrman²). Cue the patient to shift body weight slightly forward to encourage better recruitment of the gluteal muscles. Sometimes, use of a small incline will assist the patient in shifting the weight forward.

d. Kickboxing: Educate patients to decrease speed of kicks to improve control of limb.

e. Swimming: Educate patients to decrease intensity of wall push-off with turning.

Home Exercise Program

Patients should be instructed that they should not feel an increase in their symptoms during the performance of their exercises. If this occurs, they should review the instructions to the exercise to be sure that they are performing it correctly and try again. If they still experience

pain, they should discontinue this exercise until they return for their next visit.

I. Improve muscle performance

A. Gluteus maximus

1. Prone hip extension with the knee flexed.
 - a. Patient may require a pillow under the pelvis if short hip flexors.
2. Weight shifting with gluteal squeeze on the stance lower extremity.
 - a. Progress to standing on 1 leg with correct alignment
 - b. Progress to resisted activities of the opposite leg while standing on the affected leg
3. Lunges, squats.

B. Abdominals (if appropriate)

1. Strengthening: Lower abdominal progression as described by Sahrman.²
2. Recruitment: Encourage patient to pull in abdominals with functional activities.

C. Quadriceps

1. Progress quadriceps strengthening according to pain and results of resisted testing and functional testing such as stairs.

2. Quadriceps: Sit to stand, wall sits, step-ups/step downs, lunges (emphasize correct hip and tibial alignment).

II. Improve extensibility

A. Gastrocnemius muscles

1. Active sitting knee extension with dorsiflexion in neutral hip rotation.
2. Standing runners stretch.

B. Hamstrings

1. Prolonged hamstring stretch, maintain proper spinal alignment.

III. Other

A. Taping or bracing

1. Knee hyperextension.
 - a. Posterior knee X taping to decrease hyperextension of the knee
 - b. Unloader V taping to unload the fat pad

B. Pain control

1. Modalities.
 - a. Ice as often as needed.

C. Neuromuscular training (see Box 7-2)

Patellar Lateral Glide Syndrome

The principal movement impairment in patellar lateral glide syndrome is knee pain as a result of an impaired patellar relationship within the trochlear groove. Often a secondary diagnosis and therefore the movement impairments of tibiofemoral rotation (TFR) or knee hyperextension (Khex) should be considered. Correction of impairment often decreases symptoms.

Symptoms and History

- Peripatellar or retropatellar pain with any activity that requires loaded knee flexion/extension (stairs, running hills, squatting)
- Increased pain with sustained knee flexion in sitting (*movie goers syndrome*)
- Often associated with tibiofemoral rotation

Common Referring Diagnoses

- Patellofemoral joint dysfunction
- Chondromalacia patella
- Anterior knee pain
- Patellar dislocation
- Plica syndrome

Key Tests and Signs for Movement Impairment

Alignment Analysis

- Structural: Patella alta or infera
- Nonstructural: Lateral, rotated, tilted

Movement Impairment Analysis

- Squat test, step-down: Increased peripatellar pain
 - Decreased pain with manual correction of patellar positioning
- Prone knee flexion: May have pain with performance
 - Decreased pain with manual correction of patellar positioning
- Isometric quadriceps contraction: In long sitting, patella tracks laterally
- Sitting knee extension: Excessive lateral glide of the patella

Aggravating or Frequent Functional Activity

- Increased pain during activity
 - If painful, correction of patellar positioning decreases symptoms

Muscle Length

- Hip flexor length test: Short TFL-ITB. May have pain in neutral hip position
 - Decreased pain with manual correction of patellar positioning

Muscle Strength/Performance Impairments

- Possible poor performance of quadriceps, particularly the vastus medialis oblique (VMO)

Source of Signs and Symptoms

- Patellofemoral pain
 - Palpation: Positive pain along patellar facets and/or femoral condyle
- Positive McConnell test

Associated Signs or Contributing Factors**Muscle Length**

- Short/stiff lateral patellar retinacula
- Short/stiff gluteus maximus/ITB

Muscle Strength/Performance**Impairments**

- Manual muscle test: Weakness in posterior gluteus medius and hip LRs

Structural Variations

- Small patellae: May be associated with dislocation or subluxation
- Flat lateral femoral condyle
- Often associated with other movement diagnosis
 - Tibiofemoral rotation
 - Knee hyperextension

Differential Diagnosis**Movement Diagnosis**

- Tibiofemoral rotation
- Knee extension with patellar superior glide
- Knee hyperextension

Potential Diagnosis Requiring Referral Suggested by Signs and Symptoms**Musculoskeletal**

- OA/DJD
- Acute or recurrent patellar dislocation/subluxation
- Fracture
- Sinding-Larsen-Johansson disease
- AVN of knee
- Osteochondritis dissecans
- SCFE
- AVN of hip
- Legg-Calvé-Perthes disease
- L3-L5 radiculopathy

Other

- RA
- Gout
- Lyme disease
- Neoplasm
- Baker's cyst

Treatment

Treatment emphasis in patellar lateral glide syndrome is to address the impairment of patellar tracking. If patellar lateral glide syndrome is given as a secondary diagnosis, please refer to the treatment described for the primary diagnosis (tibiofemoral rotation or knee hyperextension) in addition to the treatment described below.

Patient Education

The goal of patient education is correction of impaired postural habits and movements.

- I. Alignment
 - A. Correct alignment as appropriate
- II. Functional activities that contribute to the movement impairment must be addressed
 - A. If a primary diagnosis of tibiofemoral rotation or knee hyperextension is determined, see treatment for the primary diagnosis.
 - B. Stairs
 1. Instruct in use of rail to decrease weight bearing on the involved limb.
 2. Ascending stairs.
 - a. Use quadriceps and gluteus maximus to lift body up and forward.
 3. Descending stairs.
 - a. If difficult to perform without pain during initial visit, may need to instruct in step-to pattern leading with the involved extremity.
 - b. If significantly limited, patient may need to descend stairs backwards.
 - C. Sitting
 1. Patient should avoid prolonged periods of increased knee flexion (≥ 90 degrees).
 - a. Take standing/walking breaks every 30 minutes.
 - b. When unable to take breaks, use sitting knee extension to decrease time spent in knee flexion.
 - c. In patients with short TFL-ITB, they may need to sit with the thighs slightly abducted initially. As symptoms improve, they should be instructed to gradually adduct the thigh until they are at a normal position.
 - D. Personal activities (work, school, leisure activities)
 1. Address activities that patients are performing throughout the day which are pain provoking for the patient.
 2. Fitness activities.

Home Exercise Program

The patient should be instructed that they should not feel an increase in their symptoms during the performance of their exercises. In addition to monitoring for their

symptoms, they should not experience a "pressure" in their knee during their exercises. If either pain or pressure occurs, they should review the instructions to the exercise to be sure that they are performing it correctly and try again. If they still experience pain or pressure, they should discontinue this exercise until they return for their next visit.

- I. Improve muscle performance
 - A. If a primary diagnosis of tibiofemoral rotation or hyperextension is determined, see treatment for the primary diagnosis.
 1. Quadriceps
 - a. Recommend use of functional activities to improve quadriceps performance (listed in order of difficulty beginning with least aggressive)
 - (1) Sit to stand transfers
 - (2) Step-ups may progress to step downs as patient's symptoms improve
 - (3) Lunges
 - (4) Squats
 - (5) Biofeedback may be beneficial for improving possible timing or recruitment of the vastus medialis oblique (VMO) muscle
- II. Improve extensibility
 - A. TFL-ITB
 1. Listed in the order of least aggressive to most aggressive.
 2. During all stretching exercises, be sure that the patient has good abdominal support to avoid pelvic anterior tilt or rotation.
 3. During performance of exercises that stretch the TFL-ITB, patellar taping to reduce patellar glide may be required if the patient cannot perform the exercises without an increase in symptoms.
 - a. Prone knee flexion
 - (1) May need to begin with femurs in an abducted position and gradually adduct the hips as the patient improves.
 - b. Prone hip lateral rotation
 - c. Hip flexor length test position: Allow the hip to abduct as it extends then actively adduct with the tibia in neutral
 - d. Ober test position: Hip in lateral rotation and tibia in neutral to slight medial rotation (level 3 of post. glut. med. progression)
 - B. Other muscles (as needed)
 1. Lateral patellar retinaculum
 2. Gluteus maximus/ITB
 - C. Other
 1. Patellar taping/bracing
 - a. McConnell taping for medial glide
 2. Patellar joint mobilization
 - a. Medial glide to patella

- b. Initially may need to perform least aggressive grades (I, II), but should be able to progress to more aggressive grades quickly. Grades III, IVs are usually tolerated well. Patient may be instructed in proper performance for home exercise program.
- 3. Pain control
 - a. Modalities
 - (1) Ice as often as needed
- 4. Neuromuscular training (see Box 7-2)

Knee Impairment

Knee impairment is the classification given in the absence of a specific movement impairment diagnosis or when a diagnosis cannot not be determined because of pain, physician-imposed restrictions, or both. If possible, the physical therapist should determine the pathoanatomical structure involved, as identified by the physician; the procedure performed, if any; and the stage for rehabilitation.

Factors that affect the physical stress of tissue and/or thresholds of tissue adaptation and injury¹⁰ include the following:

I. Physiological factors

A. Tissue factors specific to the knee

1. Bone

a. Tibial plateau

- (1) Cancellous bone and poor vascular supply.
- (2) Often non-weight-bearing for 2 to 3 months.

b. Patella fracture: Quad contraction often contraindicated

2. Cartilage

a. Meniscus

- (1) Red zone: Peripheral one-third vascular, with good healing potential.
- (2) Pink zone: Middle one-third vascularity, with variable healing potential.
- (3) White zone: Inner one-third avascular, with poor healing.
- (4) Increased compression of meniscus at 90 degrees of knee flexion.
- (5) Aggressive hamstring exercise is contraindicated, especially if injury to posterior horn.
- (6) Change in weight-bearing surfaces with removal of meniscus.

3. Muscle

a. Quad atrophy common postsurgery or trauma to knee

4. Tendon

a. Quad tendon rupture

- (1) Quad contraction contraindicated.
- (2) May have flexion ROM restrictions.

5. Ligament

a. ACL

- (1) New graft is weakest from 4 to 12 weeks.
- (2) Avoid anterior tibial translation.
- (3) Avoid open-chain resisted knee extension in early rehabilitation phase.

b. PCL

- (1) Avoid posterior tibial translation.
- (2) Avoid active hamstring contraction.

c. MCL

- (1) Adolescent: Separation of distal femoral epiphysis can mimic MCL sprain. Radiographs must be performed.

d. Patellar ligament rupture

- (1) Quad contraction contraindicated.
- (2) May have flexion ROM restrictions.

6. Skin

7. Nerve

- a. Fibular (peroneal) nerve injury possible with surgery or trauma to knee

B. Types of surgeries (indications)

1. Stabilization

2. Osteotomy (malalignment or osteosarcoma)

a. Femoral

b. Tibial

3. Arthroplasty (DJD, arthritis, joint destruction)

a. Total/unicompartment

(1) Cemented/uncemented

4. Debridement (tear, degeneration)

a. Meniscal

b. Patellar ligament

c. Patella

5. Repair

a. Ligament reconstruction (ACL, PCL)

b. Meniscal repair

c. Cartilage repair

(1) Microfracture

(2) Mosaicplasty, osteochondral autograft transplant (OATS)

6. Meniscal transplant

7. Soft tissue release (short tissues or spastic muscles)

(1) ITB

(2) Hamstrings

(3) Hip adductors

C. Medical complications

1. Baker's cyst

2. Peroneal nerve neurapraxia

3. Leg length changes (total knee replacement)

II. Movement and alignment factors

A. Variations

B. Standing alignment

1. May demonstrate protective stance or rotational impairments

C. Underlying movement impairment syndromes

1. TFR syndrome

a. TFR syndrome with valgus

b. TFR syndrome with varus

2. TFhypo syndrome

3. Kext syndrome

a. Kext syndrome with patellar superior glide

4. Khex syndrome

5. PLG syndrome

6. TFAH syndrome

Treatment for Knee Impairment

Emphasis of treatment is to restore ROM of the knee and strength of the lower extremity without adding excessive stresses to the injured tissues. Underlying movement impairments should be addressed during rehabilitation and functional activities to ensure optimal stresses to the healing tissues.

Impairments (Body Functions and Structures)

Pain

Be sure to clarify the location, quality, and intensity.

Stage 1

Surgical: Within the first 2 weeks of the postoperative period, some pain will be associated with exercises. Gradually, over the next few weeks, pain associated with the exercise should lessen. Sharp, stabbing pain should be avoided. Mild aching is expected after exercises but should be tolerable for the patient. This postexercise discomfort should decrease within 1 to 2 hours of the rehabilitation. Complaints of increasing pain, pain that is not decreasing with treatment, or burning pain are all “red flag” indicators that treatment is too aggressive or there is a disruption in the usual course of healing. Coordinating the use of analgesics with exercise sessions is important. Splinting, bracing, and/or assistive devices may be used during this period to protect the injured tissue.

Acute Injury: Despite discomfort, tests may need to be performed to rule out serious injury. Modalities and taping/bracing may be helpful to decrease pain. The patient may also require the use of an assistive device in the early phases of healing.

Stage 2 to 3

Surgical/Acute Injury: Pain associated with the specific tissue that was involved in the surgery should be significantly decreased by weeks 4 to 6. Precautions may be lifted during or by postoperative weeks 4 to 6. As activity level of the patient is progressed, the patient may report increased pain/discomfort with new activities such as returning to daily activities and fitness. Pain/discomfort location should be monitored closely. Muscle soreness is expected, similar to the response of muscle to overload stimulus (e.g., weight training). General muscle soreness should be allowed to resolve, usually 1 to 2 days before repeating the bout of activity. Pain described as stabbing should always be avoided.

Edema

Stage 1

Surgical/Acute Injury: Edema is quite common in the knee s/p surgery or injury. Edema has also been implicated in the inhibition of the quadriceps and therefore should be treated aggressively.¹¹⁻¹³ The patient should be educated in use of edema controlling techniques:

- Active ROM (AROM)
- Ice¹⁴

- Elevation
- Compression: Ace wraps, stockings

Patients should be encouraged to keep the lower extremity elevated as much as possible particularly in the early phases (1 to 3 weeks), without keeping the knee in a flexed position. Application of ice after exercise is recommended. Other methods to control edema in the knee include electrical stimulation or compression pumps. Edema should be measured at each visit. A sudden increase in edema may indicate that the rehabilitation program is too aggressive or a possible infection.

Stage 2 to 3

Surgical/Acute Injury: Time until swelling is resolved is variable among patients and surgical procedures. As patients increase the time spent on their feet, in regular daily activities, or doing more weight-bearing exercises, the patient may experience a slight increase in edema. This is to be expected; however, the patient should be further encouraged to use techniques stated previously to manage the edema.

Appearance

Stage 1

Surgical: Infection should be suspected if the area around the incision or the involved joint appears to be red, hot, and swollen. The physician should be consulted immediately if infection is suspected. It is common to observe bruising after surgery. This should be monitored continuously for any changes; an increase in bruising during the rehabilitation phases may indicate infection. Changes in hair growth, perspiration, or color may indicate some disturbance to the sympathetic nervous function, especially if in combination with the complaint of excessive pain. Stitches are typically removed in 7 to 14 days.

Stage 2 to 3

Surgical: Incision should be well healed. Bruising may still be present as far as 3 to 4 weeks after surgery but should be diminishing. Signs of increased bruising are a red flag and should be immediately referred to their physician.

Range of Motion

Stage 1

Surgical/Acute Injury: Refer to physician's precautions and specific protocols for guidelines regarding progression of the exercises. The most conservative, common ROM precautions include the following:

- ACL reconstruction: Flexion <120 degrees.
- Meniscal repair: Flexion <90 degrees.
- Collateral ligament repair: Avoid full extension.
- Patellar fractures and quadriceps tendon repairs: Restrictions can be varied for the amount of knee flexion allowed and/or when ROM exercises can begin.
- Mobilizations to the joint may be contraindicated.

Patellar mobilizations should begin as soon as possible after surgery. Common time frames to begin patellar mobilizations include the following:

- ACL reconstruction: Immediately after surgery.
- Meniscal repair: Immediately after surgery.
- Patellar fractures and quad tendon repairs: Within 1 week, however, consult with physician before initiation.

Tibiofemoral mobilizations after ACL reconstruction, meniscal repair or debridement, collateral ligament repair:

- There is little information in the literature that describes the “safe time” that mobilizations can begin. These mobilizations are not recommended until the initial healing phases are complete. If mobilizations are indicated, consult with physician before initiating.
- For mobilizations after meniscal debridement, it is recommended that distraction be added before performing glides to reduce shear to the meniscus.

Stage 2 to 3

Surgical/Acute Injury: Precautions are typically lifted by the time the patient reaches this stage. ROM should be approaching normal. Exercises may need to be progressed using passive force. To increase knee extension, prone knee extension, patients can be instructed to hang the limb off the edge of mat with weight on ankle. Patients should be advised to build up tolerance gradually and break up prolonged hang with knee flexion. For knee flexion the patient may raise knee toward the chest and use hands to add overpressure. Patient should be instructed that a stretching discomfort is expected; however, sharp pain should be avoided.

Mobilizations to the tibiofemoral joint may be indicated in later stages of rehabilitation to improve ROM. Consult with the physician before initiating joint mobilization after surgery of the knee.

Strength

Stage 1

Surgical/Acute Injury: Strengthening with overload often begins after the initial phase of healing (4 to 6 weeks). Isometrics and active movement within precautions may be started sooner. At times less than 4 weeks, emphasis should be placed on proper movement patterns in preparation for strengthening activities. After 4 weeks, strengthening may be gradually incorporated. Progression to resistive exercise is based on the patient's ability to perform ROM with a good movement pattern and without significant increase in pain.

Quadriceps muscles are most commonly affected with surgery or injury to the knee; however, others may be involved such as the hamstrings or gastrocnemius muscles. If the patient is having difficulty recruiting the quadriceps, the following cues are helpful:

- Have patient try to pull the knee cap up toward the hip.
- Have patient perform an isometric on the uninjured side first.

- With the patient in short sitting, the clinician raises the knee passively into extension. Then the patient attempts to hold the leg straight as you gradually remove the support of your hands. Be careful not to “drop” the limb. Only remove the amount of assistance that allows the patient to perform successfully.
- Light tapping of the fingers on the quadriceps: Be careful of incisions.
- When performing quadriceps isometrics in long sitting, monitor for compensation of the hamstrings. Patients actually use hamstrings to pull the tibia posteriorly to extend the knee. Be sure you see the quadriceps change shape. If these cues do not work, ask patients to reduce their effort. Often, they pull harder trying to recruit the quadriceps, but it only increases the activity of the hamstrings.

Electrical stimulation or biofeedback may be used to improve strengthening (see the following “Medications/Modalities” section).

The patient may also have strengthening precautions per the physician. Common examples of these precautions include the following:

- ACL reconstruction: No resisted extension during open-chain exercises.
- Meniscus repair: Restrictions of hamstring strengthening.
- Patellar fractures and quadriceps tendon repairs: Restrictions of quadriceps strengthening.

NOTE: Caution should be used in single-leg raise in patients >55 years of age and patients with history of low back pain.

Stage 2 to 3

Surgical/Acute Injury: At this stage, precautions are typically lifted; however, with surgical procedures, such as ACL reconstruction/injury, some restrictions on open-chain resisted extension may still be in place. Strength activities can be progressed as tolerated by the patient. Common functional activities that can be considered strengthening activities include wall slides, lunges, and step-downs/step-ups. A common compensation is to shift weight away from the involved limb. Be sure that the patient maintains the appropriate amount of weight bearing during closed-chain activities.

Proprioception/Balance¹⁵

Stage 1

Surgical/Acute Injury: Activities to improve proprioception of the knee joint should be incorporated as soon as possible. Early in treatment, these activities include weight shifting, progressive increases in weight bearing on the involved lower extremity, and eventually unilateral stance. As the patient can take full weight on the involved knee, activities are progressed to use of a balance board and closed-chain activities such as wall sits, lunges, and single-leg stance.

Stage 2 to 3

Surgical/Acute Injury: In this stage, precautions are typically lifted. Activities should be progressed to prepare patient to return to daily activities, fitness routines, and work or sporting activities. As the patient progresses, proprioception can be challenged by asking the patient to stand on unstable surfaces (pillows, trampoline, or BOSU ball), perturbations can be applied through having the patient catch a ball being thrown to him or her while standing on one leg. Sliding board activities have been shown to be beneficial to patients after surgery.¹⁶ See Box 7-2 for higher level neuromuscular training (Stage 3).

Cardiovascular and Muscular Endurance**Stage 1**

Surgical/Acute Injury: Early in rehabilitation, if the patient does not have adequate knee ROM to complete a full revolution on a stationary bike, unilateral cycling can be performed with the uninvolved extremity. The involved extremity is supported on a stationary surface, while the patient pedals with the uninvolved extremity. Water walking and swimming are good substitutes for full weight-bearing activities. For swimming, if kicking against the resistance is contraindicated, the patient may participate in swim drills that mainly challenge the upper extremities for conditioning. Low resistance stationary cycling can begin when knee flexion ROM is approximately 110 degrees. As strength improves, resistance may be increased.

Stage 2 to 3

Surgical/Acute Injury: The patient may then be progressed to activities such as water walking → walking on the treadmill → elliptical machine → Nordic ski machine → StairMaster → running when appropriate. The patient should be given specific instruction in gradual progression of these activities. See Box 7-1 for progression of running.

Patient Education**Stages 1 to 3**

Surgical/Acute Injury: Educate the patient in the structures and tissues involved and the specific medical precautions when indicated. Patients should also be taught schedule for use, and how to don and doff their brace/splint. Educate the patient in the timeline to return to activity, often driven by physician's guidelines and educate the patient in maintaining precautions during various functional activities such as ambulation, stairs, and transfers.

Scarring**Stage 1**

Surgical: Scarring, although a normal process of healing, must be managed well. Exercise, massage, compression, silicone gel sheets, and vibration are used to manage scars. The use of silicone gel is best supported by evidence in the literature. However, clinical experts also

commonly use the other methods of scar management. Further research is needed to determine the efficacy of these other methods. The gradual application of stress to the scar/incision helps the scar remodel so that it allows the necessary gliding between structures. A dry incision that has been closed and reopens because of the stresses applied with scar massage indicates that the scar massage is too aggressive. Scars may be classified according to type. Linear scars that are immature are confined to the area of the incision. They may be raised and pink or reddish in the remodeling phase. As they mature they become whitish and flatten. A hypersensitive scar requires desensitization. See Chapter 5 for the examination of the hand and general treatment guidelines and Box 5-3 for more treatment suggestions on managing scar.

Stage 2 to 3

A scar may continue to remodel for up to 2 years. Scar management techniques may be effective until the scar matures, although they are probably most effective early in the healing process.

Changes in Status**Stages 1 to 3**

Surgical/Acute Injury: Consider carefully patient reports of increased pain or edema, decreased strength, or significant change in ROM, especially in combination. The patient should be questioned regarding precipitating events such as time of onset, or the activity. If the integrity of the surgery is in doubt, contact the physician promptly. If the patient has fever and erythema spreading from the incision, the physician should be contacted because of the possibility of an infection.

Function (Activity Limitations/Participation Restrictions)**Mobility****Stage 1**

Surgical/Acute Injury: While following medical precautions, patients should be instructed in mobility, as follows:

- **Sit-to-stand:** The patient should be instructed in the proper use of an assistive device if a device is indicated.
- **Ambulation:** The patient may have weight-bearing precautions. The patient should be instructed in the proper use of an assistive device and proper gait pattern. Emphasis should be placed on normalizing the patient's gait pattern. If the patient is given partial or toe-touch weight-bearing restrictions, the patient should be instructed in using a heel-to-toe pattern while restricting the amount of weight that is accepted by the lower extremity. The patient should not place his or her weight on the ball of the foot only.
- **Stairs:** The patient should be instructed in the proper stair ambulation with use of an assistive device (if indicated). In the early phases of healing (after surgery or acute injury) the patient should be instructed to use a step to cadence, lead with the

involved lower extremity when descending stairs and lead with the uninvolved lower extremity when ascending stairs.

Stage 2 to 3

Surgical/Acute Injury: Instructions in mobility should be continued while following medical precautions.

All Mobility: As weight-bearing precautions are lifted, the patient should be instructed to gradually reduce the level or type of assistive device required. Progression away from the device depends on the ability of the patient to achieve a normal gait pattern. If the patient demonstrates a significant gait deviation secondary to pain or weakness, the patient should continue to use the device. This may prevent the adaptation of movement impairment and other pain problems in the future. A progression may be: walker → crutches → one crutch → cane → no assistive device.

Stairs: As the patient progresses through the healing stages and can accept more weight onto the involved leg, he or she should be instructed in normal stair ambulation.

Work/School/Higher Level Activities

Stage 1

Surgical/Acute Injury: The patient may be off work or school in the immediate postoperative period or after acute injury. When they are cleared to return to work or school, patients should be instructed in gradual resumption of activities. Emphasis should also be placed on edema control, particularly elevation and compression.

Stage 2 to 3

Surgical/Acute Injury: The patient should be prepared to return to their previous activities. Suggestions for improving proprioception and balance are provided in the preceding "Proprioception/Balance" section. In preparation to return to sports, sport-specific activities should be added. The initial phases of these activities will include straight plane activities at a slow pace and then gradually increase the level of difficulty. See Box 7-2 for more detail.

Sleeping

Stage 1 to 3

Surgical/Acute Injury: Sleeping is often disrupted in the immediate postoperative period or after acute injury. The lower extremity should be slightly elevated (foot higher than the knee and knee higher than the hip) to minimize edema. Avoid placing pillows so that the knee is held in the flexed position throughout the night.

Support

Stage 1

Surgical: A brace may be used to protect the surgical site, depending on the procedure or type of fracture. The brace should fit comfortably. The patient should be educated in the timeline for wearing the brace. Consult with physician if the wearing time is not clear.

It is common for a patient to complain of patellofemoral pain with rehabilitation after surgery. Taping can be helpful in the postoperative period. When applying tape, consider the underlying movement impairment (e.g., tibiofemoral rotation, patellar glide).

Acute injury: Taping may help decrease symptoms in a patient with acute knee injury. When applying tape, consider the underlying movement impairment (e.g., tibiofemoral rotation, knee hyperextension).

Stage 2 to 3

Surgical: The recommendations concerning the need for bracing long term are varied. Communication among the team (patient, physician, and physical therapist) is necessary. Functional bracing is recommended if the patient wishes to return to high level sporting activities and demonstrates either of the following:

1. Laxity in the joint
2. Performs poorly on functional tests¹⁷

Acute Injury: For injuries to the ACL that are not repaired or reconstructed, if the patient returns to sport, functional bracing is recommended.¹⁸

Medications/Modalities

Medications

Surgical: During the acute stage, physical therapy treatments should be timed with analgesics, typically 30 minutes after administration of oral medication. If medication is given intravenously, therapy often can occur immediately after administration. Communication with nurses and physicians is critical to provide optimal pain relief for the patient.

Acute injury: The patient's medications should be reviewed to ensure that they are taking the medications appropriately.

Aquatic Therapy

Surgical/Acute Injury: Aquatic therapy to decrease weight bearing during ambulation may be helpful in the rehabilitation of patients after fracture or surgical procedures. Often, this medium is not available but should be considered if the patient's progress is slowed secondary to pain or difficulty maintaining weight-bearing precautions. Incisions should be healed before aquatic therapy is initiated; however, materials to cover the incision may be used to allow patients to get into the water sooner.

Thermal Modalities

Surgical/Acute Injury: Instruct the patient in proper home use of thermal modalities to decrease pain. Ice has been shown to be beneficial, particularly in the immediate postoperative phases.¹⁴

Electrical Stimulation

Stage 1/Progression

Surgical/Acute Injury: Electrical stimulation can be used for three purposes: Pain relief, edema control, and strengthening. Interferential current has been shown to

be helpful in decreasing pain and edema.¹⁹⁻²¹ Sensory level transcutaneous electrical nerve stimulation (TENS) can assist in decreasing pain. Currently, no definitive answer exists for electrical stimulation for quadriceps strengthening. It was once believed that electrical stimulation did not provide a distinct advantage over high-intensity exercise training.²²⁻²³ However, more recent studies support the use of stimulation to improve motor recruitment and strength.²³⁻²⁶ Be sure to check for contraindications. Avoid areas where metal is in close approximation to the skin (e.g., wires/screws to fix patellar fracture). Electrical stimulation for quadriceps strengthening can be used in patients with total knee arthroplasty once staples have been removed.²⁵

Biofeedback

Stage 1/Progression

Surgical/Acute Injury: Biofeedback has been shown to be an effective adjunct to exercise for strengthening the quadriceps in early postoperative phases.²⁷

Discharge Planning

Stage 1

Surgical: Equipment, such as the following, may be needed, depending on the patient's abilities, precautions, and home environment.

- Assistive devices: Walker, crutches, cane
- Reacher
- Tub bench and hand-held shower

Therapy: Assess the need for physical therapy after discharge from the acute phase of recovery or from the following:

- Skilled nursing facility
- Rehabilitation facility
- Home health
- Outpatient physical therapy

After the acute phase of recovery, the patient should be reassessed to determine whether a movement impairment diagnosis exists. Supply the patient with documentation for consistency of care. Documentation should include the following:

- Physician protocol along with precautions and progression of activities
- Progress of patient during physical therapy
- Expected outcomes

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Movement System Syndromes of the Foot and Ankle

Mary K. Hastings

INTRODUCTION

Use of the movement system classification in the examination and treatment of musculoskeletal pain problems of the foot and ankle starts with the basic premise that a large component of the stress that causes tissue injury is the result of movement. Movement results in injury and pain because the motion is completed in an imprecise manner (excursion is excessive, insufficient, and/or asynchronous with the functional requirements) and/or the repetitions of the motion or the duration the posture is maintained exceeds the tissue's capabilities. The physical therapist examines muscle length and performance, structural variations, and the ease and excursion through which the foot, ankle, knee, hip, and spine move. The physical therapist determines the component impairments contributing to injurious motions and/or forces at unsuitable distal or proximal anatomical sites within the foot and entire lower extremity. Daily activities and habits of the patient are also assessed. Additionally, the physical therapist considers the impact of body weight, age, foot size, and disease on the foot and ankle.

The foot and ankle have very complex and often opposing functional responsibilities during weight-bearing activities. The foot and ankle must be flexible to adapt to uneven surfaces, transfer high forces, and allow motion of the body in multiple directions around a planted foot. During weight-bearing activities, the foot must quickly transform into a rigid lever that allows muscular contractions to propel the body forward, upward, sideways, or any combination of these motions. The foot also has an important role in balance; sensing body location and maintaining an upright posture.

The most common movement system syndromes of the foot and ankle injury are related to the inability of the foot to function equally well as a flexible adapter (requiring motion in the direction of pronation) and a rigid lever (requiring motion in the direction of supination). The injured foot often falls toward an extreme of one of these two roles (either a great flexible adapter with poor ability to transform to a rigid lever or a rigid lever

with limited flexibility). The movement impairment often presents as excessive or incorrect timing of the normal motions of pronation and/or supination.

This chapter outlines key principles involved in the assessment of alignment, structural variations, movement, and tests of muscle length and strength. The syndromes are described, and suggestions for associated impairments in the hip and knee are mentioned. Additionally, treatment for restoring precise motion through limiting hypermobility, addressing limitations in joint and muscle extensibility, and training for the change in movement in daily activities and habits is provided.

ALIGNMENT OF THE ANKLE AND FOOT

Ankle

The joints of the ankle include the proximal tibiofibular joint, distal tibiofibular joint, and the talocrural joint. The fibula has a limited weight-bearing function but serves as the attachment of the biceps femoris and fibular collateral ligament (lateral collateral ligament). Additionally, the fibula has a role in increasing torsional stiffness (rotational stability) of the lower limb.¹ The alignment of the fibula at the proximal and distal tibia is challenging to assess. The determination of normal or impaired alignment is generally by comparison to the other side.

Foot progression angle (toe-out angle) during gait is an important alignment factor to consider in the assessment (Figure 8-1). The normal values for foot progression angle are between 7 to 13 degrees.² The foot progression angle is the result of rotation at the hip joint, rotation at the tibiofemoral joint, femoral torsion, and/or tibial torsion. The contribution of rotation at the hip or tibiofemoral joints is determined by assessing joint alignment. Femoral and tibial torsion can be more difficult to determine. The assessment of femoral torsion, the twist of the femur in the transverse plane, is discussed in detail in the chapter on the hip in Sahrman.³

Tibial torsion, the twist of the bones of the tibia and fibula in the transverse plane, is often implicated in the



Figure 8-1. Walking with an increased foot progression angle.

predisposition of the lower extremity to injury. The normative data describe tibial torsion as usually between 20 to 40 degrees of lateral rotation.⁴⁻⁶ The measurement techniques to collect normative data have generally used radiological images or cadaveric analysis. The external landmarks available for use by clinicians in determining torsion are generally poor. Use of femoral landmarks for the proximal alignment of the tibia and fibula compared to the medial and lateral malleoli⁷ does not allow differentiation of lateral rotation at the tibiofemoral joint from torsion of the bones of the lower leg. Use of the tibial tuberosity and attempts to palpate the tibial condyles to determine proximal alignment is limited by variances in anatomy and difficulty in finding the tibial condyles. Because of the limitations in the nonradiological determination of tibial torsion, the clinically measured value should not be relied on, but general approach should be taken that considers the overall impact of foot progression angle on the function of the foot.

An increase in the foot progression angle rotates the foot away from the sagittal plane, into greater abduction and toward the frontal plane. During walking, the body moves forward in the sagittal plane, and rotation of the foot out of the plane of primary movement can contribute to injury. Body weight is now transferred to the medial side of the foot earlier, increasing the stress on the medial foot structures (talonavicular and first metatarsophalangeal [MTP] joint, as well as posterior tibialis muscle and tendon and the plantar fascia). The primary foot and ankle muscles involved in ambulation (the anterior tibialis and gastrocnemius/soleus muscles) are rotated out of their plane of primary importance. The fibularis (peroneus) longus and brevis become biased to aid in propelling the body forward, and the anterior tibialis has a decreased role in talocrural dorsiflexion or control of

plantar flexion and an increase in its function in inversion and control of eversion. Finally, less talocrural dorsiflexion is needed during walking, which can either contribute to a gradual reduction in dorsiflexion or can be a compensation for already reduced dorsiflexion. In summary, foot progression angle with walking can contribute to excessive stress that increases the risk of injury.

Foot

Hindfoot

The hindfoot includes the talus, calcaneus, and the subtalar joint (joint between the talus and calcaneus). Inclusion of the talus in both the ankle and the foot indicates the importance of the talus to the function of the foot, as well as the function of the leg. The talus is responsible for absorbing and transmitting rotatory forces that have come from the hip and/or knee but also transmits rotatory forces up to the knee and hip that originated in the foot. The interconnectedness of the leg to the foot by way of the talus has led many to consider alignment of the hindfoot key in understanding the mechanics of the foot. In assessing alignment of the hindfoot, one can begin by assessing standing calcaneal alignment. The calcaneal alignment is generally classified as valgus, varus, or neutral and generally rests in slight valgus (3.5 degrees).⁸ The standing alignment of the calcaneus is then compared to the position of the calcaneus in subtalar joint neutral.

Assessment of subtalar joint neutral is the only clinical method available to determine structural variation in the hindfoot. Subtalar joint neutral is difficult to determine and measure in a reliable manner. However, the neutral alignment is a useful tool in interpreting standing alignment and providing a general reference for understanding the function of the foot. The determination of subtalar joint neutral occurs in prone. The examiner grasps the head of the talus with the thumb and index finger of one hand and the fifth metatarsal head with the other hand (Figure 8-2). The examiner uses the grasp on the fifth metatarsal head to move the forefoot and hindfoot into abduction and adduction until the fingers on the head of the talus palpate an equal proportion of the head of the talus on the medial and lateral side (under the thumb and index finger). The foot is held in this position to assess alignment. The alignment of the vertical bisection of the calcaneus is compared to the bisection of the lower leg.

The hindfoot is determined to be in varus alignment if the calcaneus is inverted relative to the lower leg, in valgus alignment if the calcaneus is everted relative to the lower leg, and neutral if the calcaneus is aligned with the lower leg (Figure 8-3, *A*). The forefoot alignment is determined to be in subtalar joint neutral by comparing the plane of the hindfoot to the plane of the forefoot. If the forefoot is inverted on the hindfoot, the forefoot is considered to have a varus alignment. If the forefoot is everted on the hindfoot, the forefoot has a valgus alignment, and if the

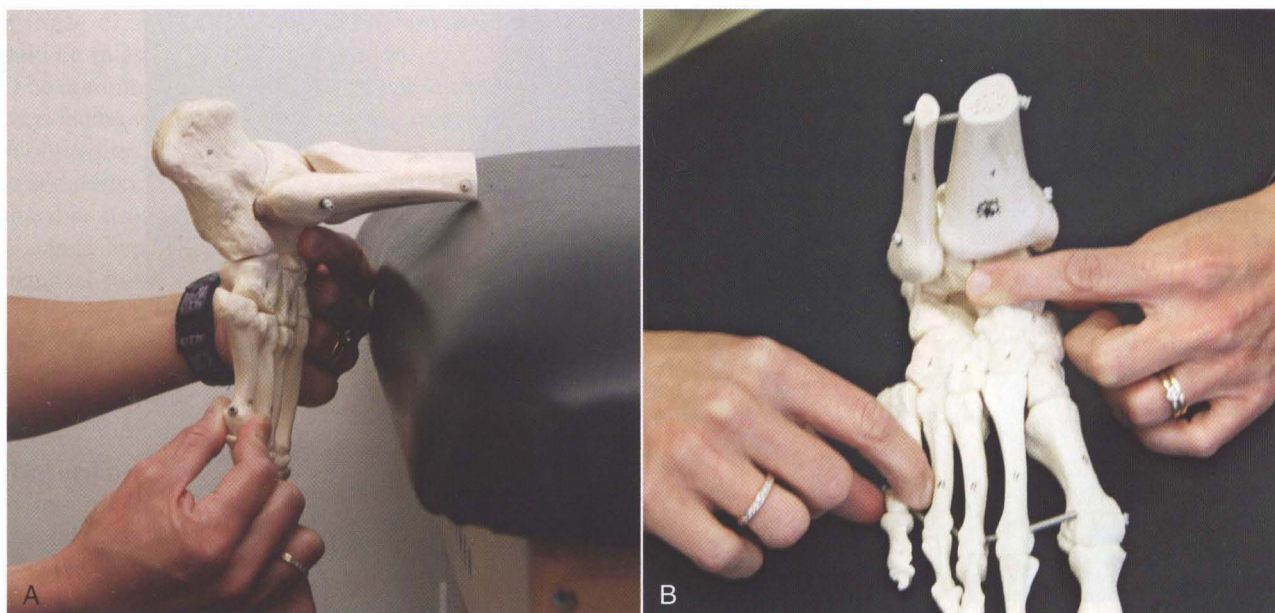


Figure 8-2. Subtalar joint neutral hand placement on skeleton: Outside hand at fifth metatarsal head and inside hand on head and neck of talus in standard position (A) and dorsal view (B).

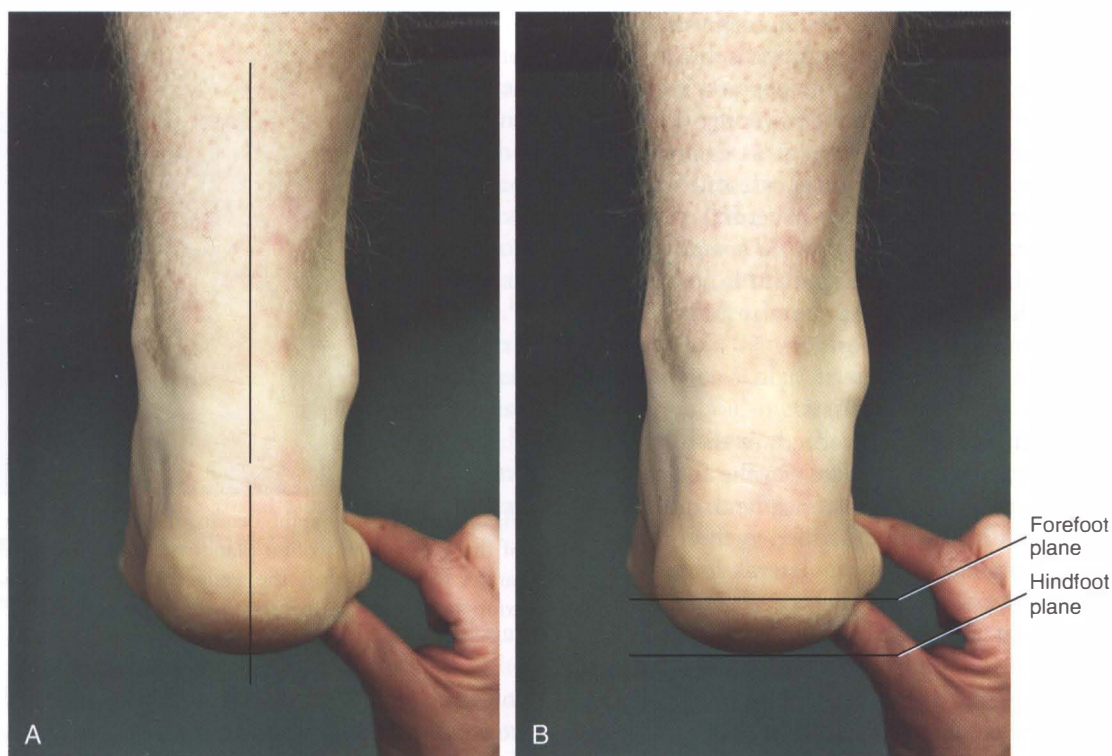


Figure 8-3. A, Neutral hindfoot alignment with vertical bisection of lower leg in line with the vertical bisection of the calcaneus. B, Neutral forefoot to hindfoot alignment with the plane of the hindfoot parallel to the forefoot.

hindfoot and forefoot planes are parallel, the forefoot has a neutral alignment (Figure 8-3, B).

The alignment of the metatarsal heads can also be assessed at this time. The metatarsal heads should be aligned along the same plane. Often the first metatarsal head will be located in a more plantar position than the

remaining metatarsal heads. This is called a *plantarflexed* (dropped) first ray, which is a forefoot compensation for structural variations of varus at the hindfoot or forefoot (Figure 8-4).

The non-weight-bearing subtalar joint neutral alignment, providing insight into structure variability, is the

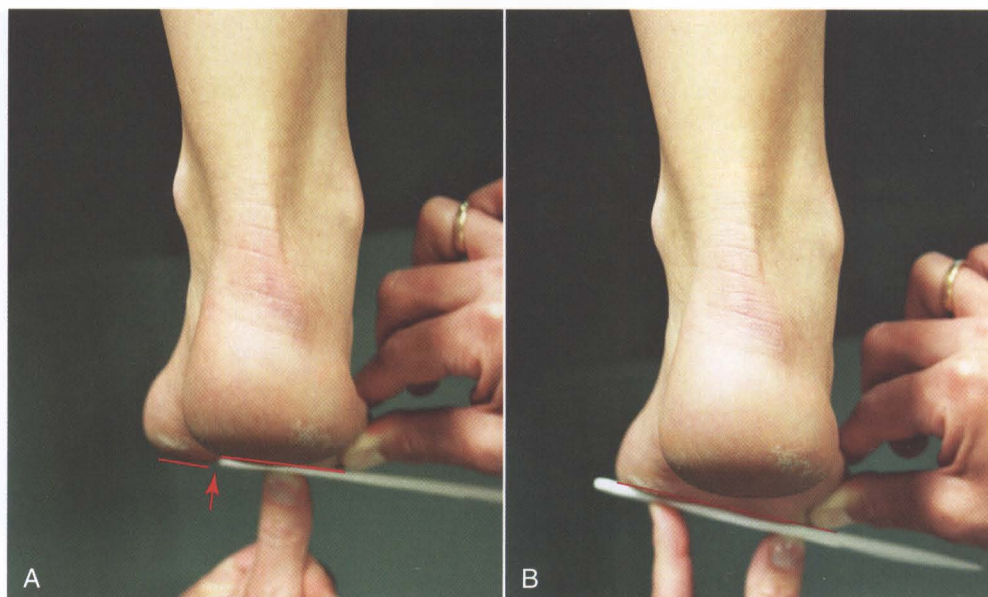


Figure 8-4. A, First metatarsal head is plantarflexed (dropped) below the plane of second to fourth metatarsal heads. B, Correction of the dropped first ray. The forefoot varus alignment relative to the hindfoot is now apparent.

backdrop for interpreting standing alignment and function. For example, suppose during prone subtalar joint assessment the neutral subtalar joint position was with the calcaneus inverted relative to the lower leg (hindfoot varus). During the standing alignment assessment, the calcaneus is vertical. The hindfoot is assessed as being able to compensate for the varus structural deviation (hindfoot alignment is termed *compensated hindfoot varus*); however, the standing calcaneal alignment is now understood as potentially harmful as the subtalar joint is being maintained near an end-range position.

Arches

Standing alignment assessment proceeds to the arches of the foot. There is truly only one arch in the foot that is continuous from anterior to posterior and medial to lateral, but the arch is usually described as three arches: the medial longitudinal arch, the lateral longitudinal arch, and the transverse arch. Much of the research on foot type, function, and injury has used the standing alignment of the medial longitudinal arch as the primary method of determining foot type.⁹⁻¹¹ The height of the arch is often a key element. Extremes of high arch and low arch are relatively easy to classify. The high arch, a supinated foot type, is often accompanied by calcaneal inversion and an adducted forefoot, and the head of the talus and navicular are more prominent on the dorsal surface of the foot. The low-arch foot, a pronated foot type, is often accompanied by calcaneal eversion and a splayed and abducted forefoot, and the head of the talus and the navicular are more prominent in the middle of the arch (medial bulge).

The lateral longitudinal arch has greater inherent bony stability than the medial longitudinal arch. The



Figure 8-5. Non-weight-bearing computed tomography image of the foot in the frontal plane with the metatarsals and phalanges removed. Note the wedged shape of cuneiforms 1 to 3 contributing to the formation of the arch.

joint surfaces of the calcaneus and cuboid are concavoconvex, providing some restriction to movement.¹² The lateral longitudinal arch height is much lower, often appearing flat in visual assessment.

The transverse arch is formed in part by the wedge shape of the cuneiforms¹² (Figure 8-5). As the transverse arch is assessed more distally on the foot, the height of the arch decreases until all metatarsal heads are in a level plane and capable of bearing weight.

Forefoot

The forefoot includes the metatarsals and phalanges. The normal alignment of the forefoot includes metatarsal and

phalanges all aligned straight on one another. The toes should be relatively flat on the ground.

The common alignment impairment at the first MTP joint is hallux valgus. This alignment presents as angulation of the first metatarsal into abduction and the phalanx into adduction. The toes will also present with alignment faults that usually include a component of metatarsal-phalangeal hyperextension with flexion at the all interphalangeal joints (claw toes) or flexion at the proximal interphalangeal joint and extension at the distal interphalangeal joint (hammer toes).

MOTIONS OF THE ANKLE AND FOOT

Static alignment determined in subtalar joint neutral and standing are only a small part of understanding how the foot functions. Examination of how the joints of the foot and ankle move and function during walking, running, hopping, squatting, and various daily activities provides the bulk of the information that directs the diagnosis and treatment.

Ankle

Proximal and Distal Tibiofibular Joints

The proximal tibiofibular joint has very little motion, and individual variability in the shape of the joint surfaces has resulted in a wide variety of associated fibular motions reported with dorsiflexion and plantarflexion.¹³ The fibula at the proximal tibiofibular joint has been reported to glide anterior, lateral, and superior with talocrural dorsiflexion and to glide posterior, medial, and inferior with talocrural plantarflexion.¹³ The distal tibiofibular joint consists of a convex fibula and a concave tibia.¹² During talocrural joint motion from neutral to dorsiflexion, the fibula at the distal tibiofibular joint has been found to have motions of internal rotation, lateral displacement (widens), and posterior and superior glide.¹⁴ During talocrural motion from dorsiflexion to plantarflexion, the fibula at the distal tibiofibular joint has been found to be medially displaced.¹⁵

Talocrural Joint

The axis of motion at the talocrural joint is not uniplanar but triplanar, crossing all three planes of motion. The motions about the axis are termed *pronation* and *supination*. Table 8-1 shows component motion description. The axis at the talocrural joint, although it crosses all three planes, lies primarily in the transverse plane in a medial-to-lateral direction. Thus plantarflexion and dorsiflexion are the primary motions.

Dorsiflexion. Adequate dorsiflexion motion at the talocrural joint is crucial in advancing the tibia over the foot in walking, running, jumping, squatting, and many other weight-bearing activities. A minimum of 10 degrees of dorsiflexion (with the knee extended) is needed for walking and 30 degrees for running.¹⁶ Dorsiflexion motion requires adequate length of the gastrocnemius

muscle, soleus muscle, and calcaneal (Achilles) tendon, as well as ligaments and joint structures of the talocrural joint. Because the head of the talus is wider anteriorly than posteriorly, a small amount of motion is required at the tibiofibular joint to fully accept the dome of the talus.¹³ If dorsiflexion is found to be limited, the source of limited talocrural motion can be assessed by measuring talocrural dorsiflexion with the knee extended and flexed and assessing talocrural joint accessory motion. Additionally, dorsiflexion should be isolated to the talocrural joint, and compensations at the foot (e.g., eversion, midtarsal dorsiflexion, and pronation) should not be allowed during dorsiflexion. The following information is gleaned from this test:

- Gastrocnemius muscle/calcaneal (Achilles) tendon short if dorsiflexion is ≤ 10 degrees with the knee extended but ≥ 10 degrees with knee flexed.
- Soleus muscle short if dorsiflexion is ≤ 10 degrees regardless of knee position and accessory talocrural motion is normal.
- Talocrural joint limitation if dorsiflexion is ≤ 10 degrees regardless of knee position and accessory talocrural joint motion is limited (cannot rule out soleus muscle limitation in this case).

Without adequate motion at the talocrural joint, the body can employ a number of strategies for compensating. The patient can increase the foot progression angle, demonstrate an early heel rise, or use a forefoot strike pattern (only the forefoot is in contact with the ground) during walking and running to compensate for the lack of dorsiflexion. Additionally, the failure to dorsiflex at the talocrural joint during stance phase can be compensated for by hyperextending the knee and/or increasing the dorsiflexion that occurs at the more distal joints of the foot: talonavicular, naviculocuneiform, calcaneocuboid, and/or cuboid-metatarsal joints (Figure 8-6).

Plantarflexion. Plantarflexion at the talocrural joint plays an important role in propelling the body during walking, running, and jumping. Normal plantarflexion motion during gait is approximately 30 degrees. Plantarflexion at the talocrural joint alone, however, is relatively ineffective in propelling the body forward. The foot (calcaneus to metatarsal heads) must become a rigid

TABLE 8-1

Motions at the Hindfoot Associated with Open- and Closed-Chain Pronation and Supination

	Open Chain	Closed Chain
Pronation	Calcaneal eversion	Calcaneal eversion
	Calcaneal dorsiflexion	Talar plantarflexion
	Calcaneal abduction	Talar adduction
Supination	Calcaneal inversion	Calcaneal inversion
	Calcaneal plantarflexion	Talar dorsiflexion
	Calcaneal adduction	Talar abduction

lever to transfer the plantarflexion force through the foot, raising the body over the toes. The foot becomes more rigid in a number of ways. First, the foot becomes rigid through maximizing bony alignment. The contraction of the plantarflexors has a supination component. Supination of the subtalar joint and transtarsal joint helps place the joints in their closed pack, which is a more stable position providing some stability to the foot.

The second way the foot becomes rigid is by the passive tensioning function of the plantar aponeurosis. The plantar aponeurosis is a thick fascial sheath originating at the calcaneal tubercle and inserting into multiple locations but primarily into the flexor tendons of the foot and the base of the fifth metatarsal. As the heel begins to rise at the end of the stance phase, the MTP joints dorsiflex and the plantar aponeurosis becomes taut. The joints of the foot are approximated, the arch rises, and the foot becomes more rigid (windlass mechanism). Third, the foot is rigid because of the muscular forces

that directly impact joint stability. The posterior tibialis muscle/tendon is aligned to provide not only a force that produces plantarflexion with supination but also a force directed along the long axis of the foot. The posterior tibialis tendon inserts into all the tarsal bones, except the talus, as well as the bases of second to fourth metatarsals. The posteriorly directed force along the long axis of the foot is critical to the function of the foot. The force provides muscular “cinching” of the foot bones, increasing foot rigidity and the effectiveness of the ankle plantarflexor muscles.¹⁷ An extreme example of failure of the mechanisms that provide rigidity to the midfoot allowing plantar flexion at the midfoot is seen in Figure 8-7. (Contraction of the gastrocnemius in subject *B* of Figure 8-7 would result in isolated plantarflexion of the calcaneus without a forceful transfer of plantarflexion to propel the body.) The intrinsic muscles of the foot also function to support the arch of the foot and provide rigidity to the foot during plantarflexion.

Foot

Subtalar Joint

The axis of motion at the subtalar joint is also triplanar. The axis, although it crosses all planes, lies primarily between the sagittal and transverse plane, allowing more inversion and eversion and abduction and adduction than plantarflexion and dorsiflexion.

Inversion and eversion. Motion at the subtalar joint is fairly limited because of the lack of symmetry in shape of the three talar facets (the posterior talar facet is concave, whereas the middle and anterior talar facets are flat to convex). Subtalar joint range of motion (ROM) is reported to be between 5 to 10 degrees of calcaneal eversion and 20 to 30 degrees of calcaneal inversion.¹⁸⁻²⁰

The triplanar motion of the subtalar joint is difficult to capture during weight-bearing activities using standard kinematic techniques. Passive calcaneal motion of inversion and eversion are easily measured goniometrically and often used to provide some indication of the movement at the subtalar joint. During walking the calcaneus contacts the ground in slight inversion



Figure 8-6. Dorsiflexion at the talocrural joint is limited. Compensation has occurred with dorsiflexion at the midtarsal joint.



Figure 8-7. **A,** An individual with diabetes and peripheral neuropathy. Note the normal upward inclination of the calcaneus. **B,** The foot of an individual with diabetes, peripheral neuropathy, and Charcot's osteoarthropathy. This individual has lost the necessary rigidity of the foot and the pull of the gastrocnemius/soleus muscle through the calcaneal (Achilles) tendon resulted in calcaneal plantarflexion.

(approximately 2.5 degrees from standing calcaneal position). The calcaneus moves into slight eversion through heel-off and then begins the return to inversion (approximately 6 degrees from the standing calcaneal position) right before toe-off.²¹

In the weight-bearing foot, the intimate connection of the talus to the lower leg through the talocrural joint links medial rotation of the lower leg to subtalar joint pronation (talar adduction and calcaneal eversion) and vice versa, subtalar joint pronation to lower leg medial rotation. The same is true for the linking of lateral rotation of the lower leg to supination and supination to lateral rotation of the leg. The linking of foot and leg motion through the subtalar joint illuminates why many have worked to assess and understand subtalar alignment, motion, and function.

Transverse Tarsal or Midtarsal Joints

The transverse tarsal joint is comprised of the talonavicular and calcaneocuboid joints. The axes of motion at the transverse tarsal joints are triplanar, allowing pronation and supination. In most feet, motion at the subtalar joint is intimately connected to the motions that occur at the talonavicular and calcaneocuboid joints. As the subtalar joint supinates, it draws the transverse tarsal joint into supination, a more stable joint position of the transverse tarsal joint (locked position), converting the midfoot into a more rigid lever. As the subtalar joint pronates the transverse tarsal joint pronates, which creates a more loose position of the joints and a more flexible midfoot.^{22,23}

The transverse tarsal joints are the intermediate joints between the hindfoot and the forefoot. One of the functions of the transverse tarsal joint is to position the forefoot for ground contact during push-off. In performing this function, the transverse tarsal joint becomes a frequent site of compensation for structural variances and movement impairments of both the hindfoot and forefoot. The transverse tarsal joint can become hyperflexible, limiting the ability of the foot to transform into a rigid lever and decreasing the stability of the longitudinal arches, which contributes to flat-foot deformities.

In the high arched or more rigid foot type, the subtalar joint and the transverse tarsal joints are maintained in the closed pack or locked position. The lack of mobility is thought to contribute to injuries at the foot and lower extremity as a result the inability of the rigid foot to dissipate the high forces occurring during weight-bearing activities.

Tarsometatarsal Joints

The tarsometatarsal joints generally have very little motion and are critical in providing the structure for the transverse arch. Motion that occurs at the tarsometatarsal joints is generally with the focus of positioning the forefoot flat on the ground for push-off. If the motion that has proceeded from the hindfoot to the midfoot during gait has inadequately prepared the forefoot for weight-bearing, the tarsometatarsal joints may assist. For

example, insufficient pronation of the hindfoot and midfoot from heel strike through midstance might result in the medial side of the forefoot being up off the weight-bearing surface. If there is motion available at the tarsometatarsal joints, a pronatory twist will occur at the tarsometatarsal joints to bring the forefoot flat.²³ A supinatory twist will occur in the tarsometatarsal joints if too much pronation has occurred at the hindfoot and midfoot during early stance phase. The site of compensatory motion often becomes the source of symptoms.

Metatarsophalangeal Joints

The MTP joints' primary direction of function is into dorsiflexion. Adequate MTP dorsiflexion allows the foot to roll over the toes as the plantarflexor muscles propel the body forward. Additionally, MTP dorsiflexion stretches the plantar aponeurosis, elevating the arch and assisting in making the foot rigid during push-off. First MTP joint dorsiflexion needed for walking is reported to be between 30 to 60 degrees.^{24,25} Lack of first toe extension prevents the normal pattern of roll-over, and weight is transferred either medial or lateral of the first toe. Medial weight transfer increases the abduction force on the proximal phalanx, predisposing the individual to hallux valgus deformity. Lateral transfer of weight increases the force borne by the second and third metatarsal heads, often resulting in pain at the MTP joints.

First MTP joint dorsiflexion can be limited by the length of the flexor hallucis longus, plantar aponeurosis (fascia), or joint restrictions. Theoretically, the contribution of flexor hallucis longus muscle length to limited MTP joint dorsiflexion motion can be determined by comparing MTP dorsiflexion ROM with the talocrural joint dorsiflexed (flexor hallucis longus on stretch) to MTP dorsiflexion ROM with the talocrural joint plantarflexed (flexor hallucis longus on slack). First MTP dorsiflexion in full plantarflexion should measure ≥ 60 degrees. First MTP dorsiflexion in full talocrural dorsiflexion is rarely measured. Hopson et al²⁵ found on average 85 degrees of MTP dorsiflexion in 0 degrees of talocrural dorsiflexion. Nawoczenski et al²⁴ found 35 to 45 degrees of MTP dorsiflexion in a standing passive and active test. Clinically, MTP dorsiflexion measured in talocrural dorsiflexion is very limited, between 10 to 15 degrees (Figure 8-8). Decreased MTP dorsiflexion in full talocrural dorsiflexion can indicate flexor hallucis muscle length impairment. However, the plantar aponeurosis may also be limiting MTP motion in this position because the position of maximum MTP and ankle dorsiflexion has been found to place maximum stretch on the plantar aponeurosis.²⁶

Functionally, there is rarely an occasion in which maximum MTP dorsiflexion is needed during maximum talocrural dorsiflexion. During gait, 30 to 60 degrees of first MTP dorsiflexion^{24,25} is needed during push-off when the talocrural joint is in approximately 10 to 25 degrees of talocrural plantarflexion.^{21,23} Thus the most functional assessment of first MTP dorsiflexion would be to assess MTP dorsiflexion motion in approximately 20

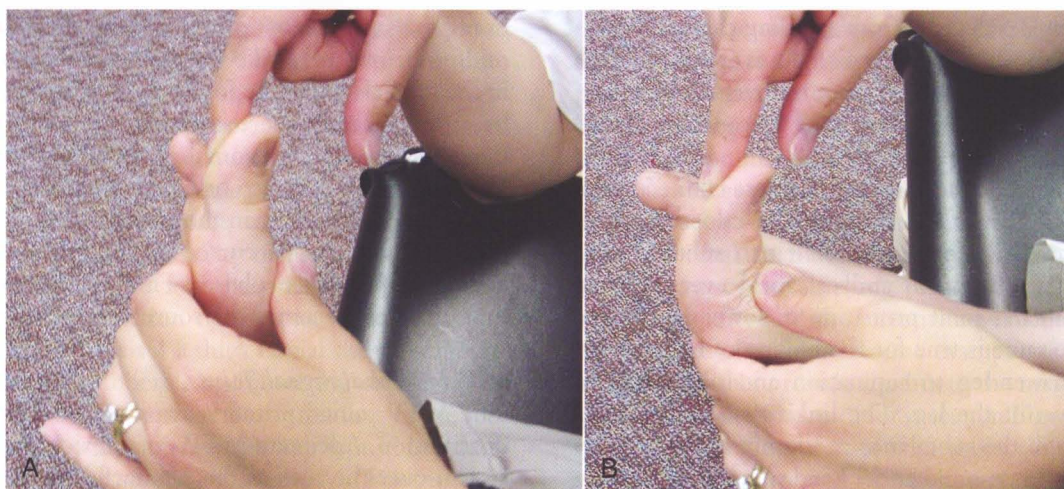


Figure 8-8. First metatarsophalangeal extension. **A**, In talocrural joint dorsiflexion. **B**, In talocrural joint plantarflexion.

degrees of talocrural plantarflexion. In summary, the following information can be gleaned from the test:

- Flexor hallucis longus short if <30 degrees of MTP joint dorsiflexion in talocrural dorsiflexion and ≥ 30 degrees of MTP joint dorsiflexion in talocrural plantarflexion. (Cannot determine the contribution of plantar aponeurosis length to test results.)
- First MTP joint limitation if first MTP joint dorsiflexion remains limited regardless of ankle position and accessory MTP joint motion is limited (cannot rule out flexor hallucis brevis or other one joint muscles crossing the MTP joint).

The contribution of MTP dorsiflexion to engage the windlass mechanism of the foot thus increasing foot rigidity during push-off is critical. Stretching into first MTP dorsiflexion should be approached with caution to avoid overlengthening of the foot structures critical for engaging the windlass mechanism of the foot.

Interphalangeal Joints

The interphalangeal joints have a critical role in increasing the area over which the weight-bearing force is distributed during push-off. To increase surface area during push-off, the toes must be flat on the ground. The intrinsic muscles of the foot are critical in stabilizing the MTP joints against excessive dorsiflexion (hyperextension) while extending the interphalangeal joints of the toes to provide a flat surface for force distribution. Without appropriate function of the intrinsic muscles of the foot, claw toe deformities develop as the extrinsic toe flexors and extensors act unopposed.

MUSCLE ACTIONS

Leg

The four muscular compartments of the leg are the superficial posterior compartment, the deep posterior compartment, the lateral compartment, and the anterior

compartment. The compartments are separated by fascial encasements that are continuations from the tensor fasciae latae of the thigh.¹² The fascial compartments assist the muscle by transferring the contractile force produced by the muscle to the bone (Figure 8-9). The fascial compartments also provide spatial constraints to edema and can compromise nerve and blood vessel function within a compartment when edema increases.

Posterior Compartments

The superficial and deep posterior compartments of the leg contain the primary plantarflexors of the ankle (the gastrocnemius, soleus, tibialis posterior, flexor hallucis longus, and flexor digitorum longus muscles), the posterior tibial artery and veins, tibial nerve, and fibular (peroneal) artery and veins. All posterior compartment muscles insert medial to the midline of the foot and therefore also assist in supination. Strong plantarflexion with supination is important in the muscular component that transforms the foot into the rigid lever for effective push off during gait. The posterior compartment also has a significant eccentric role during walking and running by controlling tibial progression over the foot and pronation of the foot from initial contact until the start of push-off.

The posterior tibialis, flexor hallucis longus, and flexor digitorum muscles and the posterior tibial artery and tibial nerve make a sharp turn around the medial malleolus and travel beneath the flexor retinaculum in the region posterior to the medial malleolus. The area in which this sharp turn occurs is a frequent site for tendon injury, as well as nerve compression.

Lateral Compartment

The lateral compartment contains the fibularis (peroneus) longus and brevis muscles and the superficial fibular (peroneal) nerve. The fibularis muscles are ankle evertors and weak ankle plantarflexors. Additionally, the fibularis

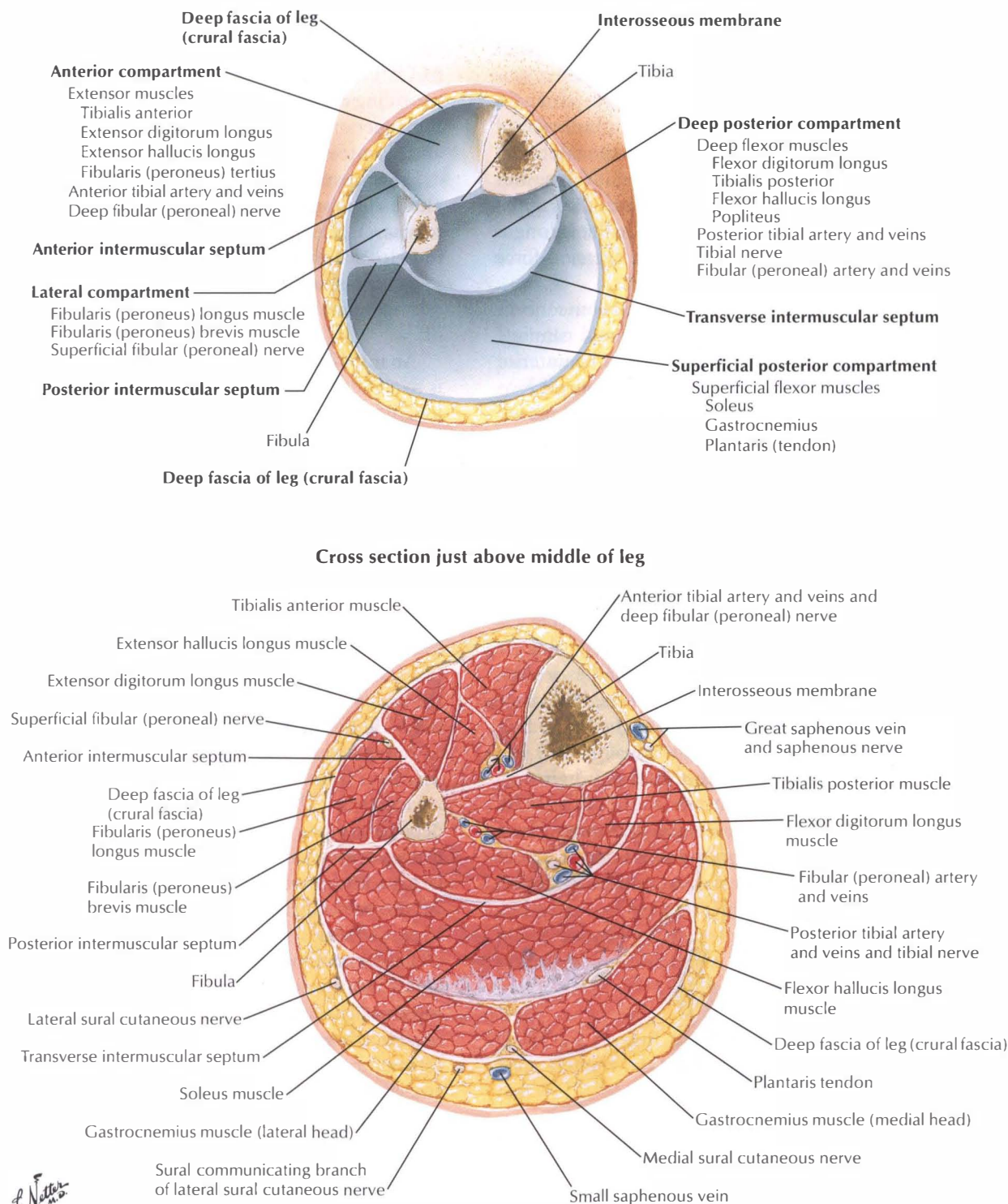


Figure 8-9. Fascial compartments and components. (From Greene WB: *Netter's orthopaedics*, Philadelphia, 2006, Saunders.)

longus muscle crosses the plantar surface of the foot and inserts on the base of the first metatarsal and medial cuneiform bone, providing a supportive sling for the foot and muscular control of the forefoot position. The fibularis brevis muscle inserts into the base of the fifth metatarsal, providing rigidity to the lateral column of the foot.

Anterior Compartment

The anterior compartment contains the tibialis anterior, extensor hallucis longus, and the extensor digitorum longus muscles; the anterior tibial artery and veins; and the deep fibular (peroneal) nerve. The muscles, the anterior tibial artery, and the deep fibular nerve pass under

the superior and inferior extensor retinaculum. All muscles within the anterior compartment are ankle dorsiflexors. The insertions of the tibialis anterior and extensor hallucis longus are medial to the talocrural joint axis, inverting the foot during dorsiflexion. The insertion of the extensor digitorum longus is lateral to the talocrural joint axis and everts the foot during dorsiflexion. For balanced dorsiflexion that occurs primarily in the sagittal plane, the anterior tibialis and extensor hallucis longus inversion force must be countered by the eversion force produced by the extensor digitorum longus.

The anterior compartment muscles function concentrically during the swing phase of walking and running, dorsiflexing the foot, and clearing the toe. The anterior compartment muscles work eccentrically to control lowering of the foot from heel strike to foot flat in a heel-strike first pattern of walking and running.

Foot

The intrinsic muscles of the foot provide important stabilization of the arches and the MTP and interphalangeal joints of the foot, as well as help regulate tension and direction of force produced by the extrinsic muscles of the foot. The quadratus plantae muscle attaches from the calcaneus to the tendons of the flexor digitorum longus muscle to redirect the diagonal force of the flexor digitorum longus so that the toes flex in the sagittal plane (Figure 8-10). The lumbricals attach from the flexor digitorum longus tendon to the medial proximal phalanx and on to the dorsal expansion of the extensor digitorum longus. When the lumbricals contract, they flex the MTP joint, place the flexor digitorum longus tendons on slack, and pull on the extensor digitorum longus dorsal expansion to extend the interphalangeal joints. The interossei

attach to the shafts of the metatarsals and insert onto the base of the proximal phalanx, assisting in flexing the MTP joint, extending the interphalangeal joints, and providing a force to abduct and adduct the toes. Through the function of the interossei and lumbricals, hammer and claw toe deformities are prevented.²³

The intrinsic muscles, in general, originate and insert along the longitudinal axis of the foot (they run proximal to distal). Through muscular contraction, the intrinsic muscles provide critical stabilization of the foot, assisting in the transformation of the foot from a flexible adaptor during initial phases of stance to a rigid lever during push off.¹²

An important function of the interossei and lumbricals is to stabilize the MTP joints during talocrural dorsiflexion. The extensor digitorum assists in producing balanced talocrural dorsiflexion but is also simultaneously acting to dorsiflex the MTP joints. MTP joint dorsiflexion during talocrural dorsiflexion is an unwanted action. First, the extensor digitorum tendon is shortened over both joints (the MTP and talocrural joints), decreasing the talocrural dorsiflexion torque production capability. Second, the plantar fascia is placed on maximum stretch, increasing the risk of injury. Finally, repetitive MTP extension contributes to hammer and claw toe deformities. The lumbricals and interossei muscles act to counter the action of the extensor digitorum longus and stabilize the MTP joints during talocrural dorsiflexion.

Interestingly, there are no intrinsic foot muscles that originate from the talus or calcaneus and attach to the navicular or cuboid. The stability of the transtarsal joint depends on bony shape, taut ligamentous restraints, and extrinsic muscles of the foot that cross this joint. The lack of intrinsic muscle joint restraints may contribute to the transtarsal joint becoming a frequent site of hypermobility.

Understanding the anatomy and kinesiology of the ankle and foot is the fundamental foundation necessary to critically examine functional activities of the foot and to determine the movement system diagnosis. The remainder of the chapter uses this knowledge of anatomy and kinesiology to assess movement and to determine when a movement impairment exists and what factors may be contributing to this movement impairment.

EXAMINATION OF THE ANKLE AND FOOT

History

A standard history should be collected by the physical therapist and should include the history of the injury, pain ratings (symptoms at their worst, best, and average) and frequency and the duration of the pain. The standard history also includes the effect of daily activities and positions on symptoms, and the physical therapist must become familiar with the patient's daily routine and requirements, as well as any changes in activity level that may have occurred around the onset of the symptoms.

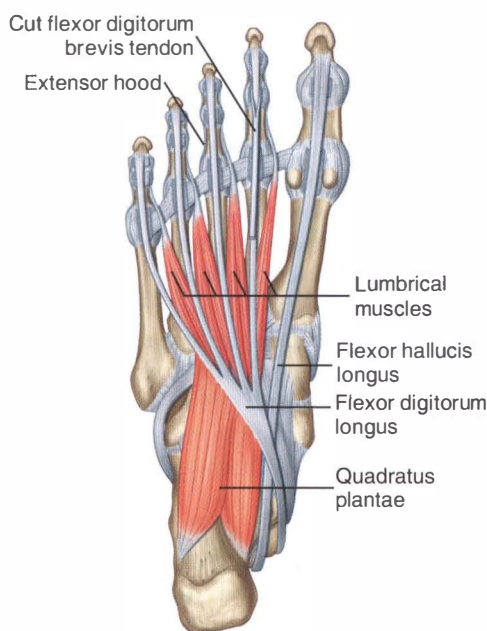


Figure 8-10. Quadratus plantae muscle. (From Drake R: *Gray's anatomy for students*, ed 2, Churchill Livingstone, 2009, London.)

The physical therapist must also ask additional questions regarding the patient's footwear. Detailed information about the type and age of the footwear and the frequency and duration that each type of footwear is worn should be obtained. The therapist should become familiar with previous inserts, orthoses, or lower extremity braces the patient has been prescribed and/or worn.

The systems review should include the patient's medical and surgical history and current medications. Musculoskeletal, neurovascular, and systemic sources of signs and symptoms must be examined and may require referral to a physician for additional management.

Potential Conditions Requiring Referral

Stress Fracture

Stress fractures are a common musculoskeletal source of undiagnosed foot and ankle symptoms that must be ruled out before completing a movement system examination and prescribing an intervention. Stress fracture pain generally is local and isolated to the bone, although symptom presentation can be diffuse and confusing. The six locations of stress fractures that are at high risk for serious sequelae if undertreated are anterior lateral tibial diaphysis, medial malleolus, talus, navicular, fifth metatarsal, and sesamoids.²⁷ Local or suspicious signs and symptoms in the high risk areas should be immediately referred to a physician because delayed treatment or undertreatment tends to result in progression to a complete fracture, a nonunion, the need for operative intervention, and/or recurrence or refracture.

Deep Vein Thromboses

Deep vein thromboses (DVT) can be the source of calf pain and edema. The strongest risk factors associated with development of a DVT include a fracture of the pelvis, femur, or tibia; hip or knee replacement; spinal cord injury; major general surgery; or major trauma. The Homans' sign²⁸⁻³⁰ (calf squeeze) has been commonly used to assess the presence of DVTs. Unfortunately, Homans' sign has little diagnostic value.³¹ The Clinical Decision Rule developed by Wells et al assesses signs and symptoms, assigning a score and a probability of the presence of a DVT and has been found reliable and valid.^{32,33}

Diabetes Mellitus

The lower extremity is at risk for devastating consequences of diabetes mellitus. Peripheral neuropathy and small vessel vascular disease can lead to unperceived injury, deformity, and nonhealing ulcers. Lower extremity amputation is often the outcome. An aggressive and complete screening for sensation and blood flow (see the "Peripheral Vascular Disease" section) should be completed on all patients who have suspicious histories. Sensation should be tested with Semmes-Weinstein monofilaments. For the foot and ankle, individuals are considered to lack protective sensation, which is sensation capable of detecting injury, if they are unable

to feel the 5.07/10-gm filament on any location on the foot.

For individuals with diabetes mellitus, the hemoglobin A1c level (HbA1c) measures the percentage of hemoglobin in the blood that has glucose attached, indicating blood glucose control over a 3 month period of time. Normally, this value should be $\leq 6\%$. A higher HbA1c value indicates poor glucose control and is correlated with an increased risk of developing complications related to diabetes.³⁴

Peripheral Vascular Disease

Peripheral vascular disease can present as claudicating pain, which is pain in the lower leg that comes on with walking and decreases or resolves with rest. The clinician should look for loss of hair on the feet and legs, decreased capillary refill, nonpalpable pulses at the dorsalis pedis and/or posterior tibial arteries, and poor skin color. The patient may also report results from an ankle-arm index assessment that compares blood pressure in the arms to blood pressure in multiple sites in the lower extremity. Normal ankle-arm index values should be between 0.91 to 1.3.³⁵ There is an increased risk of a cardiovascular event with values <1.0 and ≥ 1.4 .

Rheumatoid Arthritis

Although rare (16%), an initial presentation of rheumatoid arthritis (RA) occurs in the foot and ankle.³⁶ Specifically, individuals complain of forefoot pain. Hindfoot pain is often a later manifestation of RA.

Seronegative Spondyloarthropathies

Foot and ankle pain are also common complaints in ankylosing spondylitis, psoriatic arthritis, Reiter's syndrome, and inflammatory bowel arthritides. Foot and ankle complaints are generally accompanied by additional signs and symptoms specific to the disease.

Gout

Gout can present in an acute or chronic manner. The pain, redness, and swelling is generally localized to the first MTP.³⁷

Potential Diagnoses and/or Conditions Requiring Referral

There are a number of undiagnosed conditions that should be suspected from the history and symptoms. If the conditions are not ruled out, they require a referral to a physician in addition to physical therapy or before physical therapy (see the Chapter 8 Appendix).

Movement System Syndromes of the Ankle and Foot

A movement system diagnosis is useful because the treatment plan directly addresses the movement pattern causing excessive stress on a particular tissue and

TABLE 8-2
Foot and Ankle Syndromes

Syndrome	Key Findings	Source of Symptoms
Pronation	Incorrect timing or amount of motion of the ankle/foot in the direction of pronation during weight-bearing activities (hindfoot, midfoot, and/or forefoot).	Plantar fascia, posterior and anterior tibialis muscle/tendon, metatarsal heads, interdigital or tibial nerves, medial column joints and ligaments (talocrural, subtalar, talonavicular, naviculocuneiform, tarsometatarsal, and MTP joints)
Supination	Incorrect timing or amount of motion of the ankle and foot in the direction of supination during weight-bearing activities (hindfoot, midfoot, and/or forefoot).	Plantar fascia, fibular muscle/tendon, gastrocnemius/soleus muscle, calcaneal tendon, metatarsal heads, lateral column joints and ligaments (talocrural, subtalar, calcaneocuboid, tarsometatarsal, and MTP joints)
Insufficient dorsiflexion	Insufficient dorsiflexion during weight-bearing activities that require the tibia to advance over the foot.	Plantar fascia, gastrocnemius/soleus muscle, calcaneal tendon, calcaneal bursa, anterior tibialis muscle/tendon, deep fibular nerve
Hypomobility	Limitation in physiological and accessory motion of the ankle/foot joint(s).	Individual ankle and foot joints
Foot/ankle impairment	Tissue injury from surgery or trauma that requires protection for repair.	Individual ankle and foot tissues (bone, cartilage, muscle, tendon, ligament, skin, nerve)
Proximal tibiofibular glide	Positional fault of the fibula on tibia or hypermobility of the tibiofibular joint during hamstring contraction.	Proximal tibiofibular joint

MTP, Metatarsophalangeal.

resulting in injury. The body structures that are stressed and injured with a particular movement system syndrome are numerous and those that are listed with each movement system syndrome are not meant to be exhaustive but reflect those most commonly seen by physical therapists (Table 8-2). The source of symptoms (the body structure injured) is not specific to the movement system syndromes and should not be used in determining the movement impairment diagnosis. In the foot and ankle, where almost all muscles cross more than one joint and produce multiplanar motions, a particular body structure can be overstressed and injured by more than one individual movement (Table 8-3).

PRONATION SYNDROME

The principal movement impairment associated with pronation syndrome is pronation at the foot/ankle during weight-bearing activities that is excessive for that individual and/or when there is insufficient movement of the foot in the direction of supination in later stance phase. The pronation impairment can occur in the hindfoot, midfoot, and/or forefoot. A foot with the pronation syndrome is a flexible foot that provides the path of least resistance to motion and the site of compensation for various structural and movement impairments within the foot, ankle, knee, and hip.

Symptoms and Pain

The stress of the pronation movement impairment results in tissue injury. The tissues at greatest risk of injury

include those impacted by excessive tensile forces from overstretching or muscular efforts to resist the pronation movement and occasionally those tissues that experience compression as a result of the excessive joint position. The following section of possible structures involved in pronation syndrome is not complete but identifies the most common structures and the symptoms reported during the history component of the examination.

Plantar Aponeurosis (Fascia)

Involvement of the plantar aponeurosis is most often accompanied by patient complaints of heel pain that is worse with the first step out of bed in the morning and after a period of prolonged non-weight-bearing activities.

Posterior Tibialis Muscle and Tendon

The patient complains of pain localized to the muscle at distal one-third of the medial tibia or anywhere along the tendon as it follows its course around the medial malleolus to the primary insertion at the navicular bone. The symptoms are most apparent during the weight-bearing phase of activities as the muscle works eccentrically to control pronation and/or concentrically to supinate and plantarflex the foot and ankle.

Anterior Tibialis Muscle and Tendon

Pain is localized to the muscle at the proximal lateral tibia and/or the tendon as it inserts into the medial cuneiform and first metatarsal. The symptoms are often present at heel strike as the muscle works eccentrically to control

TABLE 8-3
Differential Diagnoses for the Foot/Ankle

Symptom Location	Possible Diagnosis	Follow-up Tests and Questions	Referral Required: Discontinue Physical Therapy	Referral Required: Continue Examination and Treatment
LOCAL BONE PAIN				
Anterior lateral tibial diaphysis	Fracture (stress)	Palpation	×	—
Medial malleolus		Vibration of bone at location	×	—
Talus		away from site of symptoms	×	—
Navicular			×	—
Proximal (base) of the fifth metatarsal			×	—
Sesamoids			×	
Shaft or head of first through fifth metatarsals			—	×
Proximal lateral tibia			—	×
Distal medial tibia			—	×
Remaining tarsals and phalanges			—	×
Joint symptoms	DJD	Palpation	—	×
	Osteochondritis desiccans	Axial joint compression		
	RA	End-range joint motions		
Medial ankle and foot pain	Posterior tibial tendon insufficiency	Failure to complete a single-leg heel rise	—	×
	Tibial nerve compression at the tarsal tunnel	Tinel's distal to proximal along the nerve path	—	×
		Sustained provocative position		
		Tinel's in provocative position		
Calf pain	DVT	Well's Clinical Decision Rule	×	—
	Compartment syndrome	Palpation	×	—
		Pulses		
Dermatomal leg and foot pain	Low back referral (L4-S2)	Sensation tests	—	×
		Back movement tests		

X, Positive finding requiring referral.

DJD, Degenerative joint disease; DVT, deep vein thrombosis; RA, rheumatoid arthritis.

plantarflexion. Anterior tibialis muscle pain is often called *shin splints* and particularly apparent after running or long distance walking.

Tibial Nerve

Pain, tingling, and/or numbness is located on the posterior medial ankle and/or the plantar surface of the foot. Determining whether the tibial nerve is involved is critical but also difficult. Tinel's tapping test along the nerve pathway and if needed, Tinel's tapping test in the provocative positions of full dorsiflexion, calcaneal eversion, and toe extension can assist the physical therapist is determining the source of symptoms.³⁸

Gastrocnemius/Soleus Muscles and Calcaneal (Achilles) Tendon

The patient complains of pain in the muscle belly or tendon, particularly during late stance, as the muscle is working eccentrically and the tendon is being placed on

stretch to control the tibia's progression over the foot and during the concentric contraction required during push-off.

Metatarsal Heads

For the movement impairment of pronation, metatarsal pain is localized to the head of the second and third metatarsals and increases during the late stance and the push-off phases of walking and running (Figure 8-11).

Interdigital Nerves

The interdigital nerves can become irritated, producing complaints of pain, tingling, or numbness between the metatarsals and into the corresponding toes. The most common location is between the third and fourth toes. The interdigital nerve often receives branches from both the medial plantar nerve and the lateral plantar nerve, increasing the size of the nerve and the risk of impingement during weight-bearing activities.

Medial Column Joints

The patient complains of generalized midfoot pain, often in the joints of the medial column (talus, calcaneus, navicular, three cuneiforms, or first, second, or third metatarsals). The pain can progress to joint degeneration and involve the joints of the lateral column.

Alignment: Structural Variations and Acquired Impairments

Standing foot alignment has been a primary method for determining foot type. The typical description of a pronated foot includes a combination of calcaneal eversion, medial bulge (prominence of the talonavicular joint medially), low medial longitudinal arch, forefoot abduction relative to the hindfoot at the transtarsal joint, and increased width of the forefoot (splayed forefoot) (Figure 8-12). Often, as the remainder of the lower extremity alignment is examined, there will be alignment impairments proximal to the foot that contribute to pronation at the foot. These include medial rotation at the hip, medial rotation at the knee, and structural variations of the femur and/or tibia that result in an increase in medially directed forces through the foot (e.g., femoral anteversion, medial tibial torsion, or genu valgus) (Figure 8-13).

There are a number of hindfoot and forefoot alignment variations that can contribute to the pronation syndrome. The most common structural variations are subtalar joint neutral alignment of hindfoot and/or forefoot varus. If adequate subtalar joint eversion motion is available, the calcaneus may evert to compensate for the varus alignment in an attempt to get the foot flat on the weight-bearing surface. If the midfoot and forefoot are flexible, they can also compensate for varus alignment faults contributing to a lowering of the medial longitudinal arch, forefoot abduction, and splaying (widening) of the forefoot (Figure 8-14). Valgus hindfoot and forefoot structural faults that persist with standing alignment can also contribute to the pronated standing alignment.

movement impairments can include excessive calcaneal eversion during the early and midstance phases, excessive arch flattening in the midstance phase, and/or insufficient movement of the foot in the direction of supination in the late stance phase (Figure 8-15). Often, there is poor contraction of the gastrocnemius muscle with very little

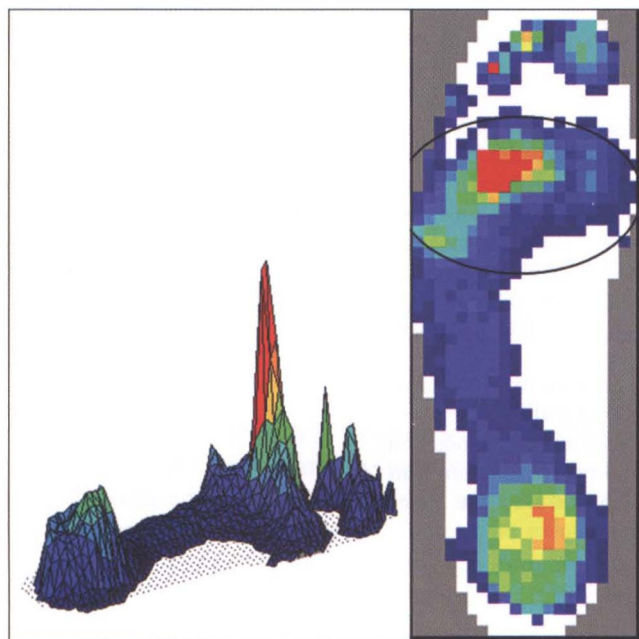


Figure 8-11. High pressure at second and third metatarsal heads in a subject with pronation during walking. Lateral midfoot pressure is related to cuboid subluxation.

Movement Impairments

Walking and Running

During walking and running, the pronation movement impairments can include excessive calcaneal eversion during the early and midstance phases, excessive arch flattening in the midstance phase, and/or insufficient movement of the foot in the direction of supination in the late stance phase (Figure 8-15). Often, there is poor contraction of the gastrocnemius muscle with very little



Figure 8-12. Left foot, classic standing alignment for pronation impairment: Calcaneal eversion, medial bulge, low medial longitudinal arch, forefoot abduction, and increased width of the forefoot.

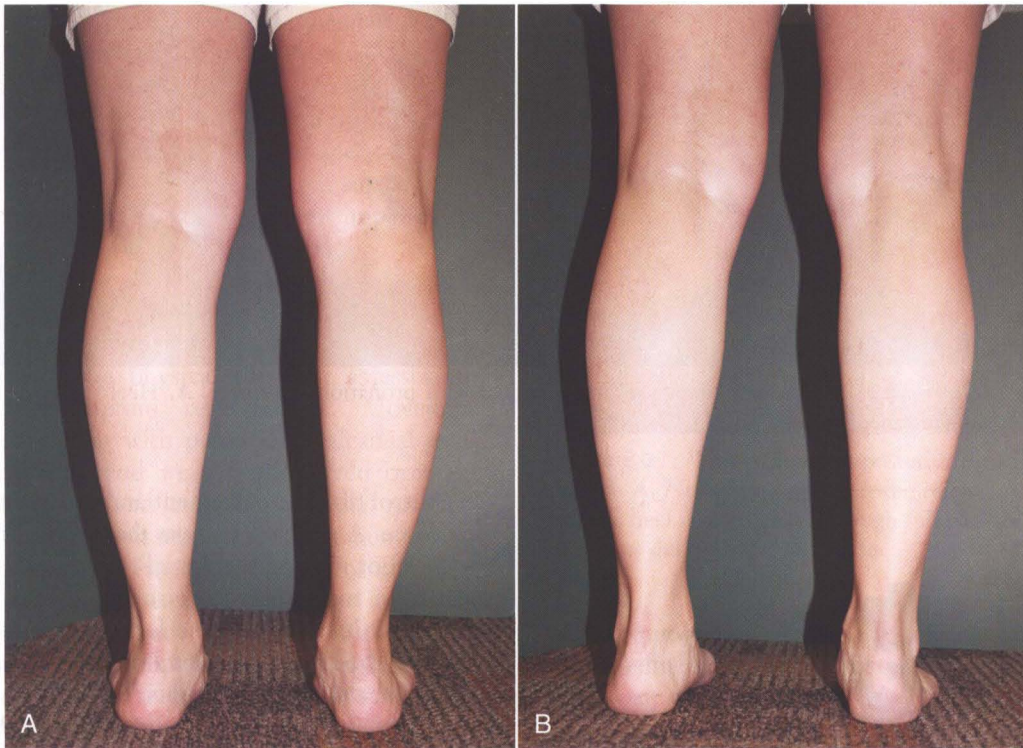


Figure 8-13. **A**, Individual with calcaneal valgus, dropped medial longitudinal arch, medial bulge, and abducted forefoot bilaterally. **B**, Same individual, is able to minimize foot pronation through correcting hip medial rotation and knee hyperextension.

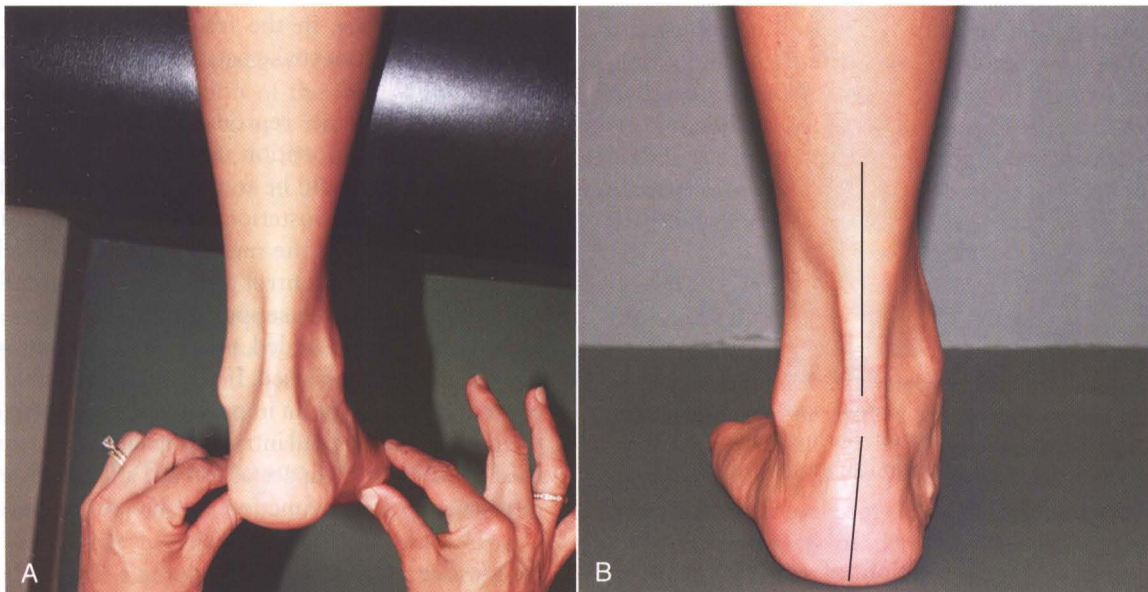


Figure 8-14. **A**, Left foot subtalar joint alignment in prone: Hindfoot in neutral alignment relative to the leg and a forefoot varus relative to the hindfoot. **B**, Left foot standing alignment includes slight calcaneal eversion, bulge in the medial longitudinal arch, and forefoot abduction. Calcaneal eversion indicates the ability of the hindfoot to assist in compensating for the forefoot varus structural variation.

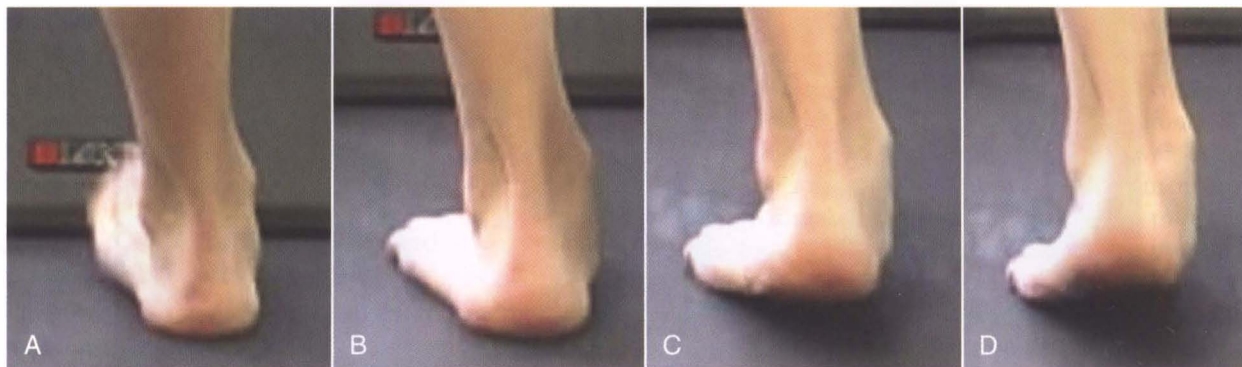


Figure 8-15. Instances in stance in an individual with pronation syndrome. A, Heel strike. B, Midstance. C, Heel off. D, Toe off.



Figure 8-16. High pressure at second and third metatarsal heads in a subject with pronation during walking. Lateral midfoot pressure is related to cuboid subluxation

push-off noted. Medial rotation of the hip with an increase in medial foot loading can also be viewed.

Plantar pressure scans taken during barefoot walking show an increase in force distributed through the medial side of the foot, as well as high pressure through second and third metatarsal heads (Figure 8-16).

During running, the pattern used by most people is to contact the ground first with the heel of the foot. A heel-strike pattern of running recruits the anterior compartment muscles to absorb shock and lower the foot down. The posterior compartment muscles are then recruited

to control tibial advancement and assist with plantarflexion force. A running pattern that results in the midfoot or forefoot making the initial contact can contribute to pronation movement impairments. With a midfoot or forefoot initial contact, the force of body weight travels through the midtarsal joint and encourages dorsiflexion motion at the midtarsal joints. Additionally, the anterior compartment muscles are not recruited and the posterior compartment muscles remain active throughout stance, placing additional stress on the gastrocnemius and posterior tibialis muscles. The patient should be encouraged to run with a relatively frequent heel-strike-first pattern. In most cases, the patient does not need to make a complete shift to a heel-strike running pattern, but often a moderate decrease in the frequency or severity of the midfoot or forefoot strike pattern can result in a decrease in symptoms.

If symptoms are reproduced during walking and running and the pronation impairment is suspected, the secondary tests would be to provide cues to contract the gastrocnemius and posterior tibialis muscles, lifting from the heel and raising the medial longitudinal arch. If the patient is unable to control pronation during walking and running, external arch support (inserts, scaphoid pads, or arch taping) can be added, and movement and symptom reproduction is reassessed. If hip and knee medial rotation control appears to be an important factor, cues to contract the gluteal muscles and intrinsic hip lateral rotators can be used to assess the impact of the hip and knee movement impairment on foot function and symptom production.

Single-Leg Hopping

The patient is asked to repetitively hop on one leg. Individuals with the pronation syndrome demonstrate calcaneal eversion, dropping of the medial longitudinal arch, forefoot abduction, and/or knee and hip medial rotation. Poor contraction of the gastrocnemius is often very apparent during the single-leg hop test. The patient has a decreased jump height and compensates for the lack of plantarflexion strength with an increased swing of the upper extremities and increased reliance on the quadriceps and/or hip extensors to complete the jump. The

contributing movement impairments of medial rotation at the hip and/or knee are also easily assessed during single-leg hop. If symptoms occur during single-leg hop, the secondary tests would be similar to those described for the walking and running test: Encourage gastrocnemius muscle contraction, add external arch support, and correct associated hip and knee movement impairments to assess movement and symptom production.

Step-Down and/or Small Knee Bend

The patient is asked to perform a step-down and/or a small knee bend. The physical therapist assesses the movement and symptom reproduction. Movement impairments consistent with pronation (calcaneal eversion, arch flattening, and weight transferred over the medial side of the foot and knee or hip medial rotation) and symptom reproduction support the movement system diagnosis of pronation. If symptoms are reproduced or the therapist suspects baseline symptoms could be reduced, the patient is cued to correct the movement impairment raising the arch, transferring weight slightly more lateral, and contracting the hip lateral rotators to control femoral medial rotation. A decrease in symptoms with the correction of the movement impairment supports the diagnosis of pronation syndrome.

Joint Integrity and Muscle Length

Talocrural Dorsiflexion

See the previous “Dorsiflexion/Talocrural Joint” section.

Passive First Metatarsophalangeal Dorsiflexion

Adequate dorsiflexion motion of the first MTP joint is required as the tibia advances over the foot and the heel begins to rise from the floor. MTP dorsiflexion is measured in full plantarflexion and in 20 degrees of plantar flexion.

Subtalar Joint Eversion

In the presence of adequate eversion ROM, varus structural variations of the hindfoot and/or forefoot often result in pronation syndrome at the hindfoot (calcaneal eversion) in weight bearing.

Muscle Strength/Performance Impairments

Determining the muscle performance impairments in the foot and ankle can be challenging. The forces experienced by the ankle and foot during walking, running, and hopping are often larger than the forces a physical therapist can generate during manual muscle testing (MMT). Additionally, the muscles of the foot and ankle often have an extremely large eccentric role that is not tested with standard MMT. Functional tests should be incorporated to determine true muscle performance.

Gastrocnemius/Posterior Tibialis Muscles

The gastrocnemius muscle is critical in producing powerful plantarflexion during walking and running. Along

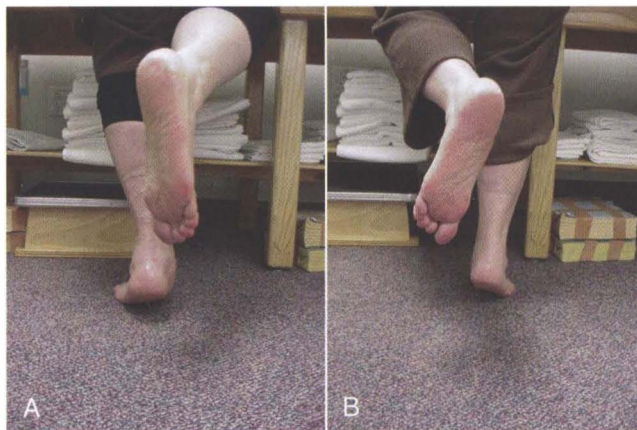


Figure 8-17. This patient has posterior tibialis dysfunction on the left. **A**, Note that on the left the calcaneus remains everted and the heel does not rise through full motion. **B**, Inversion of calcaneus during right heel raise.

with the posterior tibialis, flexor digitorum longus, and flexor hallucis longus, the gastrocnemius muscle contributes to supination of the foot during the late stance phase. To assess function, observe the calcaneus during single-leg heel rise. Together, the ankle plantarflexors should contract and result in calcaneal inversion and elevation of the calcaneus through the full available motion. The ability to complete 25 single-leg heel raises is considered normal.³⁹ Dysfunction of the posterior tibialis tendon and muscle is evident during a single-heel rise since the calcaneus does not invert, the individual is unable to complete a full heel raise, and often dorsiflexion is seen at the midfoot (Figure 8-17). During walking and running, a visible and strong contraction of the gastrocnemius muscle is expected. Weakness or poor recruitment of the plantarflexor muscles contributes to pronation that occurs past midstance.

Posterior Gluteus Medius, Gluteus Maximus, and Intrinsic Hip Lateral Rotation Muscles

Performance impairment of the hip lateral rotators results in excessive hip medial rotation. Hip medial rotation can cause pronation motion at the foot.

Intrinsic Muscles of the Foot

The intrinsic muscles of the foot are important in maintaining the arches of the foot during weight-bearing activities. The strength assessment is often indirect, observing the individual's ability to complete a towel crunch with the toes, lifting the arch, and flexing the MTP joints.

Plantar Callus Findings

Callus formation is an indication of high stress, either friction or force. In the patient with pronation syndrome the location of calluses are generally on the second metatarsal head, third metatarsal head, and/or medial side of the first toe. Callus formation at the second and third

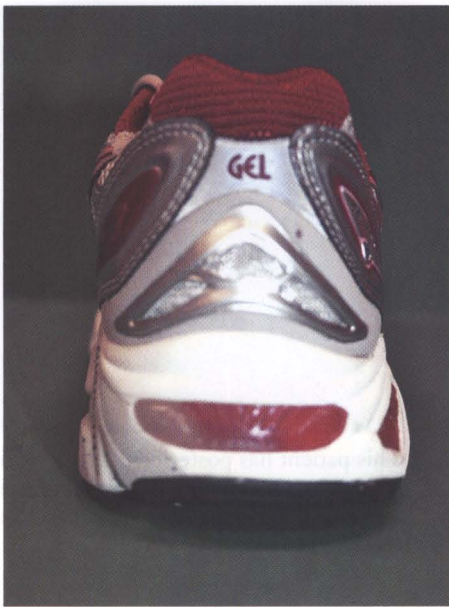


Figure 8-18. Right Asics Gel Foundation 8. Firm density material at the medial heel with less dense material laterally. Gel material is also dual density with firm gel medial and soft gel lateral.

metatarsal heads indicates that the location of force during push-off remains in the center of the foot. The normal pattern of force during the final phase of push-off is through the first and second metatarsal heads. The medial toe callus represents late pronation (pronation at push-off).

Footwear Considerations

Heel Counter

The heel counter is the posterior component of the shoe that wraps around the heel and is attached to the sole of the shoe. The purpose of the heel counter is to cup the heel and control hindfoot motion. The heel counter should fit the heel snugly and should be made of firm material. If the material is flexible or absent (e.g., an open-back sandal) there is no external assistance to control the calcaneal motion of eversion that can contribute to pronation syndrome.

Shoe Sole Components

The density (firmness) of the material used in the sole of the shoe impacts the shoe's "resistance" to a particular motion. Shoes manufactured to control pronation often have a dual or multidensity sole. A material with increased firmness is added to the medial side of the shoe (a less dense or softer material remains lateral), discouraging motion in the direction of pronation (Figure 8-18).

The location of the firm material as it relates to the patient's specific movement impairment is very important. For a patient with a neutral calcaneus but increased pronation at the midfoot, the firm material should be located only at the medial midfoot (Figure 8-19). For this

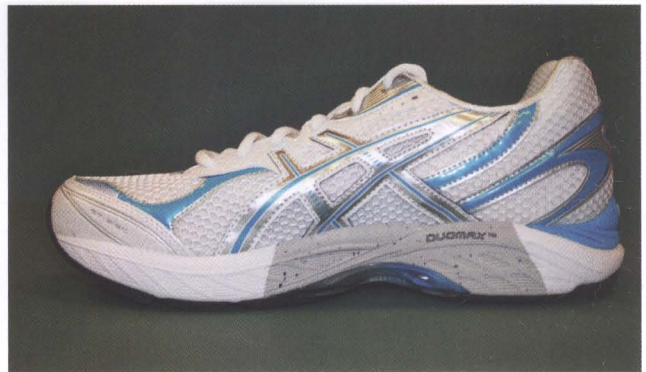


Figure 8-19. Right Asics GT-2150. Note multidensity arch material to increase support for the midfoot.

particular patient, inclusion of firm material at the hindfoot may encourage a new movement impairment of calcaneal inversion and potentially result in new symptoms. If the pronation impairment occurs at the hindfoot and midfoot, the firm material should run from the heel through the midfoot.

The general flexibility of the sole should be assessed. The sole of the shoe should bend easily only at the toe break. Where the shoe breaks is in part determined by the location of the grooves in the sole material. The removal of sole material to form the grooves encourages bending at the specific location. The groove on the shoe should match the patient's MTP joint line from the first to the fifth toes (Figure 8-20). Footwear with little sole rigidity results in bending at the midfoot, which encourages dorsiflexion at the midtarsals and tarsometatarsal joints (Figure 8-21).

Heel-to-Toe Height

Limited dorsiflexion contributes to pronation as discussed previously in this chapter. Limited dorsiflexion can be compensated for by lifting the heel slightly above the toe. This can be accomplished through footwear and is often unnoticed by the individual wearing the shoe (Figure 8-22). The onset of foot symptoms related to a change in footwear may be associated with a change in the heel to forefoot height (the amount of heel lift). Even a small reduction of heel height can increase the stress on the foot and result in injury.

Arch Support

The amount of direct arch support material in the insole of the shoe is generally small and often made of very soft (compressible) materials. The location is also fixed and may fail to support the arch in the appropriate location. External arch pads (scaphoid/navicular pads) can be easily added to most any footwear.

Last Shape

The last of a shoe is the mold used to shape the shoe. The shape of shoes is generally straight, semi-curved, or

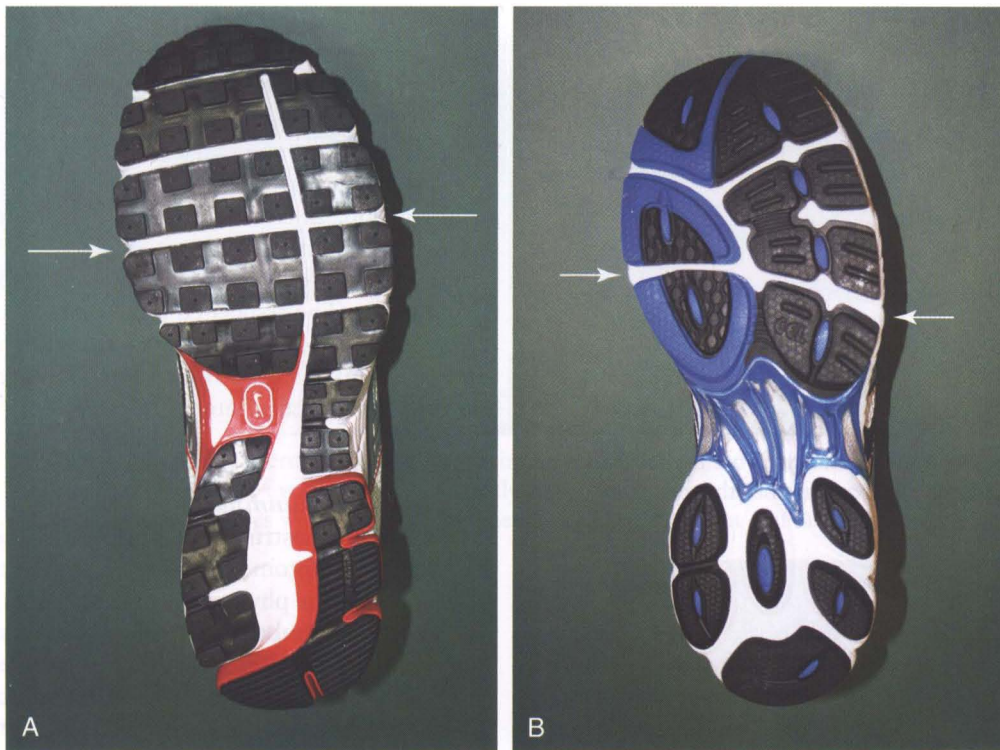


Figure 8-20. A, Left Air Pegasus+ 26. Note the white line of material at the metatarsal break is more distal lateral than medial. B, Left Asics Gel Nimbus 11. The white line of material is more proximal lateral than medial. The pattern of sole material removal at the forefoot should match the outline of the metatarsophalangeal joints where dorsiflexion occurs during walking and running.



Figure 8-21. A shoe that bends easily at the midportion of the sole.



Figure 8-22. Shoe has been cut in half. Note the difference in height of the heel of the shoe compared to the toe of the shoe.



Figure 8-23. Left New Balance 883. Pronation control shoe with a straight last.

curved. To assess last shape, bisect the heel into equal amounts of sole material, medial and lateral. Continue the line that bisects the heel up to the forefoot of the shoe. A straight last will have equal amounts of forefoot sole material on the medial and lateral sides of the line that bisects the heel (Figure 8-23). Curved lasts will have more material on the medial side of the forefoot portion of the shoe compared to the lateral side. Individuals with pronation syndrome often have a straighter foot and would fit best into a straight or semi-curved last. The shape of the shoe should not be used to force a change in foot shape.

Summary

Pronation syndrome is characterized by pronation during weight-bearing activities that is excessive for that individual and/or is occurring past midstance during walking or running. The movement impairment will be observed during weight-bearing activities (walking, running, single-leg hop, small knee bends, and/or stepping down). The movement impairment of pronation occurs in the presence of a foot that is flexible and accommodates for limitations. The associated limitation can be limited dorsiflexion motion at the talocrural joint, weakness of the foot and ankle supinators and/or foot intrinsic muscles, and/or hip lateral rotators.

Treatment

Walking and Running

The patient is instructed to work on the specific cues that assisted in symptom reduction during the examination or the cues that the physical therapist believes, with practice, may result in symptom reduction. The following cues are among the possibilities that may assist the patient:

- Contract the gastrocnemius muscle by lifting from the heel.
- Raise the medial longitudinal arch.
- Contract the gluteal muscles (squeeze the buttock of the stance leg).
- Hit with the heel first.

Many of the changes being requested of the patient during walking and running are similar to a strengthening program. As such, encourage the patient to have focused practice time and gradual implementation to avoid injury.

Muscle Performance

Weakness of the supinators (gastrocnemius and posterior tibialis muscles) can be addressed with a progressive strengthening program, which includes elastic band resistance exercise into plantarflexion and plantarflexion/inversion, heel raises, and single-leg hopping. During the exercise, assess the contraction of the gastrocnemius muscle cueing the patient to raise the heel.

Intrinsic muscles of the foot can be strengthened by completing towel crunches using the toes to grab the towel and pull the towel under the foot. The movement must be accomplished by flexing at the MTP joints, raising the arch, and cupping the foot (Figure 8-24, *A*). The patient should not be allowed to complete the towel crunch with isolated motion of the flexor digitorum longus with flexion occurring only at the proximal and distal interphalangeal joints (Figure 8-24, *B*). Weight can be added to the towel to increase resistance.

Posterior hip muscle strengthening is described in detail in Chapter 7, "Corrective Exercises: Purposes and Special Considerations," in Sahrman.³ An appropriate strengthening progression activity includes sidelying hip lateral rotation progressing to lateral rotation with abduction and adding weight as appropriate.

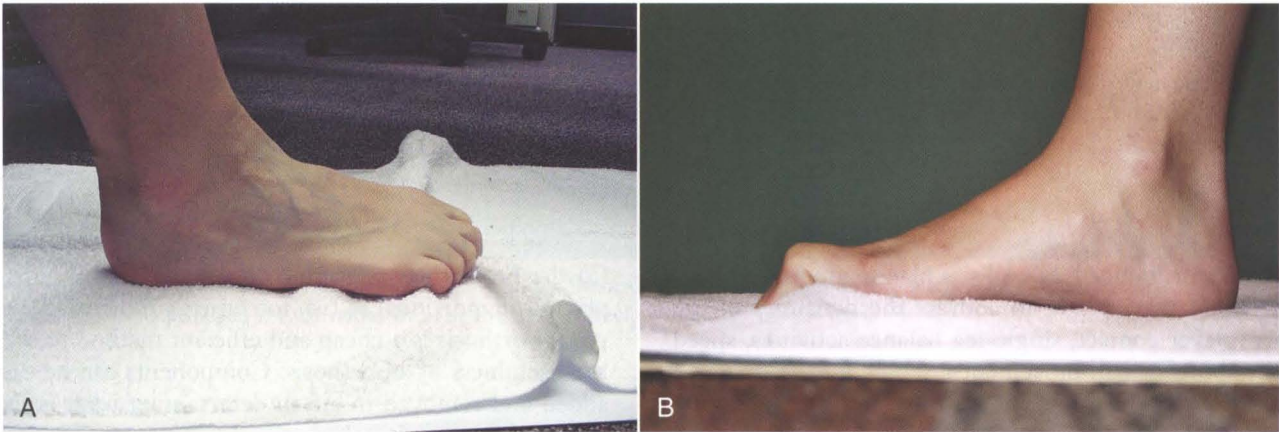


Figure 8-24. A, Towel crunch with toes using intrinsic muscles to flex the metatarsophalangeal joints. B, Toe intrinsic exercise done incorrectly using flexor digitorum longus and flexor hallucis longus to curl toes without flexing the metatarsophalangeal joint and raising the arch.

Muscle strengthening occurs when the muscle is overloaded. The general recommendations are that the exercise should be completed at 70% of the patient's maximum voluntary contraction for 10 repetitions, 3 sets, 3 to 5 times/week. In general, exercise or activity is permissible if pain remains $\leq 2/10$ on a 0 to 10 scale.

Muscle Length and Joint Integrity

Decreased length of the gastrocnemius muscle and tendon can be addressed with a small lunge stretch at the wall, dropping the heel off a ledge, or long sitting dorsiflexion towel stretch; all stretches would be done with the knee extended. The soleus muscle and tendon can be stretched by bending the knee during the wall, heel hang, or towel stretch. Unique instructions for patients with pronation syndrome include preventing pronation during the stretch (this could include active patient correction of pronation and wearing good footwear during the stretch) and keeping the foot facing forward or in line with the femur and tibia. The heel should be kept on the ground during the stretch.

To address talocrural joint limitation, a posterior glide or a distraction technique of the talus on the ankle mortise is recommended in addition to the stretches described. Additionally, a prolonged stretch can be provided by a dorsiflexion splint. The splint is a non-weight-bearing brace and is generally recommended for night wear but could be used during the day if the individual could remain non-weight-bearing during splint use. Splint use in the foot and ankle is often reserved for patients whose symptoms do not respond to the traditional treatment plan to improve dorsiflexion. Splint wearing at night can be uncomfortable, disrupting sleep, which often results in poor patient compliance.

Limited talocrural dorsiflexion can be compensated for by adding a heel lift in the shoe. A heel lift used long term can contribute to loss of talocrural dorsiflexion and should be approached with caution.

Limited extensor digitorum longus muscle and tendon extensibility can be addressed by having the patient plantarflex the involved foot with the toes plantarflexed either in a sitting position or while on hands and knees and rocking back. Limited first MTP dorsiflexion related to decreased extensibility of the flexor hallucis longus can be addressed with a prolonged stretch into dorsiflexion with the ankle in dorsiflexion. To address limitations in first MTP joint dorsiflexion, an anterior glide of the proximal phalanx on the metatarsal can be performed.

Stretching should be held for 30 seconds, 2 to 3 repetitions, completed regularly throughout the day (5 to 8 times/day), and completed 5 to 7 days/week.

Activity Modification

Activity level should be modified to decrease forces on the foot. If the symptoms are severe, the therapist should consider the use of an assistive device or a period of immobilization to decrease tissue irritability.

As the tissue heals, a cautious and gradual increase in activity will assist in returning the patient to the previous level of activity. If appropriate for the patient's goals, activity should progress to dynamic activities such as jumping, hopping, shuttle run, cutting, and so on. A guide for progressing from walking to running begins with a run/walk program. Generally, a 1:4 ratio (1 minute run with a 4 minute walk) is a reasonable place to begin. The physical therapist should closely monitor symptoms. The symptoms guidelines used in clinical practice are that symptoms should remain ≤ 2 out of 10, and symptoms that come on with activity should resolve within a very short time after activity (no longer than 1 hour). As the tissue tolerance to activity improves, the number of run/walk cycles is increased and then duration of running is increased while walking duration is decreased.

The progression to high level agility sport activity includes starting with straight plane jogging and jumping on a smooth flat surface. The most effective strategy is

to work on increasing distance before increasing speed because an increase in speed increases the peak forces through the foot and is more likely to result in tissue injury or reinjury. As the patient's tolerance of weight-bearing activities improves, the terrain should be varied, as well as the addition of hills, cutting, and progressing to unexpected turns. The equipment (balls, cleats, sticks, rackets, and so on) associated with the sport of interest should be introduced, as well as a plan to gradually introduce other players and to address the dynamics of the sport (player contact, single-leg balance activities, speed of the sport, or ball movement).

External Tissue Support

Footwear. The footwear prescription is specific to each individual, but some general guidelines for pronation syndrome can be provided. The last (shape) of the shoe should look like the patient's foot. Most often a straight or semi-curved last is appropriate. A firm heel counter to control hindfoot motion is advisable for most all individuals. If pronation occurs at the hindfoot, the shoe should include more rigid material at the medial heel and less rigid material at the lateral heel. The medial structure of the shoe should be made of firm materials, and the sole should be rigid from hindfoot through

midfoot, bending only at the metatarsal heads. The shoe length, width, and height of the toe box should accommodate the size of the foot and any deformities present.

Orthoses. Orthoses are not recommended for all patients. Indications that orthoses may be appropriate include (1) the inability to correct the movement impairment through cueing, (2) significant structural variations, (3) the problem is recurrent, or (4) the foot alignment places the individual at risk for future problems. A temporary orthosis is a cheap and efficient method to assess the usefulness of an orthosis. Components can be easily added and removed to aid in determining what is most helpful for managing the patient's symptoms. The component most often added is arch support (scaphoid/navicular pad). Medial hindfoot and forefoot posts are additional options that can assist with limiting motion that results in symptoms (Figure 8-25). The goal of the orthosis is not to achieve a subtalar joint neutral position but to prevent excessive or end-range motion so that the symptoms resolve. For local metatarsal pain, a common orthoses component is a metatarsal pad (Figure 8-26). The pad should be located just proximal (0.5 to 1 cm proximal) to the metatarsal head to unload the metatarsal heads and limit MTP hyperextension.⁴⁰

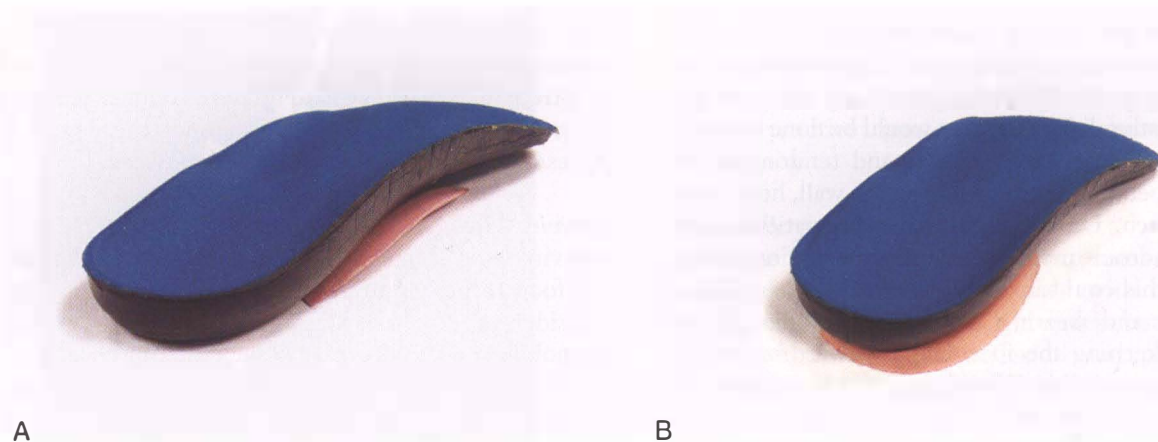


Figure 8-25. An off-the-shelf orthosis with a (A) scaphoid/navicular pad and (B) hindfoot medial post.

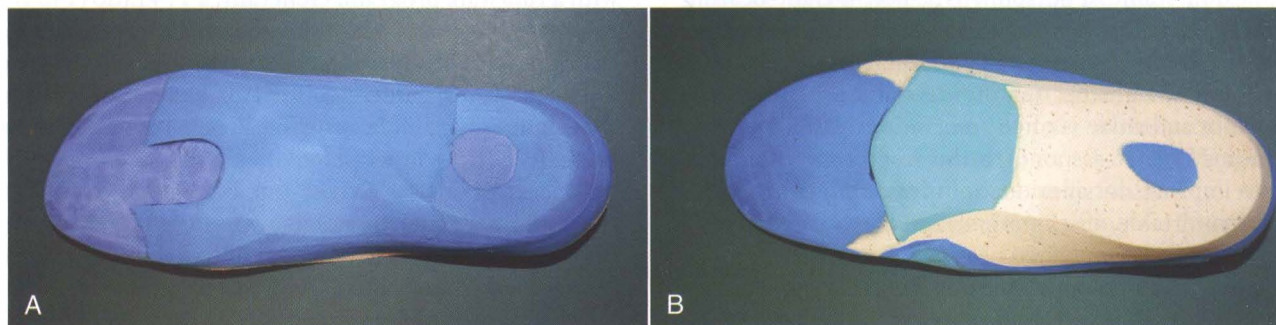


Figure 8-26. A, Total contact insert with local metatarsal relief. B, Global (all) metatarsal head relief.

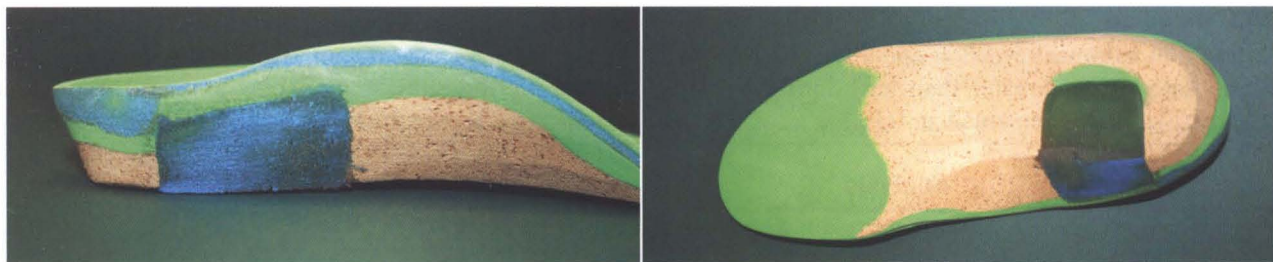


Figure 8-27. Example of a total contact orthosis with professional quality visco elastic polymer (Riecken's, Evansville, Ind.) at the medial heel.

An important orthoses modification for patients with tarsal tunnel nerve (tibial nerve) involvement is to avoid firm materials in the medial heel of the orthosis or sole of the shoe. Firm materials may contribute to nerve compression and irritation (Figure 8-27).

Taping. Taping to support the arch can assist in symptom management while additional treatment options are being implemented. There are a variety of techniques, but most have a common component of restraining longitudinal motion between the calcaneus and the metatarsal heads (Figure 8-28).

CASE PRESENTATION

Pronation Syndrome

Symptoms and History

An internist referred a 42-year-old female for evaluation and treatment of right “heel pain.” Her heel pain began approximately 10 weeks ago when she returned to work full time as a floor salesperson at a local shopping center. The patient has had to decrease her working hours from 40 to 20 because she was unable to tolerate the heel pain. The patient’s pain is located on the plantar surface of the heel. She states the pain occurs only during weight bearing and is much worse in the morning when she first gets out of bed (7/10) than later in the afternoon (4/10). She states her pain is worse when walking barefoot or in her work shoes, which are dress flats. She reports increasing pain with walking more than 15 minutes and has difficulty completing daily activities like grocery shopping and playing games with her children. She is 5 foot 6 inches and weighs 190 lb. Her Foot and Ankle Ability Measure score is 49% (100% indicates normal function).

Alignment Analysis

In standing, the foot alignment shows a vertical calcaneus and a normal-to-low arch bilaterally. The alignment of the hip and knee includes medial rotation of the femur and slight lateral rotation of the tibia bilaterally. Symptoms in standing were 3/10. In prone the assessment of subtalar joint neutral reveals a small hindfoot varus and neutral forefoot alignment.

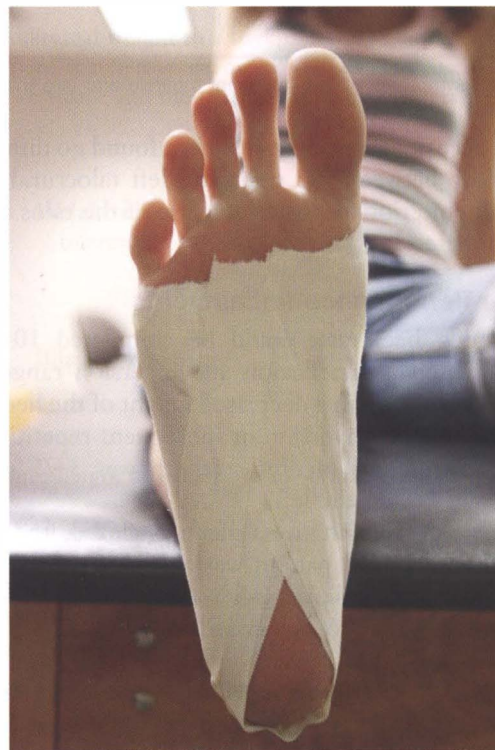


Figure 8-28. Arch taping to provide external arch support during weight-bearing activities.

Movement Analysis

Walking/running

During walking, the calcaneus hits in inversion, moves into eversion by midstance, and remains in the everted position through late stance (right foot greater than left). Symptoms during barefoot walking increased to 5/10. Secondary tests, including cues to raise her heel earlier in stance and to contract her gastrocnemius, decreased the amount of eversion during midstance to late stance and decrease her symptoms minimally (4/10).

Single-leg hopping

The patient demonstrated decreased use of plantarflexors during single-leg hopping. Symptoms were generally less (3/10) when remaining on her toes and avoiding weight bearing through the heel.

Small knee bend

An increase in calcaneal eversion and a lowering of the arch was noted (right greater than left) during a small knee bend. Symptoms remained at 3/10.

Muscle Length/Joint ROM Analysis

	Right	Left
Talocrural dorsiflexion (knee extended)	0 degrees	5 degrees
Talocrural dorsiflexion (knee flexed)	5 degrees	10 degrees
Calcaneal eversion	5 degrees	5 degrees
First MTP joint extension (30 degrees talocrural plantarflexion)	60 degrees*	60 degrees

*Increased symptoms at the calcaneal tubercle and into the arch.

Joint accessory motion assessment found no difference in mobility between the right and left talocrural joints during an anterior-to-posterior glide of the talus on the ankle mortise.

Muscle Performance Impairments

- Single-leg heel raise could be completed 10 times through full plantarflexion and inversion range with fatigue, resulting in a decreased height of the heel raise and incomplete inversion in subsequent repetitions.
- Sidelying gluteus medius strength was 3+/5 on the right and 4/5 on the left.

Towel crunch with toes: the toes flexed, the MTP joints extended. The patient was able to correct performance to lift arch and plantarflex the MTP joints, but the foot cramped after five toe crunches.

Footwear

Patient wore her work shoes, which were dress flats. The heel counter was flexible, and the sole was made of a flexible plastic.

Palpation

Symptoms were reproduced with palpation of the calcaneal tubercle on the right foot. Pain continued with palpation of the plantar aponeurosis into the arch of the foot.

Diagnosis

Pronation occurred past midstance with no motion in the direction of supination during late stance. The primary contributing factors to pronation syndrome were decreased talocrural dorsiflexion ROM from decreased length of the gastrocnemius and soleus muscles and weakness of the gluteus medius/hip lateral rotators and foot plantarflexors/supinators. There was also a slight structural variation (hindfoot varus in the presence of sufficient calcaneal eversion motion) that could contribute to pronation. Additionally, the footwear provided insufficient support and cushion for a job that requires prolonged standing. The stage for rehabilitation is 2. The pain rating was moderate to high, she was mobile but

limited in her ability to complete activities that require longer weight bearing, and her Foot and Ankle Ability Measure indicates a moderate amount of disability. Source of the symptoms was the plantar aponeurosis. The patient was seen 1 time/week for 8 weeks to assess and modify the treatment plan.

Treatment and Outcomes

Table 8-4 includes pronation syndrome interventions and outcomes.

Activity education

- First-step pain
 - Gentle dorsiflexion stretch before stepping onto the foot after a prolonged period of non-weight-bearing activity (e.g., sleeping).
 - Step directly into her most supportive shoes as she gets out of bed and for as long in the morning as she is able to avoid the trauma associated with first-step pain and morning symptoms.
- Femoral medial rotation and pronation
 - Patient instructed to squeeze the buttock, keep the knee over the toe (not medial), and lift the arch during weight-bearing activities.
 - Gluteus medius strengthening.

Arch taping resulted in an immediate decrease in symptoms with weight bearing to a 2/10. First step morning pain decreased to a 4/10 within the first week after implementation of the suggested changes to her morning routine. The temporary addition of a heel lift and scaphoid pad to the shoe was needed to assist with initial symptom relief. The patient continued the home exercise program to strengthen the hip, ankle, and foot, increase talocrural dorsiflexion motion, and modify the medial femoral rotation and foot and ankle pronation for approximately 8 weeks before symptoms consistently remained at 0/10 with a full 40-hour week of work.

SUPINATION SYNDROME

The principal movement impairment associated with supination syndrome is supination of the foot and ankle that occurs at the wrong time (heel strike to midstance in the gait cycle) or that occurs in an amount that is excessive for that individual. The supination impairment can occur in the hindfoot, midfoot, and/or forefoot. The foot with the supination impairment is generally a rigid foot with little or no ability to absorb shock and compensate for structural or movement impairments within the foot and ankle, knee, or hip.

Symptoms and Pain

Plantar Aponeurosis (Fascia)

Involvement of the plantar aponeurosis is most often accompanied by patient complaints of heel pain that is worse with the first step out of bed in the morning and after a period of prolonged non-weight-bearing function.

TABLE 8-4
Pronation Syndrome: Interventions and Outcomes

Limitation/Initial Prescription	Progression Week 1	Progression Week 3	Progression Week 6
TALOCRURAL DORSIFLEXION			
Wall stretch Heel hang Towel stretch	Progression of stretches to improve talocrural dorsiflexion may include changing from non-weight bearing to weight bearing exercises. All stretches should be held for a minimum of 30 seconds and repeated 3 to 5 repetitions and done frequently throughout the day (at least 5 times per day).		
Instruction: Prevent foot pronation, hip medial rotation, and keep foot aligned with the fibia.			
PLANTARFLEXOR MUSCLE PERFORMANCE			
Elastic band plantar flexion/ inversion	Heel raises (Bilateral progressing to unilateral)	Bilateral hopping	Single-leg hopping
Eccentric strengthening: Bilateral heel rise, lowering on one foot	Eccentric strengthening: Add additional weight to a backpack, waist, or leg and increase repetitions as the patient is able tolerate the exercise. Pain is used as an indicator that the stress is excessive and the prescription is too aggressive.		
Instruction: Squeeze the calf and relax the toes.			
INTRINSIC FOOT MUSCLE PERFORMANCE			
Towel crunches with toes	—	Weight added to towel as tolerated	—
Instruction: The arch and MTP joints should lift during towel crunches.			
GLUTEUS MEDIUS MUSCLE PERFORMANCE			
Sidelying level 2	Sidelying Level 3	Bilateral hopping	Single-leg hopping
Instruction: Avoid hip medial rotation and flexion during abduction.			
EXTERNAL SUPPORT			
Arch taping	Heel lift and scaphoid pad. Reduce height of heel lift as talocrural dorsiflexion increases.		
Footwear	Firm heel counter, firm medial heel and midfoot components, increased heel-to-toe height ratio.		

MTP, Metatarsophalangeal.

Fibular (Peroneal) Muscles and Tendon

The patient complains of pain localized to the muscles (posterior to the fibula) or anywhere along the tendon as it follows its course around the lateral malleolus to the insertion at the base of the fifth metatarsal for the fibularis brevis or following the fibularis longus as it runs along the lateral border of the cuboid and to the plantar surface of the foot. The symptoms are most apparent during the weight-bearing phase of activities as the muscle works to eccentrically control supination and dorsiflexion and during push-off as the muscle acts concentrically to assist with plantarflexion.

Gastrocnemius/Soleus Muscles and Calcaneal (Achilles) Tendon

The patient complains of pain in the muscle belly or tendon, particularly during late stance, as the muscle is working eccentrically and the tendon is being placed on stretch to control the tibia's progression over the foot and during the concentric contraction required during push-off.

Metatarsal Heads

The patient complains of metatarsal pain localized to the head of the first and fifth metatarsals that becomes worse during late stance and the push-off phase of walking and running.

Lateral Column Joints

The patient complains of generalized pain along the joints of the lateral column of the foot (talus, calcaneus, cuboid, and fourth and fifth metatarsals).

Alignment: Structural Variations and Acquired Impairments

The description of a supinated foot type includes a combination of calcaneal inversion, lateral bulge (prominence of the talonavicular joint dorsal and lateral), high medial longitudinal arch, forefoot adduction relative to the hindfoot at the transtarsal joint, and narrow forefoot width (Figure 8-29). Lower extremity alignment impairments that contribute to a supination impairment at the foot include lateral rotation at the hip and/or knee or



Figure 8-29. Supinated foot with high medial longitudinal arch.



Figure 8-30. Calcaneus stays vertical and arch is high from heel strike through push-off.

structural variations of the femur or tibia that seem to be associated with a supinated foot (e.g., femoral retroversion, lateral tibial torsion).

The most common subtalar joint neutral alignment finding in individuals with supination syndrome includes a hindfoot and/or forefoot varus in which the joint mobility is limited and there is no ability to compensate with subtalar or midtarsal joint motion. Valgus hindfoot and forefoot structural variations that are compensated by inversion in standing can also contribute to the supinated standing alignment. In the prone position, an individual with supination syndrome may also have a first metatarsal head that is plantarflexed below the plane of the second to fifth metatarsal heads; this is called a *plantarflexed* or *dropped first ray* and is a common compensation for a forefoot varus (see Figure 8-4).

Movement Impairments

Walking and Running

During walking and running, the supination movement impairment usually includes calcaneal inversion at heel

strike that remains through push-off. There is generally an absence of pronation during the initial portion of stance. The center of gravity during stance remains lateral on the weight-bearing surface of the foot (Figure 8-30). There is often a very late whip to the medial side of the foot during push-off. The foot is rigid, and there is very little shock absorption during walking and running, which can contribute to symptoms at the knee, hip, and back. The rigid foot can also produce varus motion at the knee that can contribute to knee symptoms.

The barefoot plantar pressure assessment in Figure 8-31 is common in individuals with the supination movement impairment. There is no loading of the midfoot, which reduces the surface area for force distribution (increases localized pressure). The metatarsal head pressure is high, particularly under the first metatarsal. In this individual, there is also very high medial great toe pressure, evidence of the late transfer of weight medially over the first toe.

If symptoms are reproduced during walking and running and the movement impairments previously

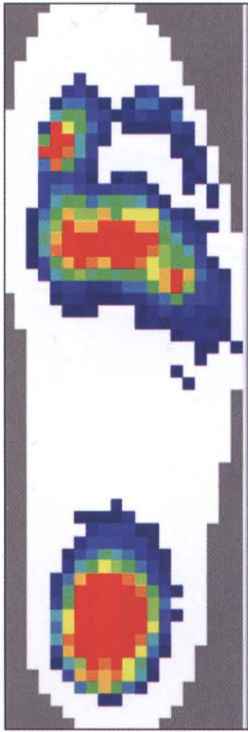


Figure 8-31. Barefoot pressure scan during walking of supinated individual. Note the lack of midfoot loading and the high forefoot pressure under the first metatarsal.

described are noted, the supination impairment is suspected. The secondary tests for supination impairment can be challenging to implement as the foot and the movement pattern are often fixed and unable to be volitionally corrected. Attempts can be made to control the offending motion (calcaneal inversion, late medial motion) with verbal cues to avoid extreme lateral loading through the foot, to soften the landing with knee flexion, and to roll medially sooner. Unfortunately, the rigidity of the foot often prevents the individual from changing the movement pattern. Attempts can be made to post the heel laterally to encourage eversion motion. Additionally, an arch support can be added to footwear to assess the effect of increasing the contact area over which the load is borne.

Single-Leg Hopping

The patient is asked to hop repetitively on one foot. The rigid foot associated with supination syndrome is an excellent lever for the plantarflexors, transferring the plantarflexor force easily and propelling the body up. Often, the patient with supination syndrome is able to jump fairly high and with what seems like little effort. The supination movement impairment at the foot is generally not apparent during the single-leg hop, since only the forefoot is striking the ground. Observation of the single-leg hop provides valuable information about plantarflexor muscle performance, as well as contributing movement impairments at the knee and hip. If symptoms occur during

single-leg hop, the secondary test would be cues to address hip and knee movement impairments (lateral rotation or varus motions) and soften the landing with knee flexion. Weakness of the gastrocnemius/soleus complex should also be assessed further through single-leg heel rises. The addition of arch support may not affect the symptoms during the test because the heel and midfoot do not touch the ground during single-leg hopping.

Step-Down and/or Small Knee Bend

During a step-down or small knee bend, the most common impairment noted is limited dorsiflexion. The compensation is often an early heel rise and the rigidity of the foot becomes apparent (no decrease in arch height during the motion). The lateral distribution of force through the foot can also be seen during the small knee bend. Symptom reproduction during low impact activities like step-downs or small knee bends is rare. However, if symptoms are reproduced or the therapist suspects baseline symptoms could be reduced, the patient is cued to correct the movement impairment keeping weight more central (away from the lateral aspect of the foot). A decrease in symptoms with the correction of the movement impairment supports the diagnosis of supination syndrome. Additionally, the physical therapist can assess the role of insufficient dorsiflexion in symptom reproduction by limiting dorsiflexion motion to avoid end-range or adding a small heel lift. If correction of the insufficient dorsiflexion results in symptom reduction, the therapist needs to consider insufficient dorsiflexion syndrome as a possible movement impairment diagnosis (see the following “Insufficient Dorsiflexion Syndrome” section).

Muscle Length/Joint Range of Motion Impairments

Talocrural Dorsiflexion and Passive First Metatarsophalangeal Dorsiflexion

Limitation in motion at the talocrural joint and the first MTP joint are also associated with the supination movement impairment. Decreased talocrural dorsiflexion during late stance results in either an early heel rise or transfer of weight lateral for the tibia to advance over the foot. Limited first MTP motion results in a transfer of force medial at late stance (push-off) or keeps the force lateral. The tests to determine source of limitation are described in the “Metatarsophalangeal Joints” section.

Subtalar Joint Eversion

Subtalar joint eversion is often limited (<0 degrees) in patients with supination syndrome.

Footwear Considerations

Heel Counter

In patients with supination syndrome the heel counter should have qualities similar to those recommended for pronation syndrome in that the counter should be made of firm material and hold the heel snugly. In the case of

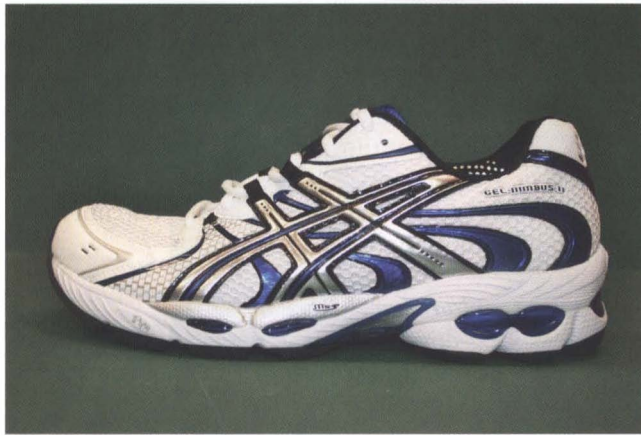


Figure 8-32. Asics GEL-Nimbus 11. Manufactured primarily for cushion and flexibility with the inclusion of gel and sole materials that attenuate shock.

supination syndrome the heel counter will help to control inversion of the calcaneus.

Shoe Sole Components

The supinated foot has a decreased ability to absorb shock during early stance and may require additional attention to cushioning. Sole components, such as air and soft materials, are marketed to attenuate shock (Figure 8-32). Footwear manufacturers rarely add firm material components to the lateral side of the shoe to encourage pronation. However, the individual with supination syndrome should not wear a shoe designed for pronation syndrome because the shoe would have firm materials medially and would encourage the supination movement impairment.

As with pronation syndrome, the sole of the shoe should bend easily only at the MTP joint line. The groove on the forefoot of the shoe should match the patient's MTP joint line from the first to the fifth toes.

Heel-to-Toe Height

Limited dorsiflexion is also associated with supination syndrome and can be compensated for by lifting the heel slightly above the toe. A reduction in the heel-to-toe height ratio can contribute to symptom onset similar to that described with pronation syndrome.

Arch Support

The lack of contact area of the supinated foot during walking contributes to high pressure. Footwear should be assessed for the ability of the insoles to provide contact, support, and force distribution through the entire foot.

Last Shape

The most common shape of a supinated foot is forefoot adduction relative to the hindfoot. A curved last generally matches the shape of the supinated foot best (Figure 8-33). The shape of the shoe should not be used to force



Figure 8-33. Left Nike Air Pegasus +26. Curved last with additional material on the medial forefoot compared to the lateral forefoot.

a change in the shape of the foot or to attempt to alter motion of the foot.

Plantar Callus Findings

In the patient with supination syndrome, the location of calluses are generally on the first metatarsal head, fifth metatarsals, and/or medial side of the first toe. Callus formation at the first and fifth metatarsal heads indicates the late lateral loading under the fifth and often a rigid first ray that bears a large load. The medial toe callus is a result of the late pronation that occurs during push-off as a result of the prolonged lateral loading in the supinated foot.

Summary

Supination syndrome is characterized by a rigid, high-arched foot that has little ability to compensate for structural and movement impairments within the foot and ankle or up the leg to the hip. The high arch, calcaneal inversion, and forefoot adduction will be apparent with weight-bearing activities. There is generally poor shock absorption and little loading through the midfoot.

Treatment

Walking and Running

The patient is instructed to work on the tasks that use specific cues that assisted in symptom reduction during the examination or the cues that the physical therapist believes with practice may result in symptom reduction. Often, the cues are related to softening the landing,

hitting more centrally on the heel, and concentrating on trying to limit lateral loading through the foot.

Range of Motion

The treatment plan for limited motion is similar to that described for pronation syndrome.

Activity Modification

The general guidelines for activity restriction and progression described in the “Pronation Syndrome” section apply here as well. For supination syndrome, specific suggestions include use of softer surfaces when shock absorption is a concern.

External Tissue Support

Footwear. Footwear for the patient with supination syndrome should include a last that looks like the patient’s foot, most often a semi-curved or curved last. As with pronation syndrome, a firm heel counter to control hindfoot motion and a sole that resists bending from hindfoot to midfoot, bending only at the metatarsal heads, is advisable for most all individuals. Cushioning is important and should be included within the shoe. The cushioning component of the footwear may wear down quickly, and footwear may need to be replaced more frequently. Finally, for all individuals, shoe length and width and height of the toe box should accommodate the size of the foot and any deformities.

Orthoses. As with pronation syndrome, orthoses are not recommended for all patients and the indications for permanent orthoses include significant structural variations, a recurrent problem, or if the foot alignment places the individual at risk for future problems. The temporary orthosis components that may be appropriate for a patient with supination syndrome include arch support to

distribute force more evenly but avoid increasing lateral forces and inversion ankle instability.

Taping. Taping to support the arch can be helpful in supination syndrome as well. The indications for taping are that providing support for the arch and assisting with force distribution (arch supports were helpful) decreased symptoms during the examination. Calcaneal (Achilles) tendon irritation can be assisted with a taping technique that provides support to the tissue (Figure 8-34).

CASE PRESENTATION

Supination Syndrome

Symptoms and History

A 35-year-old male, who stands 6 foot tall and weighs 175 lbs, was referred by an internist for evaluation and treatment of right foot pain. His foot pain began approximately 1 month ago during a 10-mile run in new shoes. He reports running approximately 30 miles/week, including 1 long run (10 to 15 miles) on the weekend.

The patient’s pain is located on the plantar surface of the fifth metatarsal head. The patient reports limitation caused by pain during walking (5/10), running (7/10), as well as a very sharp pain (8/10) when he turns on a planted right foot. The pain is reproduced when he manually extends his fifth toe and is generally tender to the touch on the plantar surface. When he is standing, symptoms are minimal (2/10) and absent when sitting. His Foot and Ankle Ability Measure score was 54% (100% indicates normal function) and the Foot and Ankle Ability Measure Sport Scale was 32% (100% indicates normal function).

Alignment Analysis

In standing, the calcaneus is inverted and the arch is high bilaterally. The forefoot is slightly adducted on the hindfoot. There is an increase in lateral tibial torsion. In prone, the assessment of subtalar joint neutral finds hindfoot and forefoot varus alignment.

Movement Analysis

Standing/walking/running

During walking and running, the calcaneus hits in inversion and remains in an inverted position through late stance. Push-off occurs through the lateral side of the foot, symptoms are 5/10. Symptoms increased to 7/10 during running, and cues to roll through the middle of the foot (not as lateral) during walking and running decreased symptoms to 4/10.

Single-leg hopping

Lateral loading of the forefoot noted with single-leg hopping and patient reports increased pain (7/10). A cue to load the foot more centrally decreased symptoms to 4/10.

Small knee bend

During the small knee bend, the patient demonstrated limited talocrural dorsiflexion ROM and weight remained



Figure 8-34. Calcaneal (Achilles) taping to reduce tensile forces at the calcaneal tendon.

on the lateral aspect of the foot. No symptoms were reproduced.

Muscle Length/Joint ROM Impairments

	Right	Left
Talocrural dorsiflexion (knee extended)	-5 degrees	0 degrees
Talocrural dorsiflexion (knee flexed)	0 degrees	10 degrees
First MTP joint extension (30 degrees talocrural plantarflexion)	25 degrees	25 degrees

Joint accessory motion assessment found limited mobility bilaterally during an anterior-to-posterior glide of the talus on the ankle mortise.

Footwear

Patient is wearing his old running shoes and brought his new running shoes with him. The new running shoes have a curved last, the metatarsal break is distal to the first metatarsal head and proximal to the fifth metatarsal head, and the sole is flexible, bending easily from the middle of the shoe to the toe.

Diagnosis

The patient's movement tests support a movement system syndrome of supination. The patient's foot is supinated throughout stance with lateral loading of the foot throughout. The likely source of symptoms is the fifth metatarsal head. The stage for rehabilitation is 2. Although the patient's symptoms are high during weight bearing, symptoms were easily reduced with modification to the walking pattern. The patient is completing daily activities, and the Foot and Ankle Ability Measure indicates moderate disability. The primary contributing factor to the movement impairment is a rigid foot that has little capacity for changing ROM. There is a varus structural variation of the hindfoot and forefoot in the presence of limited calcaneal eversion motion that contributes to supination. Additionally, the new footwear provided little support and encouraged additional lateral loading and hyperextension at the fifth metatarsal joint because the metatarsal head break in his new shoe is proximal to his joint line.

Prognosis

Prognosis is excellent for resolving symptoms with compensations that include modifying footwear with a temporary insert. The patient is relatively young with a short time since onset of symptoms. The severity of symptoms is fairly high but primarily occur with high impact activity. Clinical experience has found very little success in changing talocrural dorsiflexion and first MTP motion in individuals with very rigid and supinated feet.

Treatment

The primary goal of treatment is to decrease the load borne by the fifth metatarsal head. The patient works to avoid exaggerating the pattern of lateral loading that

his foot structure encourages. Cues to heel strike in less inversion and to roll more centrally through his foot do decrease his symptoms and should be implemented as part of the treatment plan. Additionally, a temporary orthosis can be fabricated that will include a metatarsal pad under the fifth metatarsal head to provide unloading of the bone during healing. A lateral post to encourage pronation can be added as well; however, the rigidity of the foot often prevents the lateral post from changing motion and symptoms. A stretching program to address the talocrural and first MTP motion will be implemented. The recommended footwear components for his running shoe include a last that is less curved (semi-curved), a firm heel counter, sole materials and design that allows the primary break in the shoe to occur at the location that matches his metatarsal joints, and an increased heel-to-toe ratio to compensate for limited dorsiflexion.

Outcome

The patient was seen 1 time/week for 8 weeks. The addition of the temporary orthosis with arch support and a metatarsal pad, change in footwear, stretching program, and cues for changing weight-bearing patterns reduced maximum symptoms to a 2/10 within 2 visits. Complete resolution of symptoms at the fifth metatarsal head required a 3 week rest from running. The patient continued with low-impact aerobic training (bicycling and swimming). As the symptoms improved to 0/10 with walking, running was gradually increased with a walk/run program in which the patient started with running 1 minute and walking 4 minutes for 5 bouts (total weight-bearing time was 20 minutes). Gradually, the amount of time spent running was increased, the amount of time walking was decreased, and the number of bouts were increased until the patient had returned to running 10 miles pain-free.

INSUFFICIENT DORSIFLEXION SYNDROME

The principal movement impairment associated with insufficient dorsiflexion syndrome is insufficient talocrural dorsiflexion. The impairment occurs during mid-stance to push-off or during swing phase and is not associated with excessive supination or pronation. Limited talocrural dorsiflexion is a common impairment that could be present in all other foot and ankle syndromes. A patient is given the diagnosis of insufficient dorsiflexion only after all other diagnoses have been ruled out (pronation syndrome, supination syndrome, and hypomobility syndrome).

Symptoms and Pain

Plantar Aponeurosis (Fascia)

Involvement of the plantar aponeurosis is most often accompanied by patient complaints of heel pain that are worse with the first step out of bed in the morning and after a period of prolonged non-weight-bearing activities.

Gastrocnemius/Soleus Muscle and Calcaneal (Achilles) Tendon

The patient complains of pain in the muscle belly or tendon, particularly during late stance, as the muscle is working eccentrically and the tendon is being placed on stretch to control the tibia's progression over the foot and during the concentric contraction required during push-off.

Bursa

Pain is reported at posterior calcaneus, most apparent with direct pressure. The pain provoking pressure can occur during midstance through push off, when squatting or when sitting in a position that applies direct pressure to the bursa.

Anterior Tibialis Muscle and Tendon

The patient complains of pain localized to the muscle at the anterior and lateral proximal fibula or anywhere along the tendon as it follows its course to insert on the medial cuneiform and base of the first metatarsal bone. The symptoms are most apparent from heel strike to foot flat as the anterior tibialis is working eccentrically to lower the foot to the ground or during swing phase as the anterior tibialis is working concentrically to clear the foot.

Deep Fibular Nerve

The patient reports achiness, tingling, and/or numbness on the dorsum of foot and can radiate into toes. Symptoms are most common when shoes are on (tied tightly on the dorsum of the foot) and/or during activities requiring maximum dorsiflexion (running up hills, squatting).

Talocrural Joint

The patient reports sharp pinching pain at the anterior joint line during end range dorsiflexion activities such as squatting and running up hills. The anterior talocrural joint is often point tender.

Metatarsal Heads

Metatarsal pain localized to the metatarsal head and worse during late stance and the push-off phase of walking and running.

Alignment: Structural Variations and Acquired Impairments

Patients with insufficient dorsiflexion syndrome often stand with knee hyperextension and the ankles in relative plantarflexion. There are no specific clinical tests that can be performed to evaluate the contribution of structural variations to limited talocrural dorsiflexion motion.

Movement Impairments

Walking and Running

During walking and running those with isolated insufficient talocrural dorsiflexion demonstrate a number of gait impairments during stance. The inability of the tibia to easily advance over the foot during late stance can be

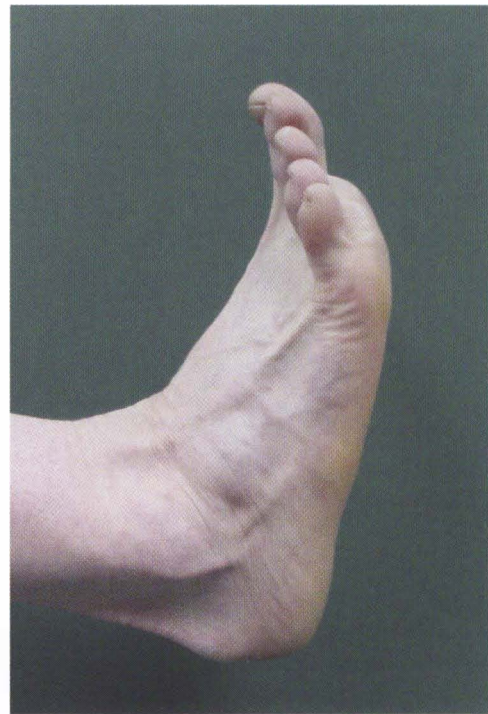


Figure 8-35. Individual with limited dorsiflexion using toe extension to compensate.

compensated for in a number of ways: (1) early heel rise, (2) knee hyperextension, and/or (3) increase in the foot progression angle (toe is pointed out). Limited talocrural dorsiflexion during swing phase is also visible, often with overuse of the extensor digitorum and poor stabilization of the metatarsal heads with the intrinsic muscles of the foot (Figure 8-35).

Individuals with insufficient talocrural dorsiflexion often rely on the passive tension of the gastrocnemius and soleus muscles and calcaneal tendon to control the advancement of the tibia over the foot during stance. There is often poor eccentric use of the gastrocnemius muscle in tibial control.

If symptoms are reproduced during stance phase of walking and running, a secondary test is adding a heel lift and assessing symptom reproduction. Cues to contract the gastrocnemius, lifting the heel actively, can be helpful in addressing the use of passive tension. The secondary test for symptoms produced during swing includes cues to relax the toes, avoiding toe hyperextension to see if symptoms are reduced.

Squat

The contribution of limited dorsiflexion to the patient's pain is often overlooked because active ROM (AROM) in non-weight-bearing activities often appears equal between sides. However, if the patient squats, the therapist will notice that on the involved side, the heel is higher or the tibia is more posterior and this end-range position with loading often reproduces the patient's complaints (Figure 8-36).



Figure 8-36. Squat test in an individual with limited talocrural dorsiflexion. Note the right heel is higher (less dorsiflexion) than the left.

The secondary test for symptoms produced during end-range squatting is to provide a posterior glide of the talus during squatting.

Step-Down and/or Small Knee Bend

During a step-down or small knee bend, an early heel rise is noted. A secondary test is to add a posterior glide at the talus during the small knee bend or step-down (Figure 8-37).

Muscle Length/Joint Range-of-Motion Impairments

Talocrural Dorsiflexion

The tests to determine the source of limitation are described in the “Pronation Syndrome” section.

Footwear Considerations

Recent Decrease in Heel-to-Toe Height

Limited talocrural dorsiflexion can be compensated for by lifting the heel slightly above the toe. A reduction in the heel-to-toe height ratio of the shoe can contribute to symptom onset similar to that described with pronation

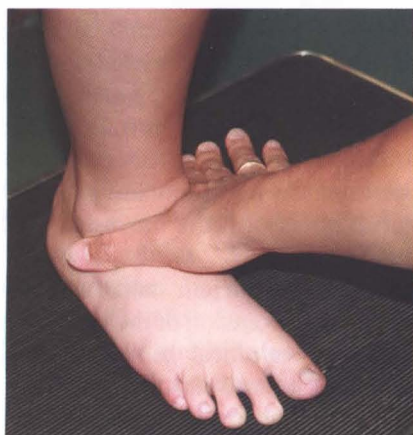


Figure 8-37. Application of a posterior/inferior glide on the talus during a step-down.



Figure 8-38. Use of tape from talus to calcaneus to stabilize the talus during tibial advancement when talocrural joint limitation is present.

syndrome. Frequent use of shoes with high heels can contribute to insufficient dorsiflexion syndrome.

Summary

Insufficient dorsiflexion syndrome is characterized by limited talocrural dorsiflexion with the absence of other movement impairments of pronation, supination, or global limitation in motion (hypomobility). The impairment is noted in late stance, during swing, and/or during activities requiring maximum talocrural dorsiflexion (squatting, step-down, lunges, and so on).

Treatment

Walking and/or Running

Walking and running cues focus primarily on encouraging active contraction of the gastrocnemius muscle to reduce the reliance on the passive tension of the gastrocnemius and soleus muscle and calcaneal tendon unit. The specific cues are to have the patient actively lift the heel during late stance.

Decreased Range of Motion

The primary treatment focuses on addressing limited talocrural motion. The treatment options related to length of the gastrocnemius/soleus muscle and tendon are similar to those described for pronation syndrome. Joint mobilizations to increase dorsiflexion are also useful. A unique treatment option to provide a self-mobilization to the talocrural joint includes applying a piece of tape from the talus anterior progressing inferiorly and posteriorly on the medial and lateral side of the talus and attaching the tape to the plantar surface of the calcaneus (Figure 8-38). With the tape in place, the patient performs standing activities requiring tibial advancement over a fixed foot (lunges, squats). The tape can be used during functional



Figure 8-39. Use of a towel to provide a posterior glide of the talus during closed-chain dorsiflexion activities.

activities to assist with providing a stabilizing force for the talus as the tibia advances over the foot during closed chain activities. The tape can be substituted with a towel, and the patient can provide the posterior inferior glide of the talus with the edge of the towel while actively advancing the tibia over the fixed foot (Figure 8-39).

Activity Modification

The general guidelines for activity restriction and progression described in the “Pronation Syndrome” section apply here as well.

External Tissue Support

Footwear. The last of the shoe should match the patient’s foot. Additionally, as with most individuals, a firm heel counter with a sole that bends at the metatarsal head break is generally appropriate. Shoe length and width and height of the toe box should accommodate the size of the foot and any deformities. An increase in the heel-to-toe ratio may be a reasonable compensation, particularly if the treatment to address talocrural dorsiflexion limitation is unsuccessful.

Orthoses. A heel lift may be indicated temporarily or permanently, depending on the ability of the stretching plan to improve talocrural dorsiflexion.

CASE PRESENTATION

Insufficient Dorsiflexion Syndrome

Symptoms and History

A 27-year-old male was referred to physical therapy by the orthopedist for treatment of right ankle pain, with an osteochondral defect of the talus and 1 year after microfracture repair.

The patient reports ankle joint pain (5/10) when performing squats during weight lifting. He has had to stop squats. He is also unable to complete some of his taekwondo kicks and positions because of ankle pain. The patient's pain is located on the anterior talocrural joint, primarily lateral. There is no pain with walking. He has minor pain (3/10) during running. Foot and Ankle Ability Measure score was 95% (100% indicates normal function), and the Foot and Ankle Ability Measure Sport Scale was 68% (100% indicates normal function).

Alignment Analysis

In standing, the calcaneus is vertical and the medial longitudinal arch height is normal. In prone, the assessment of subtalar joint neutral finds hindfoot and forefoot neutral alignment.

Movement Analysis

Standing/walking/running

During walking and running, the calcaneus hits in inversion and moves into eversion through midstance. The calcaneus moves toward inversion during push-off. The same movement pattern is noted during running. Anterior talocrural joint pain is reproduced during late stance phase. Cues to lift heel earlier in stance phase decreased anterior talocrural joint pain. No difference in dorsiflexion ROM is noted during gait assessment.

Single-leg hopping

No symptoms were reproduced, and no movement impairments noted.

Small knee bend

Small knee bend produced no symptoms, and no movement impairment was noted. A full squat was completed because of the patient's functional complaint. The heel on the right came off the ground earlier than the left. Symptoms (a pinching feeling) were reproduced at end-range. A posterior glide of the talus during the full squat relieved symptoms.

Muscle Length/Joint ROM Impairments

Talocrural dorsiflexion with the knee extended was 0 degrees on the right and 10 degrees on the left. With the knee flexed, talocrural dorsiflexion was 0 degrees on the right and 15 degrees on the left. Joint accessory mobility was limited with the anterior-to-posterior glide on the right. Subtalar joint motion is normal (10 degrees eversion, 20 degrees inversion), and first MTP motion was normal bilaterally.

	Right	Left
Talocrural dorsiflexion (knee extended)	0 degrees	10 degrees
Talocrural dorsiflexion (knee flexed)	0 degrees	15 degrees
Subtalar joint inversion	20 degrees	20 degrees
Subtalar joint eversion	10 degrees	10 degrees
First MTP joint extension (30 degrees talocrural plantarflexion)	60 degrees	60 degrees

Joint accessory motion assessment found limited mobility during an anterior-to-posterior glide of the talus on the ankle mortise on the right.

Footwear

Patient is wearing new running shoes. The last was semi-curved, and the heel counter is firm. The sole has gel pockets for cushion in the heel, increased density of the foam under the arch, and bends easily only at the metatarsal head break. The difference between the heel height and toe height of the shoe is 1 inch.

Diagnosis

The patient's movement tests support a movement system diagnosis of insufficient dorsiflexion. The patient's foot displays a normal movement pattern of pronation during early stance and supination during push-off. The likely source of symptoms is the anterior talocrural joint. The stage for rehabilitation is 3. Stage 3 is chosen because the patient has pain only with high level activities (pain is not limiting walking and running). The primary contributing factor to the movement impairment is limited talocrural dorsiflexion.

Prognosis

The prognosis for resolving symptoms so that high level activities can be performed with minimal pain is good. The patient is relatively young; however, the duration of limited motion is fairly long and the history of cartilage damage and surgical intervention leaves the status of the anatomy unknown.

Intervention

The patient was seen once/week for 4 weeks and then once every 2 weeks for 8 weeks to assist him in returning to his fitness and sport activities. The primary goal of intervention was to increase talocrural joint dorsiflexion. The home program included prolonged dorsiflexion stretches. The patient was instructed in a self-mobilization with movement using a towel at the talus during dorsiflexion in kneeling. Additionally, physical therapy treatment included anterior-to-posterior glides of the talus on the ankle mortise. The patient also experienced symptom relief with taping the talus to the calcaneus during weight-bearing activities, as well as during stretching. He was taught to tape himself for his daily fitness

activities. No footwear changes were recommended, and no heel lift was added.

Outcome

The talus taping technique decreased squatting symptoms to 2/10. The patient progressed over the next 12 weeks to being able to complete all sport activities without symptoms. There were occasional days with ankle symptoms, generally a day or 2 after a vigorous workout. However, the symptoms resolved within 2 to 3 days with rest.

HYPOMOBILITY SYNDROME

The principal movement impairment in this syndrome is associated with a limitation in the physiological and accessory motions of the foot and ankle. This may result from degenerative changes in the joint or the effects of prolonged immobilization.

Symptoms and Pain

Degenerative Changes

The patient complains of pain with weight bearing (gait, standing, and stairs) that decreases with rest. However, the patient often reports stiffness in the morning or after prolonged periods of rest. The onset of pain is generally gradual, and the location and description of symptoms is often vague and deep within the joint. Osteoarthritis (OA) in the foot and ankle is often associated with a previous history of trauma and joint narrowing and irregular articular surfaces. Rheumatoid arthritis (RA) is associated with joint stiffness, destruction, and deformity.

Immobilization

The patient reports a relatively recent trauma or surgery to the foot and ankle that resulted in a period of immobilization. Foot and ankle motion is not progressing as expected.

Alignment: Structural Variations and Acquired Impairments

There are no common structural variations associated with hypomobility. Visually, the calf will appear atrophied. General enlargement of the foot and ankle from edema may be present, as well as localized enlargement from bone and joint changes as a result of the degeneration and/or surgery.

Movement Impairments

Walking and Running

The patient demonstrates a walking pattern that includes a decreased step length on the uninvolved side, decreased stance time on the involved side, an increase in the foot progression angle (toe out), little heel strike, and push-off. The knee may hyperextend to compensate for limited ankle motion. The patient is often dependent on an assistive device and reports limited tolerance of weight-bearing activities. The patient may be unable to run or hop.

Squat, Step-Down, and/or Small Knee Bend

The patient has limited mobility during the squat, step down, and/or small knee bend. Descending stairs is problematic, and the patient may need to turn sideways and/or descend the stairs in a nonreciprocal pattern.

Muscle Length/Joint Range-of-Motion Impairments

Hypomobility syndrome includes limitations in physiological and accessory joint motion. Hypomobility syndrome is differentiated from insufficient dorsiflexion syndrome because the limitations in motion are in more directions and include more than the talocrural joint. In most cases, talocrural dorsiflexion is limited in those with hypomobility syndrome, but plantarflexion will also be limited and additional joints can be involved (subtalar, intertarsal, intermetatarsal, and MTP joints). Decreased joint motion related to surgery, trauma, and/or immobilization requires additional research by the physical therapist. A copy of the operative report and/or clarification with the surgeon can assure joints were not purposely fused or that hardware is not traversing a joint. The physical therapist needs a clear understanding as to whether joint motion should be increased or if compensations should be implemented because increasing motion is contraindicated.

During the assessment, if joint limitations are associated with osteoarthritis, repetition of passive motion often improves motion and symptoms. Throughout the examination in an individual suspected of hypomobility, it is likely that the limited joint motion is being compensated for by proximal and distal joints that do not have limited mobility. The hip abduction, knee hyperextension, and midfoot joint dorsiflexion are especially common compensatory motions.

Muscle Strength/Performance Impairments

MMTs of the ankle and foot muscles find weakness throughout. Often the patient is unable to complete even one single-leg heel rise through the full ROM.

Balance and Proprioception Impairment

The ability to maintain single-leg stance on the involved side will be impaired (poor control and decreased duration). Lack of ability to balance on one foot is often evident with the eyes open, and performance will worsen when the patient is instructed to close the eyes, limiting visual input and isolating foot and ankle proprioception.

Summary

Hypomobility syndrome is primarily defined by physiological and accessory joint limitations. Multiple directions of motions and/or joints will be involved in the loss of motion. Associated with the limitation in motion and the history of immobilization is general foot and ankle weakness and impaired balance and proprioception.

Treatment

Decreased Range of Motion

Joint stiffness from injury, surgery, and/or immobilization often requires an aggressive ROM treatment plan. Prolonged stretching with braces, casting, or increasing the duration and frequency of home stretches is often indicated. In therapy, joint mobilization and manipulation are also indicated.

Decreased motion caused by OA and RA is addressed more gently to avoid joint irritation and worsening of symptoms. The limitation to motion often involves changes in bone and joint anatomy, and ROM exercises are often used before activity to improve function and prevent progressive loss of motion not to increase joint motion.

Muscle Performance Impairments

Plantarflexor muscle performance limitations impair function the most. Generally, resistance band strengthening is an appropriate place to start since weight bearing is often painful. Progression to heel raises with a leg-press machine, bilateral heel raises, and single-leg heel raises is important. Completion of heel raises does not always translate into enough strength for push-off with walking and running.

Control of ankle dorsiflexion when landing on the toes during hopping, running, sprinting, and descending stairs is the result of an eccentric contraction of the plantarflexors. Specific eccentric overloading of the plantarflexors is critical for patients with high level activity goals.⁴¹⁻⁴³ Finally, progression to dynamic bilateral and single-leg hopping, cutting, and sport specific exercises is required for full return of plantar flexor strength.

Balance and Proprioception Impairments

Impaired balance and proprioception is often a key contributor to falls and additional injuries. The treatment plan should include progression from eyes open to eyes closed and from solid surfaces to moving/uneven surfaces (mini-trampoline) and should progress to dynamic activities like high marching over objects, kicking balls, and walking backward. When participation in sport activities is a goal, balance and proprioception activities must include progression to quick stops and starts, maintaining balance during player contact, and gradual return to full game participation.

Activity Modification

The general guidelines for activity restriction and progression described in the section on Pronation Syndrome apply here as well. If the patient has OA and RA, continuing with weight bearing, high impact, high-repetition activities (walking or running for fitness) is often contraindicated. The patient often needs to be guided into lower impact activities, such as stationary bicycling, water aerobics, or StairMaster/elliptical, or activities, such as rowing, that involve aerobic fitness

through the upper extremities. Weight loss can also significantly impact pain with weight-bearing activities and should be discussed if appropriate for the patient. Use of assistive devices may be temporarily or permanently indicated for patients with arthritis.

External Tissue Support

Footwear. For patients with hypomobility syndrome, shoe size and shape are particularly important. The involved foot and ankle is often larger, and edema fluctuates with weight-bearing activity. A shoe that has extra depth with laces is helpful to accommodate size and edema fluctuation. An increase in the heel-to-toe ratio may be a reasonable compensation, particularly if the treatment to address talocrural dorsiflexion limitation is unsuccessful.

For patients with OA or RA, there are a number of shoe modifications that can be made to assist with foot and ankle symptoms during weight bearing. A steel shank in the sole of the shoe (making the sole of the shoe rigid) with a rocker at the toe break allows the patient to more easily roll over the foot without needing as much talocrural dorsiflexion or MTP dorsiflexion.

Orthoses. For individuals with OA or RA, a total contact insert made of accommodative material is often indicated. Deformities of the foot should be considered in the design and materials chosen for the orthosis. A heel lift may be necessary to manage the loss of dorsiflexion ROM. Temporary orthoses or additional arch support are often indicated to manage foot pain that is often related to the new onset of a pronation impairment that results from the limited foot and ankle mobility.

CASE PRESENTATION

Hypomobility Syndrome

Symptoms and History

A 78-year-old male was referred by the orthopedist for evaluation and treatment of the right ankle, status/post (s/p) open reduction, internal fixation (ORIF). The patient states that 6 months ago he fell in his bathroom. His right foot was caught under the cabinet, and he heard a snap. The patient had surgery with pins and plates that provided internal fixation for a fractured tibia and fibula. He was casted for 8 weeks. He had physical therapy 3 times/week at home for the first 4 weeks. No additional physical therapy was ordered by his physician until his 6 month follow-up visit when the physician noted the continued limp and the patient complained of limited ability to complete many activities required by his daily life (taking care of his lawn, walking through the grocery store, and completing his daily walk for fitness). His Foot and Ankle Ability Measure score was 40% (100% indicates normal function).

Alignment Analysis

The ankle, foot, and toes are moderately swollen making assessment of alignment difficult.

Movement Analysis

Standing/walking/running

Patient has been using a walker since surgery and ambulates limited distances on all surfaces. There is decreased step length on the left and decreased stance time on the right. His right foot is pointed out. He reports inability to descend stairs or a curb leading with the left leg.

Muscle Performance Impairments

Patient is unable to tolerate full resistance to any motion. Approximate muscle strength of 2–/5 throughout ankle musculature.

Muscle Length/Joint ROM Impairments

	Right	Left
Ankle dorsiflexion (knee extended)	–10 degrees	6 degrees
Plantar flexion	10–30 degrees	0–48 degrees
Inversion	0–4 degrees	0–24 degrees
Eversion	0–2 degrees	0–8 degrees
First MTP dorsiflexion	0–20 degrees	0–60 degrees

Footwear

The patient is wearing a pair of old canvas slip on shoes because his old shoes have not fit since the surgery.

Diagnosis

The patient's movement tests support a movement system syndrome of hypomobility. The patient is 6 months postsurgery, the tissues have healed, but ROM continues to be limited and general foot function is compromised. The stage for rehabilitation is 2. Stage 2 is chosen because the patient is outside of the tissue protection phase and requires progression of activity, strengthening, and ROM. The primary contributing factor to the movement impairment is limited motion at the talocrural, subtalar, and MTP joints. Additionally, ankle and foot muscle performance is limited.

Prognosis

The prognosis for returning the patient to his full function is good. He is older and the duration since onset is long; however, little intervention has been attempted and activity expectations are reasonable.

Treatment

The patient was seen initially 3 times/week for 4 weeks. Treatment frequency decreased to 1 to 2 times/week for 8 additional weeks. The primary goals of intervention were to increase ROM, address muscle performance, and functional limitations. The patient was given a home and in-therapy stretching program to address the talocrural and first MTP motion and a therapist-assisted subtalar joint ROM program. The stretching program began gently, with minimal overpressure, 30-second duration hold, and 3 to 5 times/day frequency. Mobilizations were

shy of end-range and were closely monitored for symptom response. Patient progress and tolerance was assessed with the gentle ROM program. The stretching and mobilization treatments were progressed over the first 2 weeks of physical therapy, and prolonged stretching was implemented with the use of a night splint (that can be used during the day) after 3 weeks of physical therapy. Lower extremity strengthening exercises focused on calf, anterior thigh (quadriceps), and hip muscles. Additionally, general fitness was addressed with the stationary bicycling initially, progressing to treadmill and outside walking as patient tolerance increased. Single-limb stance tolerance was addressed initially in the parallel bars, progressing to walking without an assistive device and adding surface variations as tolerated. The canvas shoe provided very little stability for his foot. With the assistance of a trained footwear specialist, he was able to find a shoe that accommodated his edematous foot yet provided support during weight-bearing activities. Edema management included a double thickness of Tubigrip (ConvaTec Inc., Stillman, NJ), extending from the tip of the toes to midcalf.

Outcome

ROM was slow to progress despite the aggressive program. Dorsiflexion at the talocrural joint progressed to 0 degrees, plantar flexion increased to 35 degrees, and first MTP motion increased to 35 degrees by the end of 12 weeks of physical therapy. Despite the lack of full motion, the patient's strength, balance and proprioception, and weight-bearing tolerance increased so that the patient could walk without a noticeable limp on all flat and uneven surfaces.

FOOT AND ANKLE IMPAIRMENT

A key criterion for placement into the foot and ankle impairment diagnostic category is the need to protect tissue. Usually, the tissue involved is stressed by a surgical procedure or trauma and may cause significant pain at rest and during movement. The patient is unable to tolerate a typical movement system examination. The limitation in movement is not primarily related to a chronic pain condition. These are general guidelines and not intended to stand alone. Consult the physician for specific precautions, protocols, and progressions. The physical therapist must be familiar with the tissues that were affected in the surgical procedure or injury.

The general diagnosis of foot and ankle impairment is used if the tissue injured and/or impacted by surgery is unknown. The tissue injured and/or impacted by surgery is used in the diagnosis when it is known, through the physician's referral or the patient's medical record. For example, the diagnosis might be tibia and fibula fracture s/p ORIF. For additional information regarding the tissue impairment diagnosis, see Chapter 2.

Unique Physiological Factors for the Foot and Ankle

In most cases, the bones, muscles, tendons, cartilage, and ligaments of the foot and ankle respond to stress and follow healing patterns similar to structures elsewhere in the body. There are some unique physiological factors that are specific to the foot/ankle that will help guide the physical therapist in decision making regarding the examination and in planning the treatment program.

Bone

Fractures of the base of the fifth metatarsal have a high probability of nonunion secondary to the pull of the fibularis brevis. Additionally, stress fractures of the anterior lateral tibial diaphysis, medial malleolus, talus, navicular, and sesamoids are high-risk areas that often fail to heal; re-fractures occur and operative intervention is needed.²⁸

Muscle

It is common to lose dorsiflexion ROM and to experience gastrocnemius/soleus muscle atrophy with immobilization.

Tendon

Calcaneal (Achilles) tendon rupture can be treated conservatively with cast immobilization or be surgically repaired with a period of cast immobilization. During the healing process, strong gastrocnemius/soleus contractions and end-range dorsiflexion motions are restricted. After the period of immobilization, the physical therapist needs to cautiously strengthen the gastrocnemius/soleus muscle and tendon.

If severe, a posterior tibial tendon injury or insufficiency may result in significant deformity of the arch (flattening). If treated conservatively, this injury or insufficiency may require long periods of immobilization. Surgical repair with a tendon transfer is often required for resolution of the symptoms. Cast immobilization is typical after posterior tibial tendon repair and tendon transfer. Contraction of the posterior tibial muscle would be contraindicated until adequate healing has occurred.

Ligament

Lateral ankle sprains can be accompanied by fractures. The Ottawa Ankle Rules indicate that indications for additional imaging after ankle sprain include the inability to bear weight or tenderness at the base of the fifth metatarsal, navicular, or the posterior edge or tip of either malleolus.⁴⁴

Syndesmotic ankle sprain ("high ankle sprain") is associated with greater discomfort during weight bearing and longer healing time and may require immobilization.⁴⁵

Skin

Edema has the potential to limit mobility and compromise the space occupied by nerves and arteries. The areas where space is limited and nerves and arteries pass include



Figure 8-40. Patient 8 weeks after an open reduction internal fixation of a tibia/fibular fracture. Note dorsal pitting edema.

the compartments within the leg, the extensor retinaculum and the flexor retinaculum.

It is important to inspect the surgical incision. The therapist should note the location, appearance, mobility, sensitivity of the incision, and if the incision appears healed (approximately 10 days). Signs of infection (red, warm, drainage, patient fever, or lymph streaking) should be reported to the physician immediately.

Nerve

The common fibular (peroneal) nerve is superficial and easily injured as it wraps around the head of the fibula. The deep fibular (peroneal) nerve can be compromised as it runs through the anterior compartment of the leg and/or beneath the extensor retinaculum. The tibial nerve can be compressed as it runs through the posterior compartment and/or beneath the flexor retinaculum (tarsal tunnel). The interdigital nerve can be compromised between the metatarsals. The most common site of symptoms is between the third and fourth metatarsals. The interdigital nerve between the third and fourth metatarsals is often enlarged because it can receive nerve fibers from both the medial and lateral plantar nerves.

Unique Assessment and Treatment for the Foot and Ankle

A full and detailed list of items to assess and guidelines for test completion and interpretation are outline in Chapter 2. The items unique to the foot and ankle are highlighted here.

Edema

The foot and ankle are prone to edema after trauma and/or surgery, and this edema warrants close examination, documentation, treatment, and monitoring (Figure 8-40). Treatment often requires the use of compression garments, as well as basic techniques of ice and elevation.

Appearance

Loss of the gastrocnemius/soleus muscle bulk is the most apparent change after a prolonged period of lower extremity immobilization. However, all lower extremity

muscles (hip, knee, and foot and ankle) on the involved side will be affected by a period of immobilization.

Proprioception/Balance

When appropriate, given weight-bearing precautions, the ability to maintain single-leg stance with eyes open and with eyes closed should be assessed. Treatment must include activities with the eyes closed to remove visual compensation. Additionally, progression to dynamic activities on variable surfaces is important, including uneven (grass, rocks) and moving (wobble board) surfaces. If interested in returning to sport activities, balance during cutting or rapid changes in direction and sport-specific activities must be assessed.

Functional Mobility

Lower extremity injuries often require the use of an assistive device. The patient's ability to complete all mobility tasks while maintaining weight-bearing precautions is critical (sit to and from stand, ambulation, stairs, and transfers in and out of a car).

Plantarflexion function during walking and running should be assessed, when allowed. Often, the patient is able to complete single-leg heel raises in standing; however, dynamic plantar flexion function during walking is impaired and the heel fails to rise appropriately during push-off. During running and sprinting the patient will complain of an inability to remain on their toes. Improving gastrocnemius/soleus muscle function can be challenging. A progressive overload program must be established and include the addition of hopping and running.

Summary

Foot and ankle impairment is a classification system that allows the therapist to clarify the tissue involved, as well as the surgery. The examination is guided by the therapist's assessment of the rehabilitation stage and his or her knowledge of the surgical procedure, precautions, and rehabilitation protocol. This classification is used when there is no apparent and contributing movement impairment, or symptoms are so severe that a full movement system examination cannot be completed.

CASE PRESENTATION

Ankle Impairment Stage 1

Symptoms and History

The patient is a 40-year-old female referred by the orthopedist for physical therapy 6 weeks s/p right ankle bimalleolar fracture, ORIF. The patient reports that 6 weeks ago she missed the last step going down to her basement and fractured her right tibia and fibula. The patient reports non-weight-bearing activity in a cast for 2 weeks after surgery and progressed to partial weight bearing in a walking cast for 4 weeks. The physician started her on full weight-bearing activity 3 days ago in a boot. She reports

she always has a bit of pain even when sitting or resting (3/10). Pain increases to 5/10 with attempts at full weight bearing activity. Her Foot and Ankle Ability Measure score was 10% (100% indicates normal function).

Alignment Analysis

Patient is obese with visible psoriatic patches noted on bilateral lower and upper extremities. The ankle, foot, and toes are moderately swollen with pitting edema of the right ankle and foot.

Girth measurements:

- Figure 8 at the ankle: 60 cm right and 58 cm left
- Calf: 42.8 cm right and 44.3 cm left

Scar: Incision closed, no redness, no warmth, no drainage. Scar is slightly adhered centrally with very mild hypersensitivity to touch.

Movement Analysis

Standing/walking

Assessed in boot only without assistive device. Patient walks with decreased stance time right, no push-off on right, and decreased step length on left.

Muscle Performance Impairments

Not assessed this visit.

Muscle Length/Joint ROM Impairments

	Right	Left
Ankle dorsiflexion (knee extended)	−16 degrees	−4 degrees
Ankle dorsiflexion (knee flexed)	−10 degrees	2 degrees
Plantar flexion	51 degrees	54 degrees
Inversion	40 degrees	43 degrees
Eversion	2 degrees	8 degrees

Diagnosis

The patient's evaluation supports a diagnosis of bimalleolar fracture, s/p open reduction internal fixation, Stage 1. The patient is 6 weeks postsurgery and just beginning to progress toward full weight-bearing activities and is still in an immobilization boot. The patient would likely progress to Stage 2 quickly once weight-bearing tolerance improves. The primary contributing factor to the foot and ankle impairment is the need to protect and gradually load tissue after surgical intervention. Weight-bearing tolerance is limited, talocrural dorsiflexion is decreased, and edema is present.

Prognosis

The prognosis for returning the patient to her full weight-bearing function is good. The patient's increased weight will likely delay tolerance of full weight-bearing activities.

Treatment

The patient was seen 3 times/week for 4 weeks and then 1 to treatment times/week for 8 additional weeks. The

initial goals of treatment were to increase weight-bearing tolerance and wean her from wearing the boot. A home program was implemented to address decreased ROM and as appropriate, strength. The patient received education about edema management and scar mobilization.

Outcome

Initial attempts at weaning from the immobilization boot were met with an increase in irritation of the posterior tibialis tendon from increased pronation during weight bearing. The patient required the addition of a heel lift, scaphoid pad, and arch taping to manage the posterior tibialis tendon symptoms. Two weeks were required for the patient to wean from the boot to regular footwear for ambulation. Talocrural dorsiflexion ROM improved to -5 degrees but remained limited at 6 months after surgery. The patient was instructed to continue with talocrural dorsiflexion stretching, but she continued to need a small heel lift to avoid posterior tibialis tendon irritation.

PROXIMAL TIBIOFIBULAR GLIDE SYNDROME

The principal movement impairment is posterior and/or superior motion of the fibula on the tibia during active hamstring contraction (especially during running). The principal positional impairment is the fibula located anterior, posterior, superior, or inferior to the normal position on the tibia after trauma, particularly an ankle sprain.

Symptoms and Pain

Pain in posterolateral or lateral aspect of tibiofibular joint is often associated with running or general tibiofibular pain is associated with a history of lateral ankle sprains. Tingling or numbness can also be reported if the fibular head is compressing the common fibular (peroneal) nerve. The location of the tingling or numbness can be locally at the lateral knee or referred to the lateral distal leg and/or dorsum of the foot.

Alignment: Structural Variations and Acquired Impairments

Palpation of fibula location on tibia, relative to uninjured side, reveals malalignment (anterior, posterior, and/or superior). A glide in the direction of the positional or movement impairment increases pain. A glide in the opposite direction of the positional or movement impairment will decrease symptoms.

Movement Impairments

Walking/Running

The movement impairment is very small and not visible during motions. Symptoms are localized to the fibular head, or referred to areas innervated by the common fibular (peroneal) nerve or its branches, during walking and running. If the symptoms are reduced or go away

with stabilization of the tibiofibular joint the diagnosis of proximal tibiofibular glide syndrome is supported.

Sitting

Resisted hamstring contraction can reproduce symptoms in an individual with proximal tibiofibular glide syndrome, and the symptoms are reduced with joint stabilization.

Talocrural dorsiflexion has associated tibiofibular motions and can reproduce symptoms. If symptoms are related to proximal tibiofibular glide syndrome, stabilization at the proximal tibiofibular joint will reduce symptoms.

Muscle Length/Joint Range-of-Motion Impairments

Hamstring length and talocrural dorsiflexion impairment are common with this diagnosis. Positions when the hamstring are stretched or when the talocrural joint is at end-range of motion can reproduce symptoms. Stabilization of the fibular head during the stretch decreases symptoms.

Summary

Proximal tibiofibular glide syndrome is either a positional fault generally occurring after ankle and foot trauma (ankle sprain) or a movement impairment as a result of hamstring contraction pulling the fibula posteriorly. The positional or movement impairments are difficult to see and palpate, but when correction of a suspected positional impairment or stabilization against a suspected motion decreases symptoms, the diagnosis is supported.

Treatment

Alignment Impairments

Positional impairments of the tibiofibular joint can be addressed by gliding the fibula on the tibia as indicated by evaluation findings.

Decreased Range of Motion

Hamstring and talocrural dorsiflexion limitations should be addressed with a home program.

External Tissue Support

Taping. Taping to immobilize or limit motion between the proximal tibia and fibula can help reduce symptoms (Figure 8-41). Caution should be taken to avoid compression of the common fibular nerve as it passes superficially around the fibular head. Taping of the fibula is a required precursor to hamstring and talocrural stretching exercises that assist in stabilizing the joint during the prescribed exercise. Taping of the fibula is also helpful after mobilization treatments correcting positional impairments.

CONCLUSIONS

The foot and ankle are a complex chain of joints that must convert quickly from a flexible adapter and shock



Figure 8-41. Example of fibular taping, avoiding the fibular (peroneal) nerve while providing resistance to posterior motion of the fibular head.

attenuator to a rigid lever capable of propelling the body in all different directions. The ability of the foot to perform these diverse and opposing functions and precisely time the function to the intended task is impacted by a number of factors. Joint stability, muscle function, and motor coordination are critical to the foot and ankle. However, function at the foot and ankle is intimately connected to the function and alignment of the knee and hip. The physical therapist is the most highly trained health professional with the ability to evaluate weight-bearing activities, understand the functional requirements of the lower extremity, recognize the movement impairment(s), assess the factors that contribute to the movement impairment, and develop a focused and effective treatment plan.

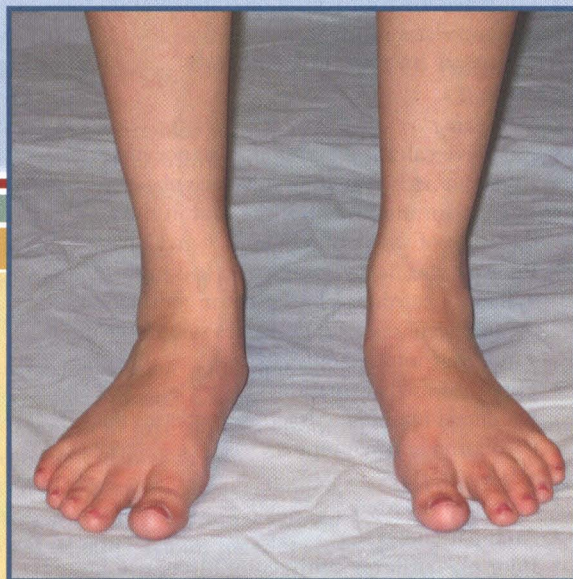
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CHAPTER 8

APPENDIX



Pronation Syndrome

The principal movement impairment in pronation syndrome is pronation at the foot and ankle. Pronation is considered abnormal and an impairment when the amount of pronation during weight-bearing activities is excessive for that individual and/or when there is insufficient movement of the foot in the direction of supination in later stance phase. The pronation impairment can occur in the hindfoot, midfoot, and/or forefoot. A foot with a pronation movement impairment is a flexible foot that compensates for various structural and movement impairments within the foot and ankle, as well as those at the knee and hip.

Symptoms and History

- **Plantar fascia:** Heel pain with first step in morning or after prolonged non-weight-bearing function
- **Posterior and anterior tibialis muscle/tendon:** Pain in muscle or tendon, most apparent with weight bearing as the muscle works to control pronation
- **Tibial nerve:** Pain, tingling, and/or numbness on the posterior, medial ankle and/or into the plantar surface of the foot
- **Gastrocnemius/soleus muscle/calcaneal tendon:** Pain in muscle or tendon as tibial forward progression is controlled in stance and during propulsion phase of weight bearing
- **Metatarsal heads:** Pain localized to the second and third metatarsal heads
- **Interdigital nerve:** Pain, tingling, or numbness between metatarsal heads (most often third and fourth) radiating into corresponding toes
- **Medial column joints:** Generalized foot pain (often in the midfoot) in the medial column joints; pain can progress to joint degeneration and involvement of the joints of the lateral column

Common Referring Diagnoses

- Shin splints
- Stress fracture
 - Tibia
 - Metatarsals
- Posterior/anterior tendonitis
- Plantar fasciitis
- Foot pain
- Tarsal tunnel syndrome
- Metatarsalgia
- Digital neuroma

Key Tests and Signs for Movement Impairment

Alignment Analysis

- Hindfoot: Calcaneal eversion
- Midfoot: Talonavicular joint dropped down (medial bulge)
- Low medial longitudinal arch
- Forefoot: Abduction in relationship to the hindfoot at the transtarsal joint
- Increased width of forefoot
- Hip/knee medial rotation or compensation for hip/knee lateral rotation

Movement Impairment Analysis

Standing

Gait/running

- Excessive calcaneal eversion in stance phase
 - Excessive arch flattening in stance phase
 - Insufficient movement of the foot in the direction of supination in later stance phase
 - Poor plantar flexor contraction and push-off
 - Support of the arch (supinator contraction, tape, scaphoid pad) decreases symptoms in the four impairments
 - Hip/knee medial rotation
 - Gluteal muscle contraction decreases medial rotation and symptoms
- ##### Single-leg hopping
- Calcaneus everted
 - Arch flattening
 - Poor plantarflexor contraction (decreased jump height)
 - Plantarflexion contraction improves jump and decreases symptoms
 - Contraction of gluteal muscles decreases medial rotation and symptoms

Step-down or small knee bend

- Calcaneal eversion
- Arch flattening
- Knee/hip medial rotation
- Weight transferred over medial column of foot

Sitting

Active first MTP extension

- First MPT extension results in plantar flexion at the first metatarsocuneiform and prominence of the MTP on the plantar surface of the foot. Symptoms may be produced at the MTP and/or metatarsocuneiform joints
- MTP or metatarsocuneiform stabilization decreases symptoms

Source of Signs and Symptoms

Heel and/or Arch Symptoms

Plantar Fascia

- Special test: Toe extension increases symptoms with/without palpation along the fascia
- Palpation: Tender at the insertion of plantar fascia on medial calcaneal tubercle and can be tender along the fascia into the midfoot

Posterior and Anterior Tibialis Muscle/Tendon

- Special test: Soft tissue differential may be weak and painful or strong and painful with appropriate resisted contraction in neutral foot position (≈ 10 degrees plantar flexion)

Palpation

- Posterior tibialis muscle and tendon: Tender distal, posterior, medial tibia to plantar navicular
- Anterior tibialis muscle and tendon: Tender at the proximal lateral tibia, dorsal/medial to first cuneiform and/or base of first metatarsal

Tibial Nerve

- Special test: Positive Tinel's, placement in provocative position (dorsiflexion, toes extended, and calcaneus everted) or Tinel's in provocative position

Hindfoot Symptoms

Gastrocnemius/Soleus Muscle/Calcaneal Tendon:

- Palpation: Tender posterior calf and tendon to calcaneus

Forefoot Symptoms

Metatarsal Heads

- Palpation: Tender at the second and third metatarsal heads

Interdigital Nerves

- Special test: Squeeze test positive (most common between third and fourth metatarsals)

Associated Signs or Contributing Factors

Structural Variations

Foot

- Subtalar joint neutral findings modified by weight bearing
- Uncompensated hindfoot valgus
- Uncompensated forefoot valgus
- Compensated hindfoot varus
- Compensated forefoot varus

Femur/Tibia

- Long leg on pronated side
- Femoral anteversion

Muscle Length/Joint ROM Impairments

Talocrural Dorsiflexion

- Limited if dorsiflexion <10 degrees with knee extended
 - Gastrocnemius short if dorsiflexion ≥ 10 degrees with knee flexed
 - Soleus short if dorsiflexion ≤ 10 degrees with knee flexed and normal accessory talocrural motion
- Talocrural joint limitation if dorsiflexion ≤ 10 degrees, regardless of knee position and limited accessory talocrural joint motion (cannot rule out soleus limitation in this case)

Passive First MTP Extension

- Limited if <60 degrees in full plantar flexion without stabilizing MTP
- Limited if <30 degrees in 30 degrees of ankle plantar flexion
 - Flexor hallucis longus short if ≥ 30 degrees of first MTP extension in full plantar flexion compared to 30 degrees of plantar flexion
 - First MTP joint limitation if first MTP extension remains limited, regardless of ankle position, and accessory MTP motion is limited (cannot rule out flexor hallucis brevis or other 1-joint muscles crossing the MTP)

Subtalar Joint Eversion

- Hindfoot pronation-eversion ROM is available

Muscle Strength/Performance Impairments

- Gastrocnemius/soleus weakness
- Posterior gluteus medius, intrinsic hip lateral rotators
- Inadequate stabilization of MTP joints by the intrinsic muscles of the foot results in extension of the MTPs during active talocrural dorsiflexion
- Dominance of extensor digitorum longus results in dorsiflexion with eversion

Improper Footwear

- Flexible heel counter
- Shoe sole components
- Recent decrease in heel-to-toe height

Activity Level

- Recent increase in activity level

Plantar Callus Findings

- Second and third metatarsals
- Medial first toe

Differential Diagnosis

Movement Diagnosis

- Insufficient dorsiflexion
- Supination

Potential Diagnosis Requiring Referral Suggested by Signs and Symptoms

Musculoskeletal

- Stress fracture
- DJD
- Low back (L4-S2)
- Posterior tibialis tendon insufficiency

Neurovascular

- DVT
 - Well's Clinical Decision Rule
 - Homans' sign
- Compartment syndrome
- Tarsal tunnel syndrome

Systemic

- RA

Treatment

Inflammation and Pain Control

- Ice
- Iontophoresis
- Electrical stimulation

Walking and/or Running

The patient is instructed to work on the specific cues that assisted in symptom reduction during the examination or the cues that the physical therapist believes with practice may result in symptom reduction. The following cues are among the possibilities that may assist the patient:

- Contract the gastrocnemius muscle by lifting from the heel.
- Raise the medial longitudinal arch.
- Contract the gluteal muscles (squeeze the buttocks).
- Hit with the heel first.

Many of the changes being requested of the patient during walking and running are similar to a strengthening program. As such, the patient should be encouraged to have focused practice time and gradual implementation to avoid injury.

Muscle Performance

- Supinators (gastrocnemius, posterior tibialis)
 - Thera-Band resistance exercise into plantarflexion and plantarflexion inversion
 - Heel raises
 - Hopping
- Intrinsic muscles of the foot
 - Towel crunches: Towel placed on the floor, use toes to grab towel and pull it under the foot. Weight can be added to the towel to increase resistance. The arch should lift; do not allow the patient to only use the flexor digitorum longus.
- Posterior hip muscles
 - Sidelying hip lateral rotation progressing to lateral rotation with abduction adding weight as appropriate. Patient may need a pillow between knees for comfort.
 - Prone hip extension with the knee flexed. Patient should be over a pillow.
 - Posterior hip muscle strengthening must progress to weight-bearing dynamic activities to prepare the muscles for walking, running, and jumping activities.

After the injured tissue has been protected from excessive stresses and the inflammation has subsided, the involved muscle and tendon should undergo a progressive strengthening program and a progressive return to activity. In general, exercise or activity is permissible if pain remains at 2/10 on a 0 to 10 scale. The strengthening exercise should be completed at a minimum of 70% maximal voluntary contraction for 10 repetitions, 3 sets, 3 to 5 times/week.

Decrease Range of Motion

- Short gastrocnemius/soleus muscle/calcaneal (Achilles) tendon.
- Wall stretch: The knee is extended for gastrocnemius muscle shortness and flexed for soleus muscle length deficits. The patient should prevent pronation (active patient correction and wearing good footwear). The patient should be instructed to keep the foot facing forward or in line with the femur and tibia. The heel should be kept on the ground during the stretch.
- Heel hang stretch: The knee can be extended or flexed as described for the wall stretch. The patient should prevent pronation through active correction and by wearing good footwear.
- Long sitting towel-assisted dorsiflexion: The patient should prevent pronation through active correction and by modifying the direction of force through the towel.
- Talocrural joint limitation: In addition to the standing stretches, joint limitations can be addressed with mobilization.
 - Mobilize the talocrural joint using a posterior glide of the talus on the ankle mortise.
 - Mobilize the talocrural joint using a distraction technique.
 - Heel lift in the shoe until length changes are apparent.
 - Night splint to maintain dorsiflexion position.
- Short extensor digitorum longus.
 - Patient plantar flexes the involved foot with the toes flexed. Can be completed in sitting or can be stretched in hands and knees rocking back.
- First MTP extension limitation:
 - Mobilize the MTP joint using an anterior glide of the proximal phalanx on the metatarsal.
 - Passive ROM (PROM) into first MTP extension (talocrural dorsiflexion with first MTP extension).

Stretching should be held for 30 seconds, 2 to 3 repetitions, completed regularly throughout the day (5 to 8 times/day), and completed 5 to 7 days/week.

Activity

- Modify activity level to decrease forces on the foot. May require use of an assistive device if symptoms are severe.
- If appropriate for the patient's goals, progress to dynamic activities such as jumping, hopping, shuttle run, cutting, and so on.
- Running progression rules:
 - Start with a run/walk program gradually progressing to all running.
 - Start with straight plane jogging and jumping on a smooth flat surface.
 - Work on distance tolerance first.
 - Increase speed as tolerated.

- Add varied terrain, hills, and cutting (these can include figure 8s).
- Finally, add cuts and turns that are unexpected. For example, have the patient run straight forward and call cut right. He or she is expected to change directions immediately. Mix the calls, including cut left, 180 degrees turn, 360 degrees turn, and bend down.

External Tissue Support

Footwear

- A last that looks like the foot. The most common last for a pronated foot is a straight or semi-curved last.
- Firm heel counter to control hindfoot motion. If pronation is occurring at the hindfoot, the shoe should include rigid material at the medial heel and less rigid material at the lateral heel.
- A sole that bends only at the metatarsal heads and rigid from hindfoot to midfoot.
- Adequate arch support with medial structures of the footwear generally made of firm, controlling materials.

- Appropriate width and depth to accommodate the foot
- Cushion indicated as needed for appropriate shock absorption.

Orthoses/Taping

- The orthosis should prevent pronation. Start with adding an arch support, then if necessary post at the hindfoot, then the forefoot. If the metatarsal heads are involved, the orthosis may also need to include a metatarsal pad.
- For calcaneal tendon involvement, hindfoot eversion must be correct with a medial hindfoot post to maximize tendon alignment.
- For tarsal tunnel involvement, hindfoot orthosis additions must be soft to avoid nerve compression.
- Arch taping: Used most frequently for involvement of the plantar fascia but is appropriate for any condition that would benefit from additional arch support and prevention of pronation.

Supination Syndrome

The principal movement impairment in supination syndrome is supination at the foot and ankle. Supination is considered abnormal and an impairment when the amount of supination during weight-bearing activities is excessive for that individual or when it occurs from heel strike to midstance in the gait cycle. The supination impairment can occur in the hindfoot, midfoot, and/or forefoot. The foot with a supination impairment is generally a rigid foot with little or no ability to absorb shock and compensate for structural or movement impairments within the foot and ankle, knee, or hip.

Symptoms and History

- *Plantar fascia*: Heel pain with first step in the morning or after prolonged non-weight-bearing function
- *Fibular muscles/tendon*: Pain in muscle or tendon, most apparent with weight bearing as the muscle works to control supination
- *Gastrocnemius/soleus muscles/calcaneal tendon*: Pain in muscle or tendon as tibial forward progression is controlled in stance and during propulsion phase of weight bearing
- *Metatarsal heads*: Pain localized to the first and fifth metatarsal heads
- *Lateral column joint*: Lateral column joint pain with weight bearing
- Generalized foot pain, knee, hip, or low back pain associated with a “rigid” foot

Common Referring Diagnoses

- Stress fracture
 - Tibia
 - First or fifth metatarsal
- Fibularis muscle strain or tendonitis
- Plantar fasciitis
- Foot pain
- Metatarsalgia

Key Tests and Signs for Movement Impairment

Alignment Analysis

- Hindfoot: Calcaneal inversion
- Midfoot: Talonavicular joint located more dorsal (lateral bulge)
- Forefoot: Adduction in relationship to the hindfoot at the transtalar joint
- High medial longitudinal arch
- Femur and/or tibia excessive lateral rotation
- Decreased width of the forefoot

Movement Impairment Analysis

Standing

Gait/running

- Decreased calcaneal eversion
- Minimal flattening of the arch from heel strike through midstance
- Hip/knee lateral rotation
- Knee varus moment
- Late stance (heel off) foot moves into pronation

Single-leg hopping

- Efficient plantar flexor force (jump is high and well controlled)
- Hip/knee lateral rotation
- Knee varus moment

Step-down or small knee bend

- Limited dorsiflexion
- Arch moves very little from initial position
- Weight transferred over lateral column

Source of Signs and Symptoms

Heel and/or Arch Symptoms

Plantar Fascia

- Special test: Toe extension increases symptoms with/without palpation along the fascia
- Palpation: Tender at the insertion of plantar fascia on medial calcaneal tubercle and can be tender along the fascia into the midfoot

Lateral Ankle/Foot Symptoms

Fibularis Muscle/Tendon

- Special test: Soft tissue differential may be weak and painful or strong and painful with appropriate resisted contraction in neutral foot position (≈ 10 degrees plantar flexion)
- Palpation: Tender posterior and lateral to the fibula, posterior to the lateral malleolus, to the base of the fifth MTP or at the cuboid as the longus runs on the plantar surface of the foot

Hindfoot Symptoms

Gastrocnemius/Soleus Muscle/Calcaneal Tendon

- Special test: Soft tissue differential may be weak and painful or strong and painful with appropriate resisted contraction in neutral foot position (≈ 10 degrees plantar flexion)
- Palpation: Tender posterior calf and tendon to calcaneus

Forefoot Symptoms

Metatarsal Heads/Sesamoids

- Palpation: Tender at the first and fifth metatarsal heads

Associated Signs or Contributing Factors

Structural Variations

Foot

- Subtalar joint neutral findings modified by weight bearing
- Uncompensated hindfoot varus
- Uncompensated forefoot varus
- Compensated hindfoot valgus
- Compensated forefoot valgus
- Plantar flexed first ray

Femur/Tibia

- Short leg on supinated side
- Femoral retroversion
- Tibial torsion

Muscle Length/Joint ROM Impairments

Talocrural Dorsiflexion

- Limited if dorsiflexion <10 degrees with knee extended
 - Gastrocnemius short if dorsiflexion ≥ 10 degrees with knee flexed
 - Soleus muscle short if dorsiflexion ≤ 10 degrees with knee flexed and normal accessory talocrural motion
- Talocrural joint limitation if dorsiflexion ≤ 10 degrees, regardless of knee position and limited accessory talocrural joint motion (cannot rule out soleus muscle limitation in this case)

Passive First MTP Extension

- Limited if <60 degrees in full plantar flexion without stabilizing MTP
- Limited if <30 degrees in 30 degrees of ankle plantarflexion
 - Flexor hallucis longus short if ≥ 30 degrees of first MTP extension in full plantarflexion compared 30 degrees of plantarflexion
 - First MTP joint limitation if first MTP extension remains limited, regardless of ankle position, and accessory MTP motion is limited (cannot rule out flexor hallucis brevis or other 1-joint muscles crossing the MTP)

Subtalar Joint Eversion

- Hindfoot eversion ROM is limited

Extensor Digitorum Longus

- Toe flexion ROM is decreased when the talocrural joint is plantarflexed compared to dorsiflexion

Improper Footwear

- Insufficient cushion
- Straight last
- Sole structure that encourages supination (lateral soft material in combination with medial rigid materials)

Activity Level

- Recent increase in activity level

Plantar Callus Findings

- First and fifth metatarsals
- Medial first toe

Differential Diagnosis

Movement Diagnosis

- Insufficient dorsiflexion

Potential Diagnosis Requiring Referral Suggested by Signs and Symptoms

- Stress fracture
- DJD
- Low back (L4-S2)

Neurovascular

- DVT
 - Well's Clinical Decision Rule
 - Homans' sign
- Compartment syndrome

Systemic

- RA

Treatment

Inflammation and Pain Control

- Ice
- Iontophoresis
- Electrical stimulation

Walking and/or Running

The patient is instructed to work on the specific cues that assist in symptom reduction during the examination or the cues that the physical therapist believes, with practice, may result in symptom reduction. Often, the cues are related to softening the landing, hitting more centrally on the heel, and concentrating on trying to limit lateral loading through the foot.

Muscle Performance

- Gastrocnemius/soleus muscle
 - Thera-Band resistance exercise into plantar flexion
 - Heel raises
 - Hopping
- Fibularis (peroneus) longus and brevis
 - Thera-Band resistance exercise into plantar flexion and plantarflexion eversion

After the tissue injury has been protected from excessive stresses and the inflammation has subsided, the involved muscle and tendon should undergo a progressive strengthening program and a progressive return to activity. In general, exercise or activity is permissible if pain remains at 2/10 on a 0 to 10 scale. The strengthening exercise should be completed at a minimum of 70% maximal voluntary contraction for 10 repetitions, 3 sets, 3 to 5 times/week.

Decreased Range of Motion

- Short gastrocnemius/soleus muscle length
 - Wall stretch: The knee is extended for gastrocnemius muscle shortness and flexed for soleus muscle length deficits. The patient should be instructed to keep the foot facing forward or in line with the femur and tibia. The heel should be kept on the ground during the stretch. The patient should prevent foot supination correction and by wearing good footwear. The stretch should be held for 30 seconds, complete 2 to 3 time/session, and done regularly throughout the day (5 to 8 times/day).
 - Heel hang stretch: The knee can be extended or flexed as described for the wall stretch. The patient should prevent subtalar joint supination through active correction and by wearing good footwear.
 - Long sitting towel-assisted dorsiflexion. The patient should prevent foot supination through active correction and by modifying the direction of force through the towel.

- A night splint to maintain dorsiflexion position is often helpful.
- Talocrural joint limitation
 - Mobilize the talocrural joint using a posterior glide of the talus on the ankle mortise
 - Mobilize the talocrural joint using a distraction technique
 - May need to include a heel lift in the shoe until length changes are apparent
 - Talocrural joint limitation
- Decreased length of extensor digitorum longus
 - Patient plantarflexes the involved foot with the toes flexed. Can be completed in sitting or if extremely short, can be stretched in hands and knees rocking back
- Decreased great toe extension
 - Mobilize the MTP joint using an anterior glide of the proximal phalanx on the metatarsal.
 - Passive ROM into great toe extension. Patient dorsiflexes the talocrural joint and then extends the great toe.

Stretching should be held for 30 seconds, 2 to 3 repetitions, completed regularly through out the day (5 to 8 times/day), and completed 5 to 7 days/week.

Activity

- Modify activity level to decrease forces on the foot. May require use of an assistive device if symptoms are severe.
- If appropriate for the patient's goals, progress to dynamic activities such as jumping, hopping, shuttle run, cutting, and so on.
- Running progression rules:
 - Start with straight plane jogging and jumping on a smooth flat surface.
 - Work on distance tolerance first.
 - Increase speed as tolerated.
 - Add varied terrain, hills, and cutting (these can include figure 8s).
 - Finally, add cuts and turns that are unexpected. For example, have the patient run straight forward and call cut right. He or she is expected to change directions immediately. Mix the calls, including cut left, 180 degrees turn, 360 degrees turn, or bend down.

Footwear

- A last that looks like the foot. The most common last for a supinated foot is a curved last.
- Firm heel counter to control hindfoot motion. The hindfoot sole material should NOT include a material density differential that would encourage calcaneal inversion.
- Cushioned, conforming insole is a key component in treating the supinated foot.
- Appropriate width and depth to accommodate the foot.
- Adequate arch support.

External Tissue Support

- Accommodative insert with soft materials. May need additional arch support to assist in distributing force through greater weight-bearing surface. If the metatarsal heads are involved, the orthotic may also need to include a metatarsal pad.
- Arch taping: Used most frequently for plantar fascia involvement but is appropriate for any condition that would benefit from additional arch support.
- Calcaneal (Achilles) tendon taping: Used to reduce stress on the calcaneal tendon.

Insufficient Dorsiflexion Syndrome

The principal movement impairment in insufficient dorsiflexion syndrome is insufficient dorsiflexion. The impairment can occur during midstance to push-off or during swing phase and is not associated with excessive supination or pronation.

Symptoms and History

- *Plantar fascia*: Heel pain with first step in the morning or after prolonged non-weight bearing
- *Gastrocnemius/soleus muscle/calcaneal (Achilles) tendon*: Pain in muscle/tendon
 - Symptoms most apparent from midstance through push-off
- *Bursa*: Pain at posterior calcaneus
 - Symptoms most apparent with direct pressure.
 - The pain-provoking pressure can occur during midstance through push-off or when squatting as the calcaneal tendon is pressing the bursa or when sitting with direct pressure is on the bursa
- *Anterior tibialis muscle/tendon*: Pain in muscle/tendon, most apparent during the swing phase of walking or jogging as the anterior tibialis attempts to dorsiflex the foot
- *Deep fibular nerve*: Achy, tingling, and numbness on the dorsum of foot and can radiate into toes; most common when shoes are on and activities requiring maximum dorsiflexion (running up hills, squatting)
- *Talocrural joint*: Sharp pinching pain at end-range dorsiflexion such as squatting and running up hills
 - The talocrural joint is often point tender
- *Metatarsal heads/sesamoids*: Pain localized to the metatarsal heads

Common Referring Diagnoses

- Achilles tendonitis
- Bursitis
- Shin splints

Key Tests and Signs for Movement Impairment

Alignment Analysis

- Knee hyperextension
- Ankle in relative plantar flexion

Movement Impairment Analysis

Standing

Gait/running

- Early heel rise after midstance as the tibia attempts to advance over the foot
- Knee hyperextension during stance
- Increase in foot progression angle
- Increase in knee flexion during stance phase
- Uses passive tension of gastrocnemius/soleus muscle/calcaneal tendon to control tibia position during stance
- Limited dorsiflexion during swing phase of gait

Full squat

- Limited dorsiflexion
- Heel is higher on involved side and/or tibia is more posterior

Step-down or small knee bend

- Early heel rise, inability to keep heel on the ground

Sitting

Active dorsiflexion

- Completes with toe extension. Poor stabilization of the MTP joints with the foot intrinsics

Muscle Length/Joint ROM Impairments

Talocrural Dorsiflexion

- Limited if dorsiflexion <10 degrees with knee extended
 - Gastrocnemius short if dorsiflexion ≥10 degrees with knee flexed
 - Soleus muscle short if dorsiflexion ≤10 degrees with knee flexed and normal accessory tal-crural motion
- Talocrural joint limitation if dorsiflexion ≤10 degrees, regardless of knee position and limited accessory talocrural joint motion (cannot rule out soleus muscle length limitation in this case)

Source of Signs and Symptoms

Hindfoot Symptoms

Plantar Fascia

- Special test: Toe extension increases symptoms with or without palpation along the fascia
- Palpation: Tender at the insertion of plantar fascia on medial calcaneal tubercle and can be tender along the fascia into the midfoot

Gastrocnemius/Soleus Muscle/Calcaneal Tendon

- Special test: Soft tissue differential may be weak and painful or strong and painful with appropriate resisted contraction in neutral foot position (≈ 10 degrees plantar flexion)
- Palpation: Tender posterior calf and tendon to calcaneus

Bursa

- Symptoms reproduced with any motion that compresses the bursa (active or passive dorsiflexion, active plantar flexion)
- Palpation: Tender at posterior heel

Anterior Ankle/Foot Symptoms

Anterior Tibialis Muscle/Tendon

- Special test: Soft tissue differential may be weak and painful or strong and painful with appropriate resisted contraction in neutral foot position (≈ 10 degrees plantar flexion)
- Palpation: Anterior tibialis muscle and tendon: Tender at the proximal lateral tibia, dorsal/medial to first cuneiform and/or base of first metatarsal

Deep Fibular Nerve

- Special test: Positive Tinel's

Talocrural Joint

- Palpation: Tender at talocrural joint space

Forefoot Symptoms

Metatarsal Heads/Sesamoids

- Palpation: Tender at metatarsal heads

Associated Signs or Contributing Factors

Muscle Length/Joint ROM Impairments

Extensor Digitorum Longus

- Plantarflexion ROM decreases when toes are flexed compared to when toes are extended

Improper Footwear

- Recent change to a shoe with a lower heel
- Frequent wearing of high heels

Activity Level

- Recent increase in activity level

Visual Appraisal

- Local signs of inflammation may be present, including edema, redness, or increased temperature

Differential Diagnosis

Movement Diagnosis

- Pronation
- Supination
- Hypomobility

Potential Diagnosis

Requiring Referral Suggested by Signs and Symptoms

Musculoskeletal

- Stress fracture
- DJD
- Low back (L4-S2)

Neurovascular

- DVT
 - Well's Clinical Decision Rule
 - Homans' sign
- Compartment syndrome

Systemic

- RA

Treatment

Inflammation and Pain Control

- Ice
- Iontophoresis
- Electrical stimulation

Walking and/or Running

- Walking and running cues focus primarily on encouraging active contraction of the gastrocnemius muscle to reduce the reliance on the passive tension of the gastrocnemius/soleus muscle/calcaneal tendon unit. The specific cues are to have the patient actively lift the heel during late stance.

Muscle Performance

- Weakness of the anterior tibialis:
 - Thera-Band resistance exercise into dorsiflexion inversion with toes curled.
- Weakness of the intrinsic muscles of the foot:
 - Towel crunches: Towel placed on the floor, use toes to grab towel and pull it under the foot. Weight can be added to the towel to increase resistance. The arch should lift; do not allow the patient to only use the flexor digitorum longus.

After the tissue injury has been protected from excessive stresses and the inflammation has subsided, the involved muscle and tendon should undergo a progressive strengthening program and a progressive return to activity. In general, exercise or activity is permissible if pain remains at 2/10 on a 0 to 10 scale. The strengthening exercise should be completed at a minimum of 70% maximum voluntary contraction for 10 repetitions, 3 sets, 3 to 5 times/week.

Decreased Dorsiflexion

- Short gastrocnemius/soleus muscle/calcaneal tendon
 - Wall stretch: The knee is extended for gastrocnemius muscle shortness and flexed for soleus muscle length deficits. The patient should be instructed to keep their foot facing forward or in line with the femur and tibia. The heel should be kept on the ground during the stretch. The patient should prevent subtalar joint pronation through active correction and by wearing good footwear. The stretch should be held for 30 seconds, completed 2 to 3 times/session, and done regularly throughout the day (5 to 8 times/day).
 - Heel hang stretch: The knee can be extended or flexed as described for the wall stretch. The patient should prevent subtalar joint pronation through active correction and by wearing good footwear.
 - Long sitting towel-assisted dorsiflexion: The patient should prevent subtalar joint pronation through active correction and by modifying the direction of force through the towel.
 - A night splint to maintain dorsiflexion position is often helpful.

- Stretches should be held for 30 seconds, 2 to 3 repetitions, completed regularly throughout the day (5 to 8 times/day), and done 5 to 7 days/week.
- Talocrural joint limitation
 - Mobilize the talocrural joint using a posterior glide of the talus on the ankle mortise.
 - Mobilize the talocrural joint using a distraction technique.
 - May need to include a heel lift in the shoe until length changes are apparent.

Activity

- Modify activity level to decrease forces on the foot until healed. May require use of an assistive device if symptoms are severe.
- If appropriate for the patient's goals, progress to dynamic activities such as jumping, hopping, shuttle run, cutting etc.
- Running progression rules:
 - Start with straight plane jogging and jumping on a smooth flat surface.
 - Work on distance tolerance first.
 - Increase speed as tolerated.
 - Add varied terrain, hills, and cutting.
 - Finally, add cuts and turns that are unexpected. For example, have the patient run straightforward and call cut right. He or she is expected to change directions immediately. Mix the calls, including cut left, 180 degrees turn, 360 degrees turn, and bend down.

External Tissue Support

Footwear

- Heel-to-toe height of the shoe that accommodates for the lack of dorsiflexion ROM. However, the goal would be to increase dorsiflexion ROM to avoid needing a shoe with a heel.
- Appropriate width and depth to accommodate the foot.
- A last that looks like the foot. May be curved, straight, or in between (midlast), depending on the shape of the individual's foot.
- Footwear should include the standard shoe components to provide the necessary support and cushion. This includes a firm heel counter, the appropriate amount of arch support, and cushion indicated as needed for shock absorption.
- The angle formed by the heel counter and the sole of the shoe at the posterior heel to the vertical line from the floor at the most-posterior portion of the sole of the shoe should be relatively small. A large angle increases the work demand on the anterior tibialis muscle and tendon.
- With involvement of the bursa, pain may occur with pressure from the heel of the shoe on the bursa. The patient may need to wear open-heeled shoes temporarily.

●Orthoses/Taping

- Insert a heel lift into the shoe to relieve stress from decreased talocrural dorsiflexion motion. As the individual completes their home stretching program, the height of the heel lift can be reduced.
- Calcaneal tendon taping: Tape the ankle posteriorly to support the tendon, place the foot in plantarflexion, tape from the distal posterior calf to midarch of the foot.

Hypomobility Syndrome

The principal movement impairment in hypomobility syndrome is associated with a limitation in the physiological and accessory motion of the foot and ankle. This may result from degenerative changes in the joint or the effects of prolonged immobilization.

Symptoms and History

Degenerative Changes (OA, RA)

- Pain with weight bearing (gait, standing, stairs), that decreases with rest
- Pain location deep in joint and often described as vague
- Gradual onset
- May complain of stiffness, especially after periods of rest
- History of remote trauma or surgery to the ankle/foot
- Narrowing of joint space seen on standing x-rays
- Typically seen in older adults >55 years old

Immobilization

- History of recent trauma or surgery
- Ankle/foot ROM has not progressed as expected (slow recovery)

Common Referring Diagnoses

- ORIF of ankle and/or foot
- Fracture of ankle and/or foot
- Tendon or muscle rupture/repair
- Microfracture surgery (most often on talus)
- Osteochondritis dissecans
- OA
- RA

Key Tests and Signs for Movement Impairment

Alignment Analysis

- Atrophy of calf and foot muscles
- Edema
- Signs of inflammation in foot and ankle

Movement Impairment Analysis

Standing

Gait/running

- Antalgic gait: Decreased step length on uninvolved side or bilaterally secondary to joint pain and ROM limitation of ankle/foot
- Poor tolerance of full weight bearing
- Dependent on assistive device for ambulation

Step-down or small knee bend

- Limited ankle mobility
- Descending stairs forward is limited by ankle mobility; patient may need to turn sideways, backward, or avoid descending reciprocally

Single-Leg Stance

- The ability to maintain single-leg stance on the involved side will be impaired (poor control and decreased duration).
- Lack of ability to balance on one foot is often evident with the eyes open and performance worsens when the patient is instructed to close their eyes, limiting visual input and isolating foot and ankle proprioception.

Muscle Length/Joint ROM Impairments

- Based on length, ROM tests, and accessory joint assessments
- Limited physiological and accessory motion of involved and surrounding foot and ankle joints
- With degenerative changes, repeated passive ROM to end-range should decrease pain or improve symptoms

Source of Signs and Symptoms**Joint/Bone Symptoms**

- Joint clearing tests (end-range joint motion with overpressure) will be painful

Associated Signs or Contributing Factors

- Palpation: Tenderness at the site of fracture/surgery
- The foot is generally sore
- Muscle Strength/Performance Impairments
- Based on MMT and/or functional performance
 - Weakness in all foot and ankle musculature, particularly the gastrocnemius

Balance/Proprioception

- Inability to maintain single-leg stance on the involved side with the control and for the duration that is performed on the uninvolved side; performance worsens with eyes closed

Differential Diagnosis**Movement Diagnosis**

- Tissue impairment

Potential Diagnosis Requiring Referral Suggested by Signs and Symptoms

- Unstable fracture
- DJD
- Sympathetically maintained pain

Treatment

Inflammation and Pain Control

- Ice (may be contraindicated if patient is hypersensitive or with OA or RA)
- Heat is often helpful in decreasing feelings of joint stiffness and pain
- Compression garment

Walking and/or Running

- The presence of OA and/or RA often requires the individual to discontinue weight-bearing, high impact, and high repetition activities (walking or running for fitness). The patient often needs to be guided into lower impact activities, such as stationary bicycling, water aerobics, or use of a StairMaster/elliptical, or activities, such as rowing, that involve aerobic fitness through the upper extremities. Weight loss can also significantly impact pain with weight-bearing activities and should be discussed if appropriate for the patient.
- Walking with a limp can result in injury to other areas of the body (knee, hip, back, or uninvolved foot). All efforts to correct the gait pattern should be employed, including work on weight shifting, a gradual increase in weight-bearing tolerance, and addressing the strength and motion impairments contributing to the gait pattern. Use of assistive devices may be temporarily or permanently indicated for patients.

Muscle Performance

- Weakness of the plantarflexors (gastrocnemius, posterior tibialis muscles)
 - Thera-Band resistance exercise into plantar flexion and plantar flexion inversion
 - Heel raises
 - Eccentric training
 - Bilateral and single-leg hopping
 - Cutting, sprinting, and sport-specific activities
- Weakness of the anterior tibialis muscle
 - Thera-Band resistance exercise into dorsiflexion and/or inversion
- Weakness of the fibular (peroneal) muscles
 - Thera-Band resistance exercise into plantarflexion and/or eversion
- Weakness of the intrinsic muscles of the foot
 - Towel crunches: Towel is placed on the floor, using toes to grab towel, then pull it under the foot. Weight can be added to the towel to increase resistance. The arch should lift; do not allow the patient to only use the flexor digitorum longus.

After the tissue injury has been protected from excessive stresses and the inflammation has subsided, the involved muscle and tendon should undergo a progressive strengthening program and a progressive return to activity. In general, exercise or activity is permissible if pain remains at 2/10 on a 0 to 10 scale. The strengthening exercise should be completed at a minimum of 70% maximum voluntary contraction for 10 repetitions, 3 sets, 3 to 5 times/week.

Decreased Range of Motion

- Decreased dorsiflexion: Short gastrocnemius/soleus muscle/calcaneal tendon
 - Wall stretch: The knee is extended for gastrocnemius muscle shortness and flexed for soleus length deficits. The patient should be instructed to keep the foot facing forward or in line with the femur and tibia. The heel should be kept on the ground during the stretch. The patient should prevent subtalar joint pronation through active correction and by wearing good footwear. The stretch should be held for 30 seconds, completed 2 to 3 times/session, and done regularly throughout the day (5 to 8 times/day).
 - Heel-hang stretch: The knee can be extended or flexed as described for the wall stretch. The patient should prevent subtalar joint pronation through active patient correction and/or wearing good footwear.
 - Long sitting towel-assisted dorsiflexion: The patient should prevent subtalar joint pronation through active correction and by modifying the direction of force through the towel.
 - A night splint to maintain dorsiflexion position is often helpful.
 - Stretches should be held for 30 seconds, 2 to 3 repetitions, completed regularly throughout the day (5 to 8 times/day), and done 5 to 7 days/week.
- Talocrural joint limitation
 - Mobilize the talocrural joint using a posterior glide of the talus on the ankle mortise.
 - Mobilize the talocrural joint using a distraction technique.
 - May need to include a heel lift in the shoe until length changes are apparent.
- Decreased plantar flexion: Short dorsiflexor muscles
 - Hands and knees rocking back.
 - Sustained active ROM (AROM) and PROM.
- Decreased inversion/eversion: Subtalar joint limitation
 - Mobilize the subtalar joint using lateral and medial glides.
- Decreased intertarsal mobility
 - Mobilize specific intertarsal joints primarily using anterior and posterior glides.
- Decreased MTP and interphalangeal flexion and extension
 - Mobilize MTP and IP joint primarily using anterior (for extension) and posterior (for flexion) glides.

General ROM Activities

- Stationary bike.
- Baps board or wobble in sitting when weight-bearing tolerance is limited, progressing to standing activities when weight-bearing tolerance increases.

Activity

- Progress weight bearing gradually, reducing dependence on and type of assistive device.

- Address cardiovascular fitness with use of low impact activities (stationary bike, swimming, rowing, or Stair-Master/elliptical training).
- If appropriate for the patient's goals, progress to dynamic activities such as jumping, hopping, shuttle run, cutting, and so on.
- Running progression rules:
 - Start with straight plane jogging and jumping on a smooth flat surface.
 - Work on distance tolerance first.
 - Increase speed as tolerated.
 - Add varied terrain, hills, and cutting (these can include figure 8s).
 - Finally, add cuts and turns that are unexpected. For example, have the patient run straight forward and call cut right. He or she is expected to change directions immediately. Mix the calls, including cut left, 180 degrees turn, 360 degrees turn, and bend down.

External Tissue Support

Footwear

- Appropriate size, width, and depth to accommodate edematous foot.
- A last that looks like the foot. May be curved, straight, or in between (midlast), depending on the shape of the individual's foot.
- Footwear should include the standard shoe components to provide the necessary support and cushion. This includes a firm heel counter, the appropriate amount of arch support, and cushion, which is indicated only as needed for shock absorption.
- For individuals with OA or RA or those who have had fusion of joints in their foot, a steel shank in the sole of the shoe will make the sole of the shoe rigid and a rocker at the toe break will allow the patient to more easily roll over the foot without needing as much talocrural dorsiflexion or MTP dorsiflexion.

Orthoses

- For individuals with OA or RA, a total contact insert made of accommodative material is often indicated. Deformities of the foot should be considered in the design and materials chosen for the orthosis.
- A heel lift may be necessary to manage the loss of dorsiflexion ROM.

- Temporary orthoses with additional arch support are often indicated to manage foot pain that is often related to the new onset of a pronation impairment that results from the limited foot and ankle mobility.

Scar

- Firm and raised
 - TopiGel sheeting (chemical reaction)
 - Pressure
- Immobile
 - Gradual application of stress to scar helps the scar remodel in such a way that it allows gliding between structures.
 - AROM and PROM
- Immobile or adhered scar
 - Massage: Use circular motions and friction, minimum 5 to 6 times/day, 5 minutes each time. Using Dycem or wearing a latex glove on the uninjured hand may help increase friction.

Hypersensitivity

- Desensitization exercises
 - Progress from light touch to more firm touch.
 - Progress from soft texture to a rough texture.
 - Add additional sensation such as vibration and tapping as tolerated.
 - Emphasize weight-bearing and ROM exercises.
 - Activity and exercise is better tolerated if heat has been applied (hot pack or exercise in warm whirlpool or pool).

Balance and Proprioception

- Stand on the involved leg with eyes open.
- Stand on the involved leg with eyes closed.
- Stand on the involved leg on foam or uneven surface with eyes open.
- Stand on the involved leg on foam or uneven surface with eyes closed.
- Stand on one leg and do the following:
 - Kick and stop a ball.
 - Throw and catch a ball.
 - Reach with hand.
- Do similar activities on a mini-trampoline or other challenging surface.

Foot and Ankle Impairment

A key criterion for placement into the foot and ankle impairment classification is the need to protect tissue. Usually, the tissue involved is stressed by a surgical procedure or trauma and may cause significant pain at rest and during movement. The patient is unable to tolerate a typical movement system examination. The limitation in movement is not primarily related to a chronic pain condition. Tissue healing and normal movement are expected. These are general guidelines and not intended to stand alone. Consult the physician's protocol for specific precautions and progressions. The physical therapist must be familiar with the tissues that were affected in the surgical procedure.

Symptoms and History

- Patient has history of surgery or acute injury.
- Knowledge of specific surgical approach or injury is mandatory.
- Patient may report severe pain.

Physiological Factors

Factors that affect the physical stress of tissue and/or thresholds of tissue adaptation and injury¹ specific to the foot are as follows.

Tissue Factors

- Bone
 - Fractures of the base of the fifth metatarsal have a high probability of nonunion secondary to the pull of the fibularis brevis. Additionally, stress fractures of the anterior lateral tibial diaphysis, medial malleolus, talus, navicular, and sesamoids are high-risk areas that often fail to heal, re-fracture, and/or need operative intervention.²
- Cartilage
- Muscle
 - Common to lose dorsiflexion ROM with immobilization.
 - Common to experience atrophy of gastrocnemius/soleus muscle with immobilization.
- Tendon
 - Calcaneal tendon rupture: Gastrocnemius/soleus muscle contraction contraindicated; may have dorsiflexion ROM restrictions.
 - Posterior tibial tendon injury or insufficiency: If severe, may result in significant deformity of the arch (flattening); may require long periods of immobilization or surgery. Contraction of the posterior tibial muscle would be contraindicated after surgery.
- Ligament
 - Lateral ankle sprain: Often accompanied by an avulsion fracture of the lateral malleolus.
 - Syndesmotic ankle sprain ("high ankle sprain"): Associated with greater discomfort during

weight-bearing function and longer healing time and may require immobilization.³

- Skin
 - Edema has the potential to limit mobility and compromise the space occupied by nerves and arteries; often encountered under the extensor retinaculum and the flexor retinaculum; note location and measure extent of edema; assess whether it is brawny or pitting.
 - Scar: Note location, appearance, mobility, sensitivity, and if incision appears healed (approximately 10 days).
 - Color: Note location and size of discoloration, including bruising and other important changes in color (red, white, blue, or black).
 - Temperature: Note location of warmth.
- Nerve
 - Deep fibular (peroneal) nerve can be compromised as it runs beneath the extensor retinaculum.
 - Tibial nerve can be compressed as it runs beneath the flexor retinaculum.
 - Interdigital nerve.

Types of Surgeries (Indications)

- Stabilization (fracture, avascular necrosis [AVN], osteosarcoma)
 - ORIF
 - External fixation
 - Fusion
 - Bone graft
- Osteotomy (malalignment or osteosarcoma)
 - Calcaneal
 - Metatarsal
 - Phalangeal
- Arthroplasty (DJD, arthritis, joint destruction)
- Compartment decompression (crush injury, overuse with loss of arterial blood flow)
- Debridement (tear, arthritis, or infection)
 - Capsule
 - Cartilage
 - Wound
- Repair (tear, graft, or cell injections—open or arthroscopic)
 - Ligament
 - Cartilage
 - Tendon
- Soft tissue release (short tissue or spastic muscle)
 - Gastrocnemius/soleus muscle/calcaneal tendon
 - Plantar fascia
- Excision
 - Neuromas
 - Tumors
 - Bone

Medications

- Consider side effects and effects of medications on tissue, exam, and intervention
 - Nonsteroidal antiinflammatory drugs (NSAIDs)

- Muscle relaxants
- Analgesics
- Steroids

Medical Complications

- DVT
- Pulmonary embolus
- Fibular (peroneal) nerve neurapraxia
- Neurovascular compromise
- Compartment syndrome
- Infection
- Nonunion and malunion

Movement and Alignment Factors

- Variations
 - Anthropomorphics
 - Structural impairments
 - Scar adhesions

- Standing alignment
 - May demonstrate protective stance or rotational impairments

Underlying Movement Impairment Syndromes

- Pronation
- Supination
- Insufficient dorsiflexion
- Hypomobility

Extrinsic Factors

- Assistive devices to unload extremity
- Orthotic devices or braces

Psychosocial Factors

- Response to pain and/or anxiety

Treatment for Foot and Ankle Impairment

Emphasis of treatment is to restore ROM of the ankle and strength of the lower extremity without adding excessive stresses to the injured tissues and within the precautions outlined by the physician. Underlying movement impairments should be addressed during rehabilitation and functional activities to ensure optimal stresses to the healing tissues.

Impairments

Pain

Be sure to clarify the location, quality, and intensity of the pain.

Stage 1

Surgical: Within the first 2 weeks of the postoperative period, some pain will be associated with exercises. Gradually over the next few weeks, pain associated with the exercise should lessen. Pain can be used as a guide to rehabilitation. Sharp, stabbing pain should be avoided. Mild aching is expected after exercises but should be tolerable for the patient. This postexercise discomfort should decrease within 1 to 2 hours of the rehabilitation. A sudden increase in symptoms or symptoms that last longer than 2 hours after exercise may indicate that the rehabilitation program is too aggressive. Coordinating the use of analgesics with exercise sessions is important.

Acute Injury: Despite discomfort, tests may need to be performed to rule out serious injury. Modalities and taping/bracing may be helpful to decrease pain. The patient may also require the use of an assistive device, walker, or crutches in the early phases of healing.

Stage 2 to 3

Surgical/Acute Injury: Pain associated with the specific tissue that was involved in the surgery should be decreased by weeks 4 to 6. As the activity level of the patient is progressed, the patient may report increased pain or discomfort with new activities such as returning to daily activities and fitness. Pain or discomfort location should be monitored closely. Muscle soreness is expected, similar to the response of muscle to overload stimulus (e.g., weight training). General muscle soreness should be allowed to resolve, usually 1 to 2 days before repeating the bout of activity. Pain described as stabbing should always be avoided.

Edema

Stage 1

Surgical/Acute Injury: Edema is quite common in the foot and ankle s/p surgery or injury. The patient should be educated in use of edema-controlling techniques, such as the following:

- Ice⁺
- Elevation
- Compression: Ace wraps, compression stockings

Patient should be encouraged to keep extremity elevated as much as possible particularly in the early phases (1 to 3 weeks). Application of ice after exercise is recommended. Other methods to control edema in the foot and ankle include electrical stimulation or compression pumps.

Measurement of edema should be taken at each visit. A sudden increase in edema may indicate that the rehabilitation program is too aggressive or the patient possibly has an infection.

Stage 2 to 3

Surgical/Acute Injury: Time until swelling is resolved is variable among patients and surgical procedures. As the patient increases the time spent on their feet in regular daily activities or more weight-bearing exercises, the patient may experience a slight increase in edema. This is to be expected; however, the patient should be encouraged to continue to use techniques stated previously to manage the edema.

Appearance

Stage 1

Surgical: Infections should be suspected if the area around the incision or the involved joint is red, hot, and/or swollen. An increase in drainage from the incision, particularly if it has a foul odor or is no longer a clear color, is also indication of an infection. Red streaks following the lymphatic system can also appear with infection. The physician should be consulted immediately if infection is suspected. It is common to observe bruising after surgery. This should be monitored continuously for any changes; an increase in bruising during the rehabilitation phases may indicate infection. Stitches are typically removed in 7 to 14 days.

Stage 2 to 3

Surgical: Incisions should be well healed. Bruising may still be present for as long as 3 to 4 weeks; however, it should be diminishing. Signs of increased bruising are a red flag and should be immediately referred to the physician.

ROM

Stage 1

Surgical/Acute Injury: To prevent contracture, ROM exercises should begin as soon as possible as allowed by the precautions. In the early phases of rehabilitation, the patient should perform ROM exercises at least three times per day and all exercises should be performed within pain tolerance. All uninvolved lower extremity joints should be exercised to prevent the development of restricted ROM at those joints. The typical exercise progression begins with gentle PROM, assisted AROM, or AROM. The choice between PROM, assisted AROM, and AROM is based in part on the tissue injured or repaired. If resistance is allowed, proprioceptive neuromuscular facilitation (PNF) techniques, such as contract-relax or hold-relax, can assist in achieving greater ROM. During Stage 1, resistance should be very

gentle and can be progressed to a submaximum level as the patient tolerates. When performing ROM exercises of the ankle in the patient with a fracture, attention to hand placement during the exercises can minimize the stresses placed on the healing fracture site. Decreasing pain and edema and improving ROM are typical signs that it is safe to progress the exercises. Refer to specific protocols for guidelines regarding progression of the exercises.

The patient may have ROM precautions per the physician. A common example is tendon transfer with no ROM of the ankle.

Mobilizations to the following specific joints may be indicated (see the next section):

- Talocrural joint
- Midtarsal joints
- Tarsometatarsal joints
- Metatarsophalangeal and interphalangeal joints

Stage 2 to 3

Surgical/Acute Injury: Precautions are typically lifted by the time the patient reaches this stage. ROM should be approaching normal. Exercises may need to be progressed using passive force. Patient should be instructed that a stretching discomfort is expected; however, sharp pain should be avoided. Mobilizations may be indicated in later stages of rehabilitation to improve ROM. Consult with the physician before initiating joint mobilization after surgery of the knee.

Decreased Dorsiflexion

- Short gastrocnemius/soleus muscle/calcaneal tendon
 - Wall stretch: The knee is extended for gastrocnemius muscle shortness and flexed for soleus muscle length deficits. The patient should be instructed to keep their foot facing forward or in line with the femur and tibia. The heel should be kept on the ground during the stretch. The patient should prevent subtalar joint pronation through active correction and by wearing good footwear. The stretch should be held for 30 seconds, completed 2 to 3 times/session, and done regularly throughout the day (5 to 8 times/day).
 - Heel hang stretch: The knee can be extended or flexed as described for the wall stretch. The patient should prevent subtalar joint pronation through active correction and by wearing good footwear.
 - Long sitting towel-assisted dorsiflexion: The patient should prevent subtalar joint pronation through active correction and by modifying the direction of force through the towel.
 - A night splint to maintain dorsiflexion position is often helpful.
 - Stretches should be held for 30 seconds, 2 to 3 repetitions, completed regularly throughout the day (5 to 8 times/day), and done 5 to 7 days/week.
- Talocrural joint limitation
 - Mobilize the talocrural joint using a posterior glide of the talus on the ankle mortise.

- Mobilize the talocrural joint using a distraction technique.
- May need to include a heel lift in the shoe until length changes are apparent.

Decreased Plantar Flexion

- Short dorsiflexor muscles
 - Hands and knees rocking back
 - Sustained AROM/PROM
- Talocrural joint limitation
 - Mobilize the talocrural joint using an anterior glide of the talus on the ankle mortise.
 - Mobilize the talocrural joint using a distraction technique.

Decreased Inversion/Eversion

- Subtalar joint limitation
 - Mobilize the subtalar joint using lateral and medial glides.

Decreased Intertarsal Mobility

- Mobilize specific intertarsal joints, primarily using anterior and posterior glides.

Decreased Metatarsophalangeal and Interphalangeal Flexion and Extension

- Mobilize MTP and interphalangeal joints, primarily using anterior (for extension) and posterior (for flexion) glides.

General Range-of-Motion Activities

- Stationary bike.
- Baps board or wobble in sitting when weight-bearing tolerance is limited, progressing to standing activities when weight-bearing tolerance increases.

Muscle Performance

Stage 1

Surgical/Acute Injury: Strengthening often begins after the initial phase of healing (4 weeks). The emphasis should be placed on proper movement patterns in preparation for strengthening activities. After 4 weeks, strengthening may be gradually incorporated. Progression to resistive exercise is based on the patient's ability to perform ROM with a good movement pattern and without increase in pain. Weights, Thera-Band, or isokinetic equipment may be used. Specific exercise protocols provided by physicians and physical therapists should be evaluated to ensure that all exercises are appropriate for the individual's situation. Gastrocnemius/soleus muscles are most commonly affected with surgery or injury to the ankle; however, others may be involved. Electrical stimulation or biofeedback may be used to improve strengthening (see the "Medications, Modalities, and Additional Interventions" section). The patient may have strengthening precautions per the physician.

Stage 2 to 3

Surgical/Acute Injury: After the tissue injury has been protected from excessive stresses and the inflammation has subsided, the involved muscle and tendon should undergo a progressive strengthening program and a progressive return to activity. At this stage, precautions are typically

lifted. Strength activities can be progressed as tolerated by the patient. In general, exercise or activity is permissible if pain remains at 2/10 on a 0 to 10 scale. The strengthening exercise should be completed at a minimum of 70% maximum voluntary contraction for 10 repetitions, 3 sets, 3 to 5 times/week.

- Plantarflexors (gastrocnemius, posterior tibialis muscles)
 - Thera-Band resistance exercise into plantarflexion and plantarflexion inversion.
- Heel raises: This exercise can be started with both feet on the ground with greater weight on the uninjured side. As strength improves, the patient is instructed to increase weight on the involved extremity with the goal of completing the heel raise with all of the individual's weight on the involved side (single heel raise). The exercise should be performed with good control during the concentric and eccentric portions of the exercise.
- Bilateral and single-leg hops.
- Anterior tibialis muscle
 - Thera-Band resistance exercise into dorsiflexion inversion: Have the patient curl the toes down if the extensor digitorum and extensor hallucis are dominant.
- Fibular (peroneal) muscles
 - Thera-Band resistance exercise into plantarflexion eversion.
- Intrinsic muscles of the foot
 - Towel crunches: Towel placed on the floor, use the toes to grab the towel, pulling it under the foot. Weight can be added to the towel to increase resistance. The arch should lift; do not allow the patient to only use the flexor digitorum longus.

Proprioception and Balance⁵⁻¹²

Stage 1

Surgical/Acute Injury: Activities to improve proprioception of the lower extremity should be incorporated as soon as possible. Begin early in treatment, using activities such as weight shifting, progressive increases in weight-bearing function on the involved lower extremity, and then eventually unilateral stance. As the patient improves, the eyes should be closed to increase the challenge for the lower extremity. As the patient can take full weight on the involved lower extremity, activities are progressed to use of a balance board and closed chained activities such as wall sits and lunges.

Stage 2 to 3

Surgical/Acute Injury: In this stage, precautions are typically lifted. Activities should be progressed to prepare patient to return to daily activities, fitness routines, and work or sporting activities. As the patient progresses, proprioception can be challenged by asking the patient to stand on unstable surfaces (pillows, trampoline, or BOSU ball), perturbations can be applied through having the patient catch a ball being thrown to him or her while

standing on one leg. Sliding board activities have been shown to be beneficial to patients after surgery.¹³ The prescription regarding frequency and duration of proprioceptive exercise training remains unclear, but research in this area supports a measurable and sustainable change in balance measures with a maximum of 10 weeks of training, 3 to 5 days/week, for 10 to 15 minutes.⁶⁻¹²

Cardiovascular and Muscular Endurance

Stage 1

Surgical/Acute Injury: Stationary bicycle riding can be started early in the rehabilitation if the patient's weight-bearing precautions allow. If weight-bearing precautions prohibit riding with the involved extremity, unilateral cycling can be performed with the uninvolved extremity. The involved extremity is supported on a stationary surface, while the patient pedals with the uninvolved extremity. The individual should start with low resistance stationary cycling and as strength improves, resistance should be increased. Water walking and swimming are good substitutes for full weight-bearing activities. For swimming, if kicking against the resistance is contraindicated, the patient may participate in swim drills that mainly challenge the upper extremities for conditioning.

Stage 2 to 3

Surgical/Acute Injury: The patient may be progressed to activities such as water walking, to walking on a treadmill, to an elliptical machine, to a Nordic ski machine, to a StairMaster, and then running and hopping when appropriate. The patient should be given specific instructions in gradual progression of these activities. See the "Work, School, and Higher-Level Activities" section for progression of running.

Patient Education

Stage 1 to 3

Surgical/Acute Injury: Educate the patient in specific medical precautions when indicated.

- Instruct the patient in proper method to don and doff brace if indicated.
- Educate the patient in timeline to return to activity, often driven by physician's guidelines.
- Educate the patient in maintaining precautions during various functional activities (e.g., ambulation, stairs, and transfers).
- Educate the patient in appropriate wound care and monitoring.

Scar and Sensitivity

Stage 1 to 3

Surgical: The gradual application of stress to scars, incisions, or port holes helps the scar remodel. Exercise, massage, compression, silicone gel sheets, and vibration are used in the management of scar. A hypersensitive scar requires desensitization. A dry incision that has been closed and reopens as the result of the stresses applied

with scar massage indicates that the scar massage is too aggressive. Refer to specific guidelines for management of scar for more treatment suggestions. Scars may require desensitization exercises as follows:

- Progress from light touch to more firm touch.
- Progress from soft texture to a rough texture.
- Add additional sensation such as vibration and tapping as tolerated.
- Emphasize weight-bearing and ROM exercises.
- Activity and exercise is better tolerated if heat has been applied (hot pack or exercise in warm whirlpool or pool).

Changes in Status

Stage 1 to 3

Surgical/Acute Injury: Consider carefully reports of increased pain or edema or significant change in ROM, especially in combination. The patient should be questioned regarding precipitating events (e.g., time of onset, activity, and so on). If the integrity of the surgery is in doubt, contact the physician promptly. If the patient has fever and erythema spreading from the incision, the physician should be contacted because of the possibility of infection.

Functional Mobility

Basic Mobility

Stage 1

Surgical/Acute Injury: The patient should be instructed in mobility while following medical precautions.

Sit to Stand: The patient should be instructed in the proper use of assistive device if a device is indicated and performance maintains prescribed weight-bearing precautions.

Ambulation: The patient may have weight-bearing precautions. The patient should be instructed in the proper use of an assistive device and proper gait pattern. Emphasis should be placed on normalizing the patient's gait pattern. If the patient is given partial or toe-touch weight-bearing restrictions, the patient should be instructed in using a heel-to-toe pattern while restricting the amount of weight that is accepted by the lower extremity. The patient should not place his weight on the ball of his foot only.

Stairs: The patient should be instructed in the proper stair ambulation with use of an assistive device (if indicated). In the early phases of healing (s/p surgery or acute injury), the patient should be instructed to use a step-to cadence, lead with the involved lower extremity when descending stairs, and lead with the uninvolved lower extremity when ascending stairs.

Stage 2 and 3

Surgical/Acute Injury:

All Mobility: As weight-bearing precautions are lifted, the patient should be instructed to gradually reduce the level or type of assistive device required. Progression

away from the device depends on the ability of the patient to achieve a normal gait pattern. If the patient demonstrates a significant gait deviation secondary to pain or weakness, the patient should continue to use the device. This may prevent the adaptation of movement impairment and development of pain problems in the future. A progression may be as follows: walker to crutches to one crutch to cane to no assistive device.

Stairs: As the patient progresses through the healing stages and can accept more weight on the involved leg, he or she should be instructed in normal stair ambulation for ascending and descending.

Work, School, and Higher-Level Activities

Stage 1

Surgical/Acute Injury: The patient may be off work or school in the immediate postoperative period or after acute injury. When the patient is cleared to return to work/school, he or she should be instructed in gradual resumption of activities. Emphasis should also be placed on edema control, particularly elevation and compression.

Stage 2 and 3

Surgical/Acute Injury: The patient should be prepared to return to their previous activities. Suggestions for improving proprioception and balance are provided in a previous section. In preparation for the return to sports, sport-specific activities should be added. The initial phases of these activities will include straight plane activities at a slow pace and then gradually increase the level of difficulty. The following sections are examples of activity progression:

Agility Exercises: Emphasis is placed on proper form.

- Hopping timed: Within each level, begin with short bouts of hopping and longer rests between (15 seconds on, 30 seconds off), then increase on time and decrease off time (30 seconds on, 15 seconds off).
- Hopping bilateral lower extremities with support of the upper extremities to decrease the amount of stress through the knee.
- Hopping bilateral lower extremities without support.
- Hopping bilateral lower extremities in different directions: Side-to-side, back and forth, box, V, and zigzag hopping.
- Progress to same activities with unilateral lower extremities.
- Jumping from short surface (2 inches). Emphasis should be placed on landing on both feet evenly, knees flexed, and with neutral knees over toes (avoid excessive valgus or femoral medial rotation). The patient should also think about landing softly to help absorb the landing.^{5,14}
- Jump forward, backward, and off to each side.
- Progress by increasing the height of the surface.
- Jumping up on to surface: Begin with shorter surface and increase height when appropriate.
- Other plyometrics: Ladder drills.

Running: Early in the phases of running, the emphasis is placed on achieving an ideal gait pattern; speed or distance should not be emphasized. Assess gait pattern and instruct as appropriate. Cues are often needed to achieve a heel-toe gait pattern. The patient should run on even and soft surfaces initially. It is expected that the patient may experience some generalized discomfort or swelling with the initiation of running. If this generalized pain and swelling persists longer than 48 hours, then the running must be decreased. If the patient describes a stabbing pain or a pain that is consistent with tissue injury, running should be stopped and the patient reevaluated.

- Patient should be able to walk 30 minutes without an increase in pain or swelling to begin.
- Run 1: Walk 4 minutes, run 1 minute, repeat 4 times for 20 minutes.
- Rest day.
- Run 2: Walk 3 minutes, run 2 minutes, repeat 4 times for 20 minutes.
- Rest day.
- Run 3: Walk 2 minutes, run 3 minutes, repeat 4 times for 20 minutes.
- Continue to progress running appropriately. This example will not be appropriate for all patients and must be adjusted as needed.

Once the patient can run 1 mile without increasing pain or swelling, begin with other running drills such as the following:

- Figure 8 running, beginning with a large “8,” then decreasing the size of the “8” gradually.
- Zigzag running with soft cuts, hard cuts, cut and spin: Care should be taken to evaluate how the patient chooses to cut. Often (particularly in non-contact injuries), you will note that the patient has adopted an inefficient cutting pattern such as planting the left foot when trying to cut to the left.

Drills: Once the patient can complete cutting drills without pain or swelling and demonstrates good control of the lower extremity, variations can be added such as the following:

- Drills with sport-specific equipment (e.g., basketball, hockey stick, soccer ball)
- Partner drills

Special notes: If plyometrics and strengthening are to be performed during the same visit, plyometrics should be performed before the strengthening activities.⁵

Functional testing: Consider functional tests before the patient's return to sport. There are many functional tests available. The validity of these tests is controversial; however, each test can offer some insight to how the patient may perform in their specific sport. It is recommended that a battery of tests be used to assess the aspects of balance, coordination, agility, and strength. Common test items for the ankle/foot include the following:

- Single-leg hop for distance¹⁵
- Triple-leg hop for distance¹⁵
- 6-Meter hop for time^{15,16}

- Crossover hop for distance¹⁵
- 6-Meter shuttle run^{17,18}
- Vertical jump^{19,20}
- Lateral step²¹

Sleeping

Stage 1 to 3

Surgical/Acute Injury: Sleeping is often disrupted in the immediate postoperative period or after acute injury. The lower extremity should be slightly elevated (foot higher than the knee and knee higher than the hip) to minimize edema.

Support

Stage 1

Surgical: A brace may be used to protect the surgical site, depending on the procedure or type of fracture. A brace should fit comfortably. The patient should be educated in the timeline for wearing the brace. Refer to specific protocol or consult with physician if the wearing time is not clear.

Stage 2 to 3

Surgical: The recommendations concerning the need for bracing long term are varied. Communication among the team (patient, physician, and physical therapist) is necessary. Functional bracing is recommended if the patient wishes to return to high level sporting activities and demonstrates either laxity in the joint and/or performs poorly on functional tests.

Medications, Modalities, and Additional Interventions

Medications

Surgical: During the acute stage, physical therapy treatments should be timed with analgesics, typically 30 minutes after administration of oral medication. If medication is given intravenously, therapy often can occur immediately after administration. Communication with nurses and physicians is critical to provide optimal pain relief for the patient.

Acute Injury: The patient's medications should be reviewed to ensure that the patient is taking the medications appropriately.

Modalities: Thermal

Surgical/Acute Injury: Instruct the patient in proper home use of thermal modalities to decrease pain. Ice has been shown to be beneficial, particularly in the immediate postoperative phases.²²

Electrical Stimulation

Stage 1 to 3

Surgical/Acute Injury: Electrical stimulation can be used for three purposes: Pain relief, edema control, and strengthening. Interferential current has been shown to be helpful in decreasing pain and edema.²³⁻²⁵ Sensory level transcutaneous electrical stimulation (TENS) can assist in decreasing pain.

Currently, there is no definitive answer for the use of electrical stimulation for gastrocnemius/soleus muscle strengthening. It was once believed that electrical stimulation did not provide a distinct advantage over high-intensity exercise training.^{26,27} However, more recent studies support the use of stimulation to improve motor recruitment and strength.²⁷⁻³⁰ When strengthening the gastrocnemius/soleus muscles, portable units may not provide adequate stimulation and wall units are preferred; however, recent advances have produced more efficient portable units.

Be sure to check for contraindications. Avoid areas where metal is in close approximation of the skin.

Aquatic Therapy

Surgical/Acute Injury: Aquatic therapy to decrease weight bearing during ambulation may be helpful in the rehabilitation of patients after fracture or surgical procedures. Often, this medium is not available but should be considered if the patient's progress is slowed secondary to pain or the patient has difficulty maintaining weight-bearing precautions. Incisions must be healed before aquatic therapy is initiated.

Discharge Planning: Equipment

Stage 1

Surgical: Equipment that may be needed depends on the patient's abilities, precautions, and home environment.

- Assistive device: Walker, crutches, or cane
- Reacher
- Tub bench and hand-held shower

Discharge Planning: Therapy

Assess the need for physical therapy after discharge from an acute stay at a skilled nursing or rehabilitation facility, or if the patient has been discharged from a home health program or outpatient physical therapy.

After the acute phase of recovery, the patient should be reassessed to determine whether a movement impairment diagnosis exists. The patient should be given documentation for consistency of care. Documentation should include the following:

- Physician protocol, including precautions and progression of activities
- Progress of patient during physical therapist's care
- Expected outcomes

Proximal Tibiofibular Glide Syndrome

The principal movement impairment in proximal tibiofibular glide syndrome is posterior or superior motion of the fibula on the tibia during active hamstring contraction (especially during running). The principal positional impairment is the fibula located anterior, posterior, superior, or inferior to the normal position on the tibia after trauma, particularly an ankle sprain.

Symptoms and History

- Pain in posterolateral or lateral aspect of tibiofibular joint often associated with running or a history of lateral ankle sprains
- Numbness in the lateral/anterolateral knee and/or leg

Common Referring Diagnoses

- Knee pain
- Hamstring tendinopathy
- Fibular (lateral) collateral ligament sprain
- Posterolateral corner injury
- Entrapment of superficial fibular nerve

Key Tests and Signs for Movement Impairment

Alignment Analysis

- Palpation of the fibula location on tibia, relative to uninjured side reveals malalignment (anterior, posterior, and/or superior).
- A glide in the direction of the positional or movement impairment increases pain.
- A glide in the opposite direction of the positional or movement impairment decreases symptoms.

Movement Impairment Analysis

Sitting

- Resisted hamstring contraction increases pain at the tibiofibular joint.
- Manual stabilization of tibiofibular joint during hamstring contraction decreases pain.

Muscle Length/Joint ROM Impairments

- Positioning of limb at end-range of hamstrings muscle length (single-leg raise position of sitting knee extension) increases symptoms.

Source of Signs and Symptoms

Proximal Tibiofibular Joint Symptoms

- Palpation reveals local tenderness at the joint

Common Fibular (Peroneal) Nerve Symptoms

- Positive Tinel's test

Associated Signs or Contributing Factors**Muscle Length/Joint ROM Impairments**

- Based on length or ROM tests

Talocrural Dorsiflexion

- Limited if dorsiflexion <10 degrees with knee extended
 - Gastrocnemius muscle short if dorsiflexion ≥ 10 degrees with knee flexed
- Soleus muscle short if dorsiflexion ≤ 10 degrees with knee flexed and normal accessory talocrural motion
- Talocrural joint limitation if dorsiflexion ≤ 10 degrees, regardless of knee position and limited accessory talocrural joint motion (cannot rule out soleus muscle length limitation in this case)

Hamstring Muscle Length

- Knee extension limited >20 degrees from full extension

Differential Diagnosis**Movement Diagnosis**

- Hip extension with knee extension
- Hip extension with medial rotation
- Tibiofemoral rotation
- Knee extension

Potential Diagnosis Requiring Referral Suggested by Signs and Symptoms**Musculoskeletal**

- L3-L5 radiculopathy
- Meniscal injury
- Fibular (lateral) collateral ligament sprain
- Posterolateral corner injury
- Fracture

Neurological

- Fibular nerve compression palsy

Treatment

Inflammation and Pain Control

- Ice
- Iontophoresis
- Electrical stimulation

Walking and/or Running

- Walking and running cues focus on using proximal hip extensors and lateral rotator (gluteus maximus, gluteus medius, and intrinsic hip lateral rotators) to assist with controlling hip motion and decreasing use of lateral hamstrings.

Muscle Performance

- Gluteus maximus
 - Prone hip extension with the knee flexed.
 - Positioning: Patient's that have short hip flexors will require a pillow under the pelvis. Patient must be able to control the tibial positioning during prone knee flexion to begin this exercise.
 - Lunges, squats.
- Intrinsic hip lateral rotators and posterior gluteus medius (if indicated)
 - Prone hip lateral rotation isometrics (prone foot pushes)
 - Prone hip abduction
 - Sidelying hip abduction with lateral rotation (level 1, 2, or 3)

Monitor that patient feels the contraction in the "seat" region; the therapist must palpate to be sure that the patient is recruiting the correct muscles. Common cues for improve performance of the hip lateral rotators include the following:

- Positioning: The pelvis may be rotated posteriorly too far. Ask the patient to roll the pelvis anteriorly.
- Positioning: Place a pillow between the knees.
- Spin the thigh around an axis longitudinally through the femur.
- Weight shifting with gluteal squeeze on the stance lower extremity; progress to standing on one leg with correct alignment; progress to resisted activities of the opposite leg while standing on the affected leg.
- Lunges: Resisted; using Thera-Band around proximal thigh, the therapist pulls in the direction of medial rotation and adduction.

After the tissue injury has been protected from excessive stresses and the inflammation has subsided, the involved muscle and tendon should undergo a progressive strengthening program and a progressive return to activity. In general, exercise or activity is permissible if pain remains at 2/10 on a 0 to 10 scale. The strengthening exercise should be completed at a minimum of 70% maximum voluntary contraction for 10 repetitions, 3 sets, 3 to 5 times/week.

Decreased Dorsiflexion

- Short gastrocnemius/soleus muscle/calcaneal tendon
 - Wall stretch: The knee is extended for gastrocnemius muscle shortness and flexed for soleus muscle

length deficits. The patient should be instructed to keep their foot facing forward or in line with the femur and tibia. The heel should be kept on the ground during the stretch. The patient should prevent subtalar joint pronation through active patient correction and by wearing good footwear. The stretch should be held for 30 seconds, completed 2 to 3 times/session, and done regularly throughout the day (5 to 8 times/day).

- Heel hang stretch: The knee can be extended or flexed as described for the wall stretch. The patient should prevent subtalar joint pronation through active correction and by wearing good footwear.
- Long sitting towel-assisted dorsiflexion. The patient should prevent subtalar joint pronation through active correction and by modifying the direction of force through the towel.
- A night splint to maintain dorsiflexion position is often helpful.
- Stretches should be held for 30 seconds, 2 to 3 repetitions, completed regularly throughout the day (5 to 8 times/day), and done 5 to 7 days/week.
- Talocrural joint limitation
 - Mobilize the talocrural joint using a posterior glide of the talus on the ankle mortise.
 - Mobilize the talocrural joint using a distraction technique.
 - May need to include a heel lift in the shoe until length changes are apparent.

Decreased Hamstring Muscle Length

- Hamstrings
 - Active sitting knee extension with dorsiflexion with hip in neutral rotation.

Positional Fault

- Mobilization/manipulation of the fibula on the tibia as indicated by evaluation findings.
 - The choice of which grade of movement to choose depends on how much shortening has occurred to the associated joint structures. Chronic conditions typically have shortening of the tissues surrounding the joint. Thus chronic conditions usually respond to prolonged stretching (creep) of the tissues gained with grade IV oscillations, primarily ending with grade III oscillations to ease the joint gently out of the grade IV stretching that was just performed.
 - Acute conditions are not likely to have shortening of surrounding tissues and often are too painful to be mobilized back and forth. Rather, a high-velocity movement is much less painful and corrects the fault.

External Tissue Support

Orthoses/Taping

- Potential to develop a taping strategy to attempt to immobilize or limit motion between the proximal tibia and fibula

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