# Painful Shoulder

## *Exercise Can Reduce Pain and Improve Mobility and Function*

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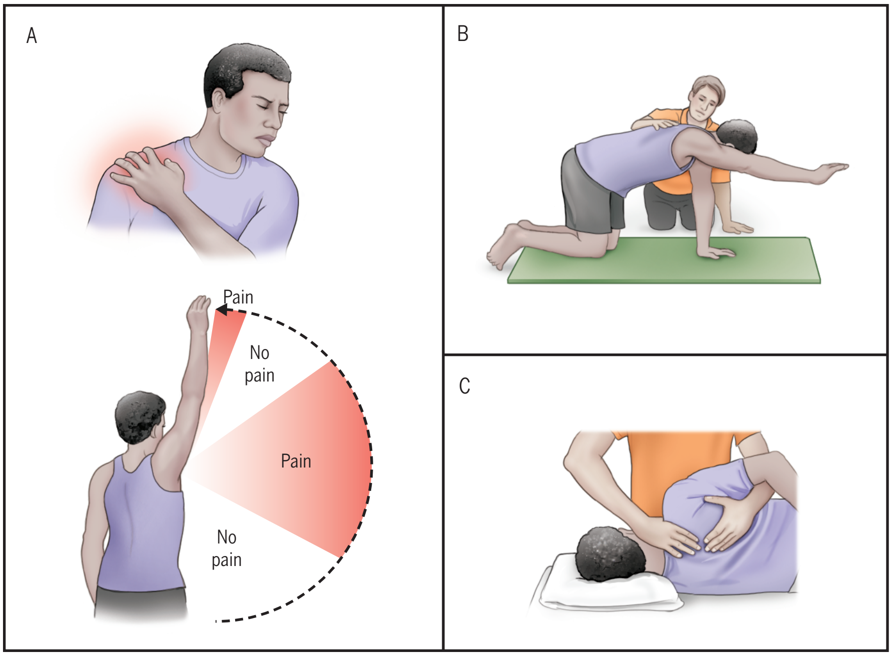
Shoulder pain is common, especially as we age. Pain that limits your ability to raise your arm above your head or rotate your shoulder is called "subacromial shoulder pain." Other names you may hear include rotator cuff tendinopathy, subacromial impingement syndrome, or rotator cuff–related shoulder pain. You may feel this type of pain during everyday activities, such as getting dressed.

The good news is that most people with subacromial shoulder pain improve with physical therapy. A review of the most up-to-date research published in the March 2020 issue of *JOSPT* concluded that shoulder exercises are the best way to manage this pain.




**ADDRESSING SHOULDER PAIN.** Shoulder pain that limits your ability to raise your arm or rotate your shoulder, as shown here (from between 45° and 60° to 120° and from 170° to 180°), is often called "subacromial shoulder pain" (A). Exercises that focus on strengthening your shoulder and shoulder blade are most likely to reduce pain and improve mobility. Your physical therapist will supervise these exercises in the clinic and may ask you to perform some of them at home to improve your results (B). Manual therapy of the shoulder can also be effective when combined with shoulder exercises (C).

### NEW INSIGHTS

The authors of the *JOSPT* review analyzed 202 systematic reviews published between 2012 and 2018 for quality and relevance. Sixteen reviews were included. The strongest recommendation was for shoulder exercises that were supervised in the clinic or performed at home. Different types of shoulder exercises reduced pain, improved shoulder movement, and increased shoulder function. The most common exercises prescribed included strengthening the muscles around the shoulder and shoulder blade, as well as exercises to improve shoulder mobility or quality of movement.

For patients with persistent shoulder pain, exercise therapy was just as effective as a corticosteroid injection in the short term and shoulder decompression surgery in the long term. In addition to shoulder exercises, manual therapy can help to decrease pain and improve shoulder mobility. The authors also recommended against using laser, ultrasound, extracorporeal shockwave, or pulsed electromagnetic energy therapy to treat subacromial shoulder pain, due to the lack of supporting evidence.

### PRACTICAL ADVICE

Shoulder exercises are as effective as shoulder surgery and injections, and are less expensive and unlikely to generate negative side effects. They also offer the general health benefits of exercise.

To help guide your treatment and tailor a program to your needs, your physical therapist will discuss your concerns with you and perform a thorough evaluation. Depending on the findings, you may be prescribed different shoulder-strengthening and/or mobility exercises, which may be combined with manual therapy.

This *JOSPT* Perspectives for Patients is based on a literature review by Pieters et al titled "An Update of Systematic Reviews Examining the Effectiveness of Conservative Physical Therapy Interventions for Subacromial Shoulder Pain" (*J Orthop Sports Phys Ther 2020;50(3):131-141. https://doi.org/10.2519/jospt.2020.8498*).

This Perspectives article was written by a team of *JOSPT*'s editorial board and staff. Deydre S. Teyhen, PT, PhD, Editor, and Jeanne Robertson, Illustrator.

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# Four Examples of Potential Competing Interests Affecting How Clinicians Read and Use Research: Financial, Academic, Idealistic, and Personal

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The integrity of published scientific literature relies on transparency. There are processes in place to promote transparency and enhance the trustworthiness of study results. Journals, including the *Journal of Orthopaedic & Sports Physical Therapy* (*JOSPT*), require full disclosure of competing interests when authors submit manuscripts for publication. A competing interest is "a financial or intellectual relationship that may impact an individual's ability to approach a scientific question with an open mind."[5] The purpose of this editorial is to discuss the types of competing interests that may influence the work of authors.

## What Is a Competing Interest?

There are many potential sources of competing interests. One that *JOSPT* readers and authors would probably consider an obvious problem is a financial competing interest. When a researcher who conducts a randomized clinical trial demonstrating that intervention A is superior to a control group and the researcher has a financial stake in the outcome, the study results are at high risk of bias. Financial competing interests can include company ownership, speaker fees, royalties, payment for developing educational content, and salary.

Other less obvious competing interests can also have a pervasive impact on research integrity. These include academic, idealistic, or personal competing interests.[3,4] For example, a researcher who conducts a randomized controlled trial demonstrating that intervention A is superior and also teaches a course or publishes a book about the intervention or subject may have an academic competing interest. A physical therapist who specializes in manual therapy might view the results of a study comparing the effects of manual therapy to cortisone injections differently than a physiatrist.

Similarly, when researchers conduct a study, their experience and values consciously and unconsciously color the way they interpret data, which may be considered an idealistic competing interest. For example, a researcher who thinks that the pharmaceutical industry prioritizes large profits at the expense of a stressed health care system and patients who cannot afford medications may interpret study results examining the benefits of medications differently than someone who perceives the pharmaceutical industry in a more positive light.

Authors may also have personal competing interests. Imagine a study's principal investigator with a family member or friend whose reputation and life's work are invested in supporting a point of view. Personal interests could bias the study's results and potentially impact career opportunities for friends and family members of the researcher. However, it may be difficult to filter out the bias inherent in personal preference.

## Disclosure of Competing Interests

If every person with a potential competing interest was excluded from publishing, there would be no one left to publish on a topic.[1] All authors are human, and all authors (and readers) have some kind of competing interest—no matter how small. Disclosing potential conflicts of interest allows the reader to assess the likelihood and impact of such conflicts.

JOSPT encourages authors to disclose any relationship or financial affiliation with any commercial organization that has a direct financial interest in any matter included in the manuscript, or any other relationship or conflict that may be perceived to be a competing interest. JOSPT does not punish authors for disclosing potential competing interests—the *Journal* welcomes authors contributing to transparency. Disclosure of competing interests by authors does not adversely affect reviewers' quality rating of a manuscript.[2] Disclosing potential competing interests helps us all—*Journal* Editorial Board members, peer reviewers, and you, the reader—to judge whether the competing interest may have impacted the results of the research. ◉

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# Driving the Musculoskeletal Diagnosis Train on the High-Value Track

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Clinicians who provide high-value musculoskeletal care offer evidence-based management that can improve pain, function, and quality of life.[2,3] However, the current approach to improving outcomes emphasizes treatment strategies at the expense of accurate diagnosis.[3] Guidelines rarely provide quality information on differential diagnosis and prognosis.[3,9] The disconnect is worrying, because accurate diagnosis can lead to more appropriate care and improved patient outcomes. In this Viewpoint, we reflect on how the clinician can refine musculoskeletal diagnoses to provide high-value care. We (1) argue that the link between musculoskeletal diagnosis and patient outcomes must be strengthened, (2) introduce a diagnostic framework to help clinicians go beyond "special tests," and (3) present new methods for researchers to move forward from diagnostic accuracy studies.

## The Missing Link Between Musculoskeletal Diagnosis and Patient Outcomes

Musculoskeletal clinicians are unraveling the consequences of overdiagnosis and overuse of low-value services that negatively impact patient outcomes. Even when high-value musculoskeletal interventions are provided, effect sizes are typically moderate at best, and many patients continue to experience substantial pain or limitations.[9]

Reliance on oversimplified definitions of musculoskeletal diagnoses may limit the clinician's capacity to help patients.[9] Reviews, guidelines, and trials emphasize diagnostic labels such as "nonspecific low back pain," "neck pain," "knee osteoarthritis," "subacromial pain," "patellofemoral pain," and "femoroacetabular hip impingement."

Oversimplified diagnoses fail to acknowledge the complexity of common musculoskeletal conditions. Without an accurate diagnosis, it is difficult to plan treatment. Improving the process underpinning musculoskeletal diagnosis is required to deliver high-value care that is based on drivers of pain and disabilities. Adopting diagnostic frameworks may facilitate this process.

A diagnostic framework is a tool to help the clinician organize and prioritize information collection (eg, prognosis and phenotypes). Synthesis of complex patient data is the foundation of a "high-value" diagnosis.[1]

## Diagnostic Frameworks: The Next Step After Special Tests

The pathoanatomical model, based on special tests, underpins assessment of most musculoskeletal conditions. This approach is coherent with biologically driven constructs but fails to disentangle all clinical, psychological, behavioral, social, or environmental profiles known to impact the experience of living with musculoskeletal conditions. Diagnostic frameworks may help clinicians assess the complexity underlying common musculoskeletal conditions.

To reach a high-value musculoskeletal diagnosis that reflects the complexity of a condition, the following components must be thoughtfully assessed and integrated, often over multiple visits.

- Physical examination of strength, flexibility, biomechanical and mobility deficits, and movement patterns
- Symptoms and their impact using relevant patient-reported outcomes of pain and activity limitations
- Presence and relative contribution of psychological factors
- Structural and anatomical deficits relevant to the symptoms (eg, pathoanatomical causes, mechanism, instability)
- Risk factors and prognosis
- Neurological testing (eg, reflexes, sensory testing, pain pressure)

Integrating information to gain an understanding of the clinical profile of a musculoskeletal condition is a daunting task without a tool to orient clinical

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reasoning. We looked for tools that would help the clinician synthesize information obtained from various measures and better understand the complex drivers of pain and disability for common diagnostic labels and found 2 examples.

**Example 1: The Pain and Disability Drivers Management Model for Low Back Pain** Nonspecific low back pain is one of the most heterogeneous musculoskeletal diagnostic labels.[9] We designed[8] and validated[7] the Pain and Disability Drivers Management (PDDM) model to identify the domains driving pain and disability, based on the International Classification of Functioning, Disability and Health.

The PDDM model comprises 5 domains on which to base clinical assessment:

1. Nociceptive pain drivers (somatic, inflammatory, or mixed pain)
2. Nervous system dysfunction drivers (sensitization of peripheral and/or central nervous systems)
3. Cognitive-emotional drivers (maladaptive cognitions and/or behaviors)
4. Contextual drivers (occupational-related and environmental social contextual factors)
5. Comorbidity drivers (physical and/or mental health comorbidities)[8]

Underlying each domain is a series of elements (moderators of treatment) to assess whether a patient has a positive driver in each domain. To operationalize in clinical practice, 47 clinicians and researchers deemed to be experts in pain management participated in a modified Delphi survey. We generated a set of 51 essential elements across the 5 domains that require assessment[7] (**APPENDIX**, available at www.jospt.org).

The PDDM model serves as a diagnostic framework by its capacity to help identify, organize, and facilitate characterizing complex cases of low back pain (**FIGURE**). We are currently assessing clinicians' perceptions of the PDDM model to refine the diagnosis, reduce diagnostic uncertainty, establish a clinical profile, and improve decision-making processes related to treatment options.

**Example 2: Diagnostic Framework for Patellofemoral Pain** Patellofemoral pain also hides complex clinical profiles.[10] A group of experts designed an evidence-based pathomechanical model of patellofemoral pain, including different biomechanical profiles.[5] The model requires the integration of physical (eg, strength, mobility) and mechanical elements that may point to various treatment options.[5] The framework will be refined as new evidence arises, such as the influence of psychosocial factors.[10] The clinical practice guideline for patellofemoral pain recently published in *JOSPT* also proposes a classification based on the International Classification of Functioning, Disability and Health.[10]

These examples provide innovative ways of integrating information to refine common musculoskeletal diagnoses. Frameworks could be useful for other musculoskeletal conditions such as shoulder pain, neck pain, or knee osteoarthritis. If diagnostic frameworks represent a feasible solution to improve the value of musculoskeletal diagnoses, new methods will be required to assess their effectiveness.

## Moving From Diagnostic Accuracy Studies to Diagnostic Randomized Trials: How Researchers Can Help Clinicians and Patients

The field of musculoskeletal diagnosis has relied on diagnostic accuracy studies and metrics (eg, sensitivity and specificity)

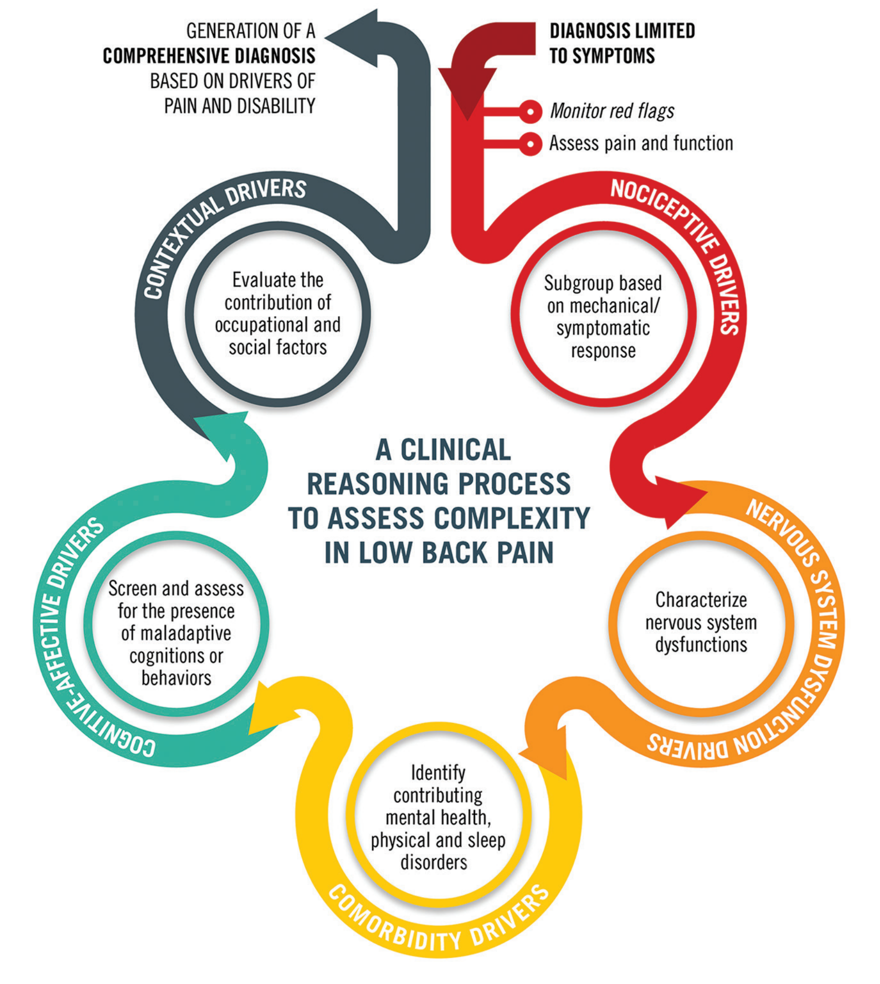


**FIGURE.** A clinical-reasoning process to assess complexity in low back pain.

comparing tests to a reference standard. Researchers involved in musculoskeletal diagnosis require new methods to evaluate the effectiveness of diagnostic frameworks for improving patient outcomes.

The Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach aims to assess the certainty of evidence from systematic reviews.[4,6] Initially designed for reviews of interventions, the GRADE approach proposed new methods to link the effect of diagnostic tests to improving patient outcomes.[4,6]

In the GRADE framework, a diagnostic accuracy study is the first step in deciding whether a test is valid for clinical use.[4,6] However, a test's accuracy is an intermediate stage in the diagnostic process that becomes valuable when it drives efficient decision making to improve outcomes.[4] For example, there is strong evidence for the diagnostic accuracy of physical tests for anterior cruciate ligament tears. Yet, the diagnosis alone provides little information to guide decisions about treatment or timing for return to sports, which impact downstream patient outcomes.

The GRADE working group has proposed using the diagnostic randomized trial to assess the effectiveness of diagnostic strategies for improving patient outcomes.[4,6] This design requires formulating the trial's question in the "PICO" (population, intervention) format, where the diagnostic strategy becomes the intervention to which patients are randomized.[4,6]

In a diagnostic randomized controlled trial that could inform musculoskeletal physical therapy practice (see the figure in the **APPENDIX**), the study population could involve patients labeled as "nonspecific low back pain" in primary care clinics. Patients randomized to the intervention arm would receive an initial assessment from physical therapists trained in using the PDDM diagnostic framework. Patients randomized to the control arm would be assessed by physicians using basic musculoskeletal assessment methods and offered management options based on current guidelines. Outcomes would include patient-reported outcomes (eg, function, quality of life) and clinician/system outcomes (eg, treatment decisions, health care utilization). Mustafa et al[4] provide further methodological requirements of a high-quality diagnostic trial.

## SUMMARY

Improving musculoskeletal diagnosis is the foundation of high-value care. Diagnostic frameworks that integrate information from multiple sources can help clinicians better diagnose common musculoskeletal problems, improve decision making, and provide tailored care. Designing and testing diagnostic frameworks will be an iterative process as researchers learn more about how to leverage drivers of pain and disabilities to improve patient outcomes.

### Key Points

- Framing diagnosis in a high-value care paradigm implies linking diagnosis with patient outcomes.
- Diagnostic frameworks based on current knowledge of drivers of pain and disabilities in musculoskeletal conditions can help clinicians assess complexity and guide decision making.
- The diagnostic randomized controlled trial is an appropriate study design to assess the effectiveness of diagnostic frameworks for improving patient outcomes. ◉

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## APPENDIX

### CLINICAL ELEMENTS INTEGRATED IN THE PAIN AND DISABILITY DRIVERS MANAGEMENT MODEL FOR LOW BACK PAIN[8]

| Domain | Elements Assessed for Each Domain | Included Validated Assessment Tools |
|---|---|---|
| Nociceptive pain drivers | 1. Specific mechanical pattern of pain<br>2. Low back pain without any specific mechanical pattern<br>3. Nociceptive pain related to identifiable structural stability deficits (post fracture, post surgery)<br>4. Presence of signs/symptoms of an active inflammatory process | The Brief Pain Inventory is designed to assess pain intensity (at its worst, least, and average levels) and the extent to which pain interferes in daily life in relation to 7 domains of functioning (general activity, mood, walking ability, normal work, relations, sleep, and enjoyment of life) on a scale of 0 to 10 |
| Nervous system dysfunction drivers | 1. Radicular pain pattern<br>2. Tingling/paresthesia or burning/shooting pain<br>3. Signs of radiculopathy<br>4. Signs of myelopathy<br>5. Evidence of increased neural mechanosensitivity<br>6. Evidence of hyperalgesia (lower pain threshold at distal sites)<br>7. Evidence of allodynia (provoked or spontaneous)<br>8. Evidence of widespread pain location: widespread pain outside the anatomical relationship to low back pain<br>9. Evidence of disproportionate pain intensity in relation to injury<br>10. Hypersensitivity of senses unrelated to the musculoskeletal system<br>11. Evidence of sympathetic nervous system dysfunction (eg, sweating/dryness, skin temperature changes)<br>12. Symptoms of dysesthesia<br>13. Sleep disturbances secondary to painful symptoms | The pain*DETECT* questionnaire is a reliable screening tool to predict the likelihood of a neuropathic pain component. The total score indicates whether the pain is less likely to be neuropathic (negative; 0-12), uncertain (13-18), or likely to be neuropathic (positive; 19-38)<br>The Central Sensitization Inventory consists of a self-reported tool to assess symptoms of CS. It contains 2 sections, parts A and B. Part A contains 25 items with 5-point Likert scales and a total score ranging from 0 to 100, and is intended to give an overview of the symptoms that are common in CS. Part B identifies whether the patient has been diagnosed with specific disorders associated with CS, as well as anxiety and depression |
| Comorbidity drivers | 1. Identified/known co-occurring painful musculoskeletal pathologies (eg, osteoarthritis, rheumatoid arthritis, or any other painful musculoskeletal pathology triggering pain<br>2. Identified/known co-occurring disorders related to pain sensitization, such as chronic fatigue, migraines, irritable bowel syndrome, or fibromyalgia<br>3. Mental health disorders (within the DSM): depressive disorders, anxiety disorders, personality disorders, history of substance-use disorder<br>4. Patient-reported sleep disturbances<br>5. Posttraumatic stress disorder | From the patient's history |
| Cognitive-emotional drivers | 1. Pain catastrophizing<br>2. Pain-related anxiety<br>3. Negative mood<br>4. Fear of movement<br>5. Pain-related fears<br>6. Poor self-efficacy<br>7. High illness perception<br>8. Pain expectations<br>9. Negative/low expectation of recovery<br>10. Low pain coping<br>11. Poor knowledge relating to pain science<br>12. Facial expressions (eg, grimacing or wincing)<br>13. Verbal/paraverbal pain expressions (eg, pain words, grunts, sighs, and moans)<br>14. A guarded posture (eg, keeping the back straight while lifting)<br>15. Bending/rubbing the back after performing an activity<br>16. Completely avoiding performing a task<br>17. Perceived injustice<br>18. Perception that medical treatments are still needed or incomplete<br>19. Discordance between reported behaviors (by the patient) and observed behaviors (by the therapist) | The SBT is a screening questionnaire consisting of 9 items based on psychosocial factors used to categorize patients with low back pain, based on risk (low, medium, or high) for poor disability outcomes. Overall scores (ranging from 0 to 9) are determined by summing all responses, and the SBT psychosocial subscale (items 5-9, ranging from 0 to 5) is determined by summing all items related to psychosocial factors of prolonged disability, such as catastrophizing and pain-related fear and anxiety |

*Table continues on page A2.*

## APPENDIX

| Domain | Elements Assessed for Each Domain | Included Validated Assessment Tools |
|---|---|---|
| Contextual drivers | 1. Low return-to-work expectations<br>2. Low job satisfaction<br>3. Perception of heavy work<br>4. High job stress<br>5. High occupational demands<br>6. Job flexibility (nonmodifiable work or hours)<br>7. Employer policies regarding return to work are limited or restrictive<br>8. Poor attitudes of employer, family, or health care professionals<br>9. Low or no access to care<br>10. Communication barriers | The Örebro Musculoskeletal Pain Screening Questionnaire is a 25-item questionnaire used to determine the risk of long-term absenteeism from work due to low back pain, based on occupational and social factors. It also has a shorter 10-item version, which has comparable predictive properties to those of the long version while being easier to use in clinical settings |

*Abbreviations: CS, central sensitization; DSM, Diagnostic and Statistical Manual of Mental Disorders; SBT, STarT Back Screening Tool.*

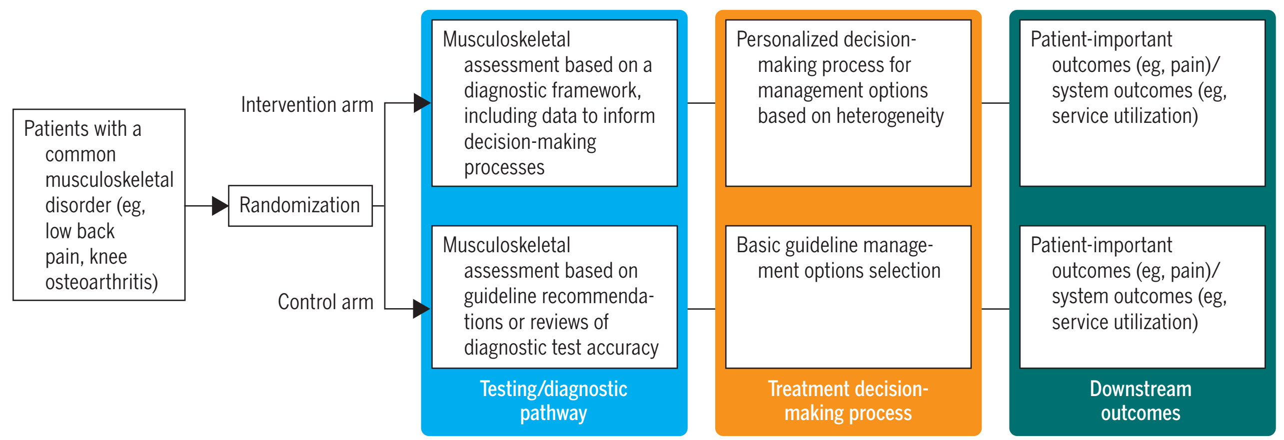


**FIGURE.** The diagnostic randomized controlled trial compares an "intervention arm," where participants are randomized to being assessed with a diagnostic framework, to a "control arm," where participants are assessed with "usual" diagnostic tests. The design allows the assessment of the complete decision-making process linking diagnosis to patient outcomes. For more details, see Mustafa et al.[4]

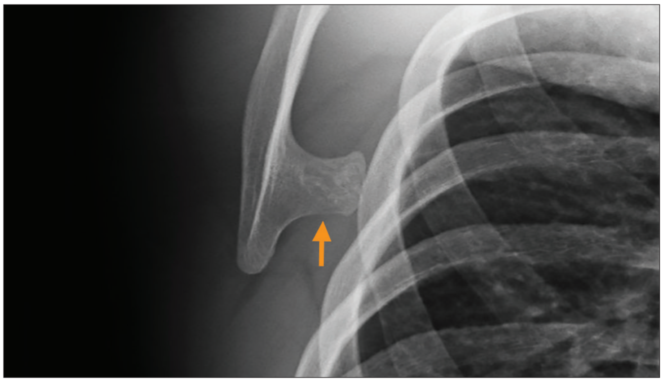

**FIGURE 1.** Lateral scapular radiograph showing an osseous lesion projecting ventrally from the inferior aspect of the scapula (arrow), measuring 2.2 × 2.6 cm.

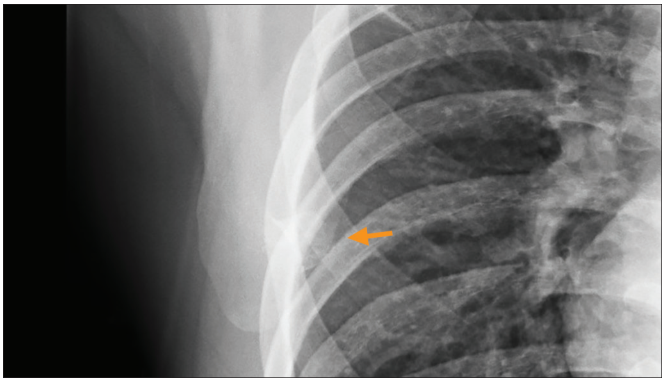

**FIGURE 2.** Anteroposterior scapular radiograph showing an osseous lesion from the inferior aspect of the scapula (arrow).

# Scapular Osteochondroma in a Skeletally Mature Man

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A 27-YEAR-OLD MAN WAS REFERRED to physical therapy by his primary care physician for chronic, intermittent right shoulder girdle pain that had progressively worsened in severity after an anterior glenohumeral dislocation in a motor vehicle accident 6 years prior. Radiographs of the shoulder were noncontributory.

The patient reported a grinding sensation and pain of 3/10 on a numeric pain-rating scale (0-10) at the posteroinferior aspect of the scapula, which limited his performance of overhead recreational activities. Upon examination, his active and passive range of motion of the cervical spine and right shoulder was within normal limits. Manual muscle testing throughout the shoulder girdle was within normal limits; however, resisted abduction and flexion produced pain over the lower scapulothoracic region. Palpation revealed a nontender, firm mass along the ventral side of the right scapular inferior angle. Due to the mass, the patient was referred back to his physician for further diagnostic testing, including scapular radiographs. In the interim, the patient attended 4 physical therapy sessions over 2 weeks that focused on manual therapy at the scapulothoracic region and did not lead to sustained improvement.

Radiographs of the scapula demonstrated an osseous lesion projecting from the ventral inferior scapula (**FIGURES 1** and **2**). He was referred to an orthopaedic surgeon and underwent resection and biopsy of the mass, which was diagnosed as an osteochondroma.[1] At 8 weeks following surgery, the patient had no complaints of right shoulder girdle pain and returned to participation in all previous recreational activities.

Osteochondroma, also known as exostosis, is a benign proliferation of cartilage and bone that develops near the growth plates of long bones, at the pelvis, or, in 1% of cases, at the scapula.[3] It occurs most often between the ages of 10 and 30 years, equally affects males and females, and rarely becomes symptomatic after skeletal maturity.[2] The recurrence rate following resection is low.[3] ◉ *J Orthop Sports Phys Ther 2020;50(3):168. doi:10.2519/jospt.2020.9325*

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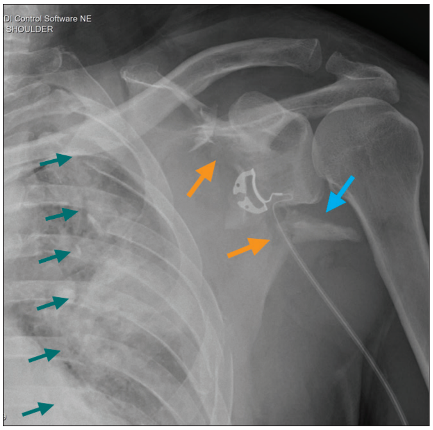

**FIGURE 1.** Anteroposterior radiograph of the left shoulder, positioned in internal rotation, demonstrating a comminuted and displaced fracture of the scapular body and neck (orange arrows). A large osseous fragment is present (blue arrow). Multiple rib fractures are evident (green arrows). The radiopaque device is an electrocardiogram lead and wire.

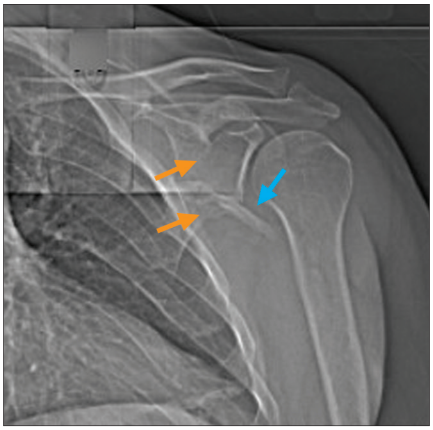

**FIGURE 2.** Computed tomography scout (anterior-to-posterior view) locating scan of the left shoulder 8 months after injury demonstrating a well-healed fracture of the scapular body and neck (orange arrows). Note the malunion of the osseous fragment (blue arrow).

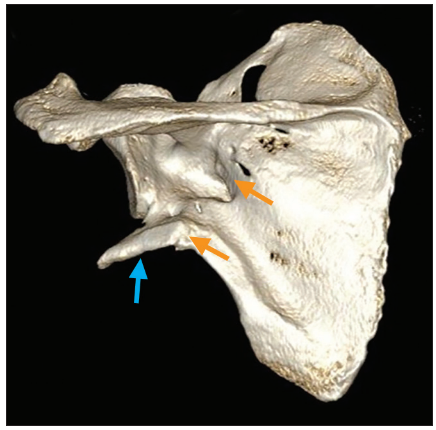

**FIGURE 3.** Posterior-to-anterior computer modeling image reconstructed from multiple axial, noncontrast computed tomography images taken 8 months post injury. The blue arrow shows the location of the 3.0-cm osseous projection as a result of fracture malunion. The orange arrows represent the locations of healed fracture sites.



# Posttraumatic Malunion Following Comminuted Scapular Fracture

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A 42-year-old, right hand–dominant, male police officer sustained multiple injuries in a motorcycle accident, including a comminuted fracture of the scapula and several rib fractures (**FIGURE 1**). He was hospitalized 11 days for treatment of a concussion and hemopneumothorax. His fractures were managed conservatively, and he was discharged with his left arm in a sling.

Four months after his injury, the patient was prescribed outpatient physical therapy for chronic lumbar and cervical spine pain, as well as persistent functional limitations of the left shoulder, including decreased overhead mobility. After 2 months of outpatient physical therapy, the patient's cervical and lumbar spine function were restored but his shoulder mobility deficits persisted.

A second physical therapy opinion was sought 6 months post injury for the left shoulder. This examination revealed that his range of motion, both active and passive, was limited by sharp, deep anterolateral shoulder pain and an empty end feel. Flexion and abduction range of motion was 140°, and external rotation was 45° in 45° of abduction. Glenohumeral joint inferior and posterior glides were hypomobile, with pain limiting the end-feel assessment. No deficits were noted with midline manual muscle testing and sensation testing.

Given his functional deficits, including an inability to return to work, he was referred to an orthopaedist for additional imaging and consultation. The scout image (**FIGURE 2**) and computer modeling from computed tomography images (**FIGURE 3**; **FIGURE 4**, available at www.jospt.org) revealed scapular malunion. The left scapular ossific projection was removed through incision with blunt dissection. Following surgery, the patient resumed physical therapy and at 2 months returned to work without limitations.

Poor functional outcome following conservative care is associated with scapular malunion.[1] This case highlights the need for the physical therapist to refer for imaging to help identify the potential cause of abnormal joint arthrokinematics and limited function in a patient with scapular malunion. ◉ *J Orthop Sports Phys Ther 2020;50(3):167. doi:10.2519/jospt.2020.8927*

Reference

1. Cole PA, Talbot M, Schroder LK, Anavian J. Extra-articular malunions of the scapula: a comparison of functional outcome before and after reconstruction. *J Orthop Trauma*. 2011;25:649-656. https://doi.org/10.1097/BOT.0b013e31820af67f

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# An Update of Systematic Reviews Examining the Effectiveness of Conservative Physical Therapy Interventions for Subacromial Shoulder Pain

**OBJECTIVE:** To update a systematic review published in 2013 that focused on evaluating the effectiveness of interventions within the scope of physical therapy, including exercise, manual therapy, electrotherapy, and combined or multimodal approaches to managing shoulder pain.

**DESIGN:** Umbrella review.

**LITERATURE SEARCH:** An electronic search of PubMed, Web of Science, and CINAHL was undertaken. Methodological quality was assessed using the AMSTAR (A MeaSurement Tool to Assess systematic Reviews) checklist for systematic reviews.

**STUDY SELECTION CRITERIA:** Nonsurgical treatments for subacromial shoulder pain.

**DATA SYNTHESIS:** Sixteen systematic reviews were retrieved. Results were summarized qualitatively.

**RESULTS:** A strong recommendation can be made for exercise therapy as the first-line treatment to improve pain, mobility, and function in patients with subacromial shoulder pain. Manual therapy may be integrated, with a strong recommendation, as additional therapy. There was moderate evidence of no effect for other commonly prescribed interventions, such as laser therapy, extracorporeal shockwave therapy, pulsed electromagnetic energy, and ultrasound.

**CONCLUSION:** There is a growing body of evidence to support exercise therapy as an intervention for subacromial shoulder pain. Ongoing research is required to provide guidance on exercise type, dose, duration, and expected outcomes. A strong recommendation may be made regarding the inclusion of manual therapy in the initial treatment phase. *J Orthop Sports Phys Ther 2020;50(3):131-141. Epub 15 Nov 2019. doi:10.2519/jospt.2020.8498*

**KEY WORDS:** *conservative treatment, exercise, rotator cuff, shoulder pain, systematic review, tendinopathy*

Shoulder pain is common, increases with age, and is often associated with incomplete resolution of symptoms.[17,28] *Subacromial shoulder pain* (SSP)[2] describes the clinical presentation of pain and impairment of shoulder movement and function, usually experienced during shoulder elevation and external rotation. Other terms to describe these symptoms include *subacromial impingement syndrome, rotator cuff tendinopathy,*[22] and, more recently, *rotator cuff–related shoulder pain.*[20] Multiple structures, including the subacromial bursa, the rotator cuff muscles and tendons, the acromion, the coracoacromial ligament, and capsular and intra-articular tissue, may be involved in the pathogenesis of SSP.[18] Other factors, such as altered shoulder kinematics associated with capsular tightness,[37] rotator cuff and scapular muscle dysfunction,[7,19,23] overuse due to sustained intensive work,[6,13,25] and poor posture,[3,21] have also been hypothesized as contributing to the pathogenesis of SSP. Although change in load is implicated as the main factor associated with onset, the pathogenesis is possibly multifactorial, and this has led to a multitude of suggestions for management.[24,39]

In 2013, Littlewood et al[22] reviewed the scientific literature regarding management of rotator cuff tendinopathy. Although the magnitude of the improvement was uncertain, the review reported that exercise and multimodal physical therapy might be effective in the management of rotator cuff tendinopathy. Consequently, it is recommended that graduated exercise should be prioritized as the primary treatment option, due to its clinical effectiveness (equivalent to surgery), cost-effectiveness (less expensive than surgery), and other associated health benefits.

We aimed to update the findings reported by Littlewood et al[22] to determine whether more recently published literature

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provided further understanding of the best management of SSP. The study background and findings are summarized in **APPENDIX A** (available at www.jospt.org).

## METHODS

### Data Sources and Search Strategy

An electronic search of 3 databases (PubMed, Web of Science, CINAHL) was independently conducted by 3 researchers. The search terms used are displayed in **APPENDIX B** (available at www.jospt.org). As the search limits of the Littlewood et al[22] systematic review were dated up to August 2012, data limits of this review were September 2012 to September 2018.

### Study Selection

Study selection was undertaken by 3 reviewers independently. Systematic reviews that included randomized controlled trials (RCTs) involving people with signs and symptoms suggestive of SSP were included. The following diagnostic categories were considered as being equivalent to SSP: rotator cuff tendinopathy, painful arc syndrome, subacromial bursitis, rotator cuff tendinosis, supraspinatus tendinitis, and contractile dysfunction. Systematic reviews had to evaluate the effectiveness of the following nonsurgical, nonpharmacological treatments: exercise, exercise combined with manual therapy, multimodal physical therapy, corticosteroid injection, laser, ultrasound, extracorporeal shockwave therapy, or pulsed electromagnetic energy. Corticosteroid injection is not an intervention within the scope of physical therapy, but as this intervention was already discussed in the Littlewood et al[22] systematic review and is strongly related to physical therapy rehabilitation policies, we included this intervention in the review.

### Data Extraction

Three reviewers, using a data-extraction tool developed for this review, individually extracted data regarding methodological quality, design, population, sample size, intervention, outcome, and results, and a consensus was subsequently reached.

### Quality Appraisal

An appraisal of methodological quality was undertaken by 3 reviewers independently using the AMSTAR (A MeaSurement Tool to Assess systematic Reviews) checklist (**TABLE 1**). The AMSTAR checklist consists of 11 items. Each item can be answered with "yes," "no," "can't answer," or "not applicable."[33] The AMSTAR checklist characterizes quality at 3 levels: 8 to 11 is high quality, 4 to 7 is moderate quality, and 0 to 3 is low quality.[32] The AMSTAR checklist was chosen to provide homogeneity with the review findings reported by Littlewood et al.[22] Recent

**TABLE 1** Results of the AMSTAR Quality Appraisal[a]

| | Item[b] | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Study | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | Total |
| Abdulla et al[1] | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | No | No | 8/11 |
| Bury et al[5] | Yes | No | Yes | Yes | No | Yes | Yes | Yes | Yes | No | Yes | 8/11 |
| Desjardins-Charbonneau et al[8] | Yes | Yes | Yes | No | No | Yes | Yes | Yes | Yes | Yes | Yes | 9/11 |
| Desmeules et al[9] | Yes | No | Yes | Yes | No | Yes | Yes | Yes | No | No | Yes | 7/11 |
| Desmeules et al[10] | Yes | No | Yes | Yes | No | No | Yes | Yes | Yes | No | Yes | 7/11 |
| Dong et al[11] | Yes | Yes | No | Yes | No | No | Yes | No | No | No | Yes | 5/11 |
| Goldgrub et al[14] | Yes | Yes | Yes | No | No | Yes | Yes | Yes | Yes | No | Yes | 8/11 |
| Haik et al[15] | Yes | Yes | Yes | No | No | No | Yes | Yes | Yes | Yes | Yes | 8/11 |
| Haslerud et al[16] | Yes | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | No | 7/11 |
| Page et al[26] | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | 9/11 |
| Page et al[27] | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | No | Yes | 9/11 |
| Saito et al[29] | Yes | Yes | Yes | No | No | Yes | Yes | Yes | Yes | No | No | 7/11 |
| Saracoglu et al[30] | Yes | Yes | Yes | No | No | Yes | Yes | Yes | Yes | No | Yes | 8/11 |
| Steuri et al[35] | Yes | Yes | Yes | No | Yes | No | Yes | Yes | Yes | No | Yes | 8/11 |
| van der Sande et al[38] | Yes | Yes | No | Yes | No | No | Yes | Yes | No | No | No | 5/11 |
| Yu et al[40] | Yes | Yes | Yes | No | No | Yes | Yes | No | No | No | Yes | 6/11 |

*Abbreviation: AMSTAR, A MeaSurement Tool to Assess systematic Reviews.*
[a]*Criteria from Shea et al.*[33]
[b]*Items: 1, Was an a priori design developed? 2, Was there duplicate study selection and data extraction? 3, Was a comprehensive literature search performed? 4, Was the status of publication used as an inclusion criterion? 5, Was a list of studies (included and excluded) provided? 6, Were the characteristics of the included studies assessed and documented? 7, Was the scientific quality of the included studies assessed and documented? 8, Was the scientific quality of the included studies used appropriately in formulating conclusions? 9, Were the methods used to combine the findings of the studies appropriate? 10, Was the likelihood of publication bias assessed? 11, Was the conflict of interest stated?*

guidelines for updating systematic reviews advise researchers to replicate the original methods as closely as possible.[12]

Cohen's kappa coefficient was calculated to compare the preconsensus scoring of the different reviewers. As kappa was greater than 0.81 ($\kappa = 0.92$), it can be interpreted as almost perfect.

Appraisal of individual component studies was beyond the scope of our umbrella review, as this was the aim of the original systematic reviews, which included an appraisal of studies' quality. With respect to the selected systematic reviews, methods were used to capture essential features of the quality of the evidence, and these are described in detail in the next section.

### Data Analysis

The level of evidence used in the tables (**TABLES 2** through **9**) to present the different reviews is the evidence that was reported in every original review (high/moderate/low).

The method to evaluate the strength of recommendation is as follows: a strong recommendation was made when at least 50% of the reviews considering a specific topic had at least moderate-level evidence, with at least 1 review having high-level evidence. A moderate recommendation was made when at least 50% of the reviews had moderate-level evidence. A weak recommendation was made when fewer than 50% of the reviews had moderate-level evidence.

## RESULTS

### Study Selection

The study-selection process is detailed in the **FIGURE**. The electronic literature search (PubMed, Web of Science, and CINAHL) resulted in 107, 109, and 40 articles, respectively. Duplicates were identified and removed using EndNote X8 (Clarivate Analytics, Philadelphia, PA), and 202 abstracts remained. Screening the title and abstract of the remaining articles resulted in the exclusion of 160 articles on the basis of population, intervention, outcome, and design. After reading the full text of the remaining articles, another 26 articles were excluded. Two articles were excluded because they were already included in the previous review.[22] To reach a consensus on the eligibility of studies, the reviewers had a consensus meeting. Consequently, full agreement was obtained (100%) between all 3 reviewers, which made arbitration by an external reviewer unnecessary. After the consensus meeting between the 3 reviewers, 16 relevant studies were appropriate for data extraction.

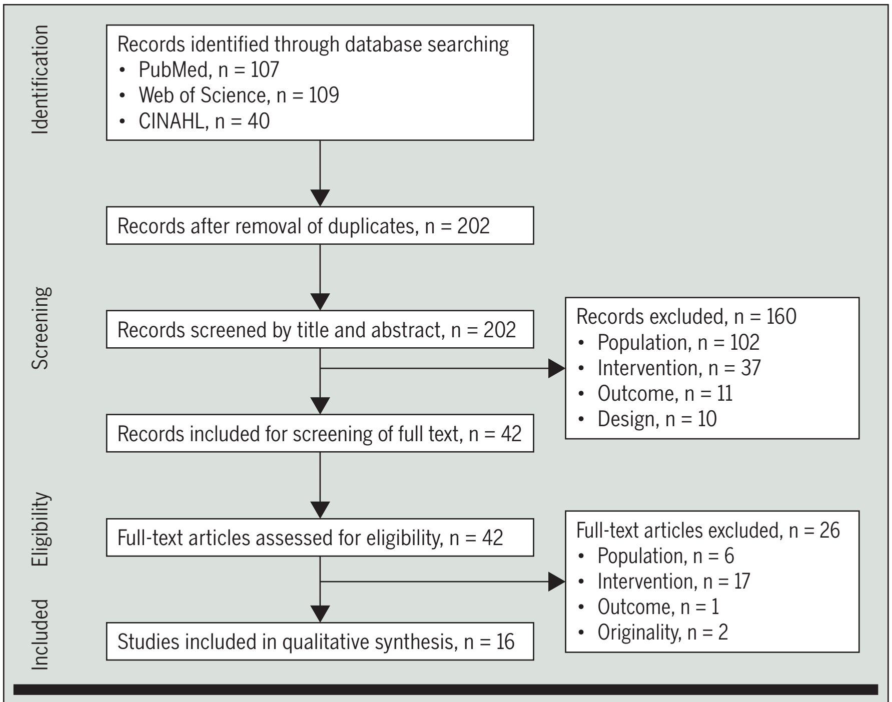


**FIGURE.** Study-selection process.

### Quality Appraisal

The results of the AMSTAR quality appraisal are shown in **TABLE 1**. Nine of 16 included systematic reviews were high quality (8/11 or greater). The remaining 7 studies were moderate quality. The main reason for not meeting an AMSTAR criterion was failure to assess the likelihood of publication bias. This means that the authors of these systematic reviews did not assess potential publication bias by means of graphical aids (eg, a funnel plot) and/or statistical tests (eg, the Egger regression test or Hedges-Olken test).

### Study Characteristics

A summary of all details and characteristics of all systematic reviews included is presented in **TABLES 2** through **9**.

### Exercise for SSP

Seven systematic reviews relating to the effectiveness of exercise for SSP were retrieved (**TABLE 2**). The reviews were of variable quality (AMSTAR range, 5-8/11). Abdulla et al[1] reported high-level evidence that supervised progressive shoulder exercises alone or combined with home-based shoulder exercises were effective in the short term for the management of SSP of variable duration (exercise program of 8 weeks). Dong et al[11] (moderate-level evidence) reported exercise therapy as an ideal treatment in the early stage of SSP. For persistent SSP, supervised and home-based progressive strengthening exercises led to similar outcomes as shoulder decompression surgery in the long term. Supervised strengthening and stretching exercises provided similar short-term benefits to those of a single corticosteroid injection or a multimodal program for the management of low-grade nonspecific shoulder pain of varied duration.[1,5] Bury et al[5] (moderate-level evidence) and Saito et al[29] (high-level evidence) reported that a scapula-focused approach could offer benefits over generalized approaches at short-term follow-up (4-6 weeks); both pain and shoulder function were significantly improved. For construction workers with SSP, there was low- to moderate-level evidence that exercise was effective for pain reduction and improvement of return-to-work time when compared with a control intervention or placebo.[9] Exercise therapy was effective for improving pain scores, active range of motion, and overall shoulder function at short-term (6-12 weeks) and long-term follow-ups (greater than 3 months).[15,35] Multiple forms of exercise were reported to be beneficial: scapular stability exercises, rotator cuff strengthening, and shoulder flexibility exercises.[15,29,35] A strong recommendation can be made in favor of exercise therapy for patients with SSP.

### Exercise Combined With Manual Therapy for SSP

Six systematic reviews evaluated the effect of manual therapy combined with exercises (**TABLE 3**). The systematic reviews were of variable quality (AMSTAR range, 5-9/11). Four reviews[8,15,26,35] reported moderate- and high-level evidence that manual therapy in addition to exercise reduced pain in the short term. Desmeules et al[9] (low-level evidence) reported no significant improvement in outcome when exercise was combined with manual therapy, compared to exercise alone. Dong et al[11] concluded (low-level evidence) that exercise resulted in a better effect on pain reduction when combined with manual therapy, but this review had the lowest quality of the studies considering the effects of manual therapy combined with exercise. Based on the results, a strong recommendation may be made in favor of exercises combined with manual therapy.

### Multimodal Physical Therapy for SSP

Three systematic reviews reported the effect of multimodal physical therapy (**TABLE 4**). The systematic reviews were of variable quality (AMSTAR range, 5-8/11). Multimodal therapy was defined as combined nonsurgical treatment, including passive physical modalities, exercise, manual therapy, taping, corticosteroids,

**TABLE 2** Systematic Reviews Relating to the Effectiveness of Exercise Therapy for SSP

| Study | Sample Size | Patients Included | Results[a] | Risk of Bias[b] | Level of Evidence[b] |
|---|---|---|---|---|---|
| Abdulla et al[1] | 11 | 466 | Evidence suggests that supervised and home-based progressive shoulder-strengthening and stretching exercises for the RC and scapular muscles are effective options for the management of SSP in both the short and long term<br>No effect sizes reported | Low (SIGN criteria) | High |
| Bury et al[5] | 7 | 190 | Evidence that a scapula-focused approach (exercise therapy and stretching) benefits patients with SSP over generalized approaches up to 6 weeks post commencement of treatment<br>Effect size for short-term pain, 0.714 (0.402, 1.026); effect size for short-term function, 14.008 (11.159, 16.857) | Unclear (PEDro scale) | Moderate |
| Desmeules et al[9] | 10 | 788 | Low- to moderate-grade evidence that therapeutic exercises provided in a clinical setting are an effective modality to treat workers suffering from RC tendinopathy and to promote return to work<br>No effect sizes reported | Low (Cochrane risk-of-bias tool) | Moderate |
| Dong et al[11] | 33 | 2300 | Evidence that exercise and other exercise-based therapies are ideal treatments for patients at an early stage of SSP<br>No effect sizes reported | Low (Cochrane risk-of-bias tool) | Moderate |
| Haik et al[15] | 64 | 6319 | High evidence that exercise therapy should be the first-line treatment to improve pain, function, and range of motion<br>No effect sizes reported | Low (PEDro scale) | High |
| Saito et al[29] | 6 | 250 | High evidence that scapula-focused interventions can improve shoulder pain and function in the short term (4 weeks post commencement of treatment)<br>Effect size for pain, –0.88 (–1.19, –0.58); effect size for shoulder function, –11.31 (–17.20, –5.41) | Low (Cochrane risk-of-bias tool) | High |
| Steuri et al[35] | 200 | 10529 | Evidence that, for pain and shoulder function, exercise was superior to nonexercise control interventions. Specific exercises were superior to generic exercises<br>Effect size for pain, –0.94 (–1.69, –0.19); effect size for shoulder function, 0.57 (–0.85, –0.29) | Low (Cochrane risk-of-bias tool) | Moderate (GRADE approach) |

*Abbreviations: GRADE, Grading of Recommendations Assessment, Development and Evaluation; PEDro, Physiotherapy Evidence Database; RC, rotator cuff; SIGN, Scottish Intercollegiate Guidelines Network; SSP, subacromial shoulder pain.*
[a]*Values in parentheses are 95% confidence interval.*
[b]*Reported in the original review.*

or electrotherapy. One study[11] concluded, based on low-level evidence, that exercise combined with other therapies (Kinesio Taping, specific exercises, and acupuncture) provided a beneficial treatment effect. For taping as adjunct therapy, the effectiveness was weak for improvement of pain, disability, range of motion, and strength[30] (low-level evidence). Pulsed electromagnetic field therapy, localized corticosteroid injection, and ultrasound therapy were suggested as potential additional second-line treatments. Goldgrub et al[14] reported low-level evidence to support the effectiveness of multimodal care

**TABLE 3** Systematic Reviews Relating to the Effectiveness of Exercise Combined With Manual Therapy for SSP

| Study | Sample Size | Patients Included | Results[a] | Risk of Bias[b] | Level of Evidence[b] |
| --- | --- | --- | --- | --- | --- |
| Desjardins-Charbonneau et al[8] | 21 | 554 | Moderate evidence that manual therapy intervention added to an exercise program significantly reduces pain in individuals with SSP. Unclear whether manual therapy can improve function<br>No effect sizes reported | Low (Cochrane risk-of-bias tool) | Moderate |
| Desmeules et al[9] | 10 | 788 | No significant difference between exercise therapy or exercise combined with manual therapy<br>No effect sizes reported | Low (Cochrane risk-of-bias tool) | Low |
| Dong et al[11] | 33 | 2300 | Low-level evidence that exercise results in a better effect on pain reduction when combined with manual therapy<br>No effect sizes reported | Low (Cochrane risk-of-bias tool) | Low |
| Haik et al[15] | 64 | 6319 | High evidence regarding the effectiveness of exercises associated with mobilizations to optimize improvements in pain and function in the short term<br>No effect sizes reported | Low (PEDro scale) | High |
| Page et al[26] | 60 | 3620 | High evidence that no clinically important differences are measured between manual therapy combined with exercise and placebo with respect to overall pain, function, pain on motion, global treatment success, quality of life, and strength in the short term<br>No effect sizes reported | High (Cochrane risk-of-bias tool) | High (GRADE approach) |
| Steuri et al[35] | 200 | 10529 | Evidence that manual therapy plus exercise is superior to placebo or exercise alone for pain and shoulder function, but only at short-term follow-up (immediately after the intervention)<br>Effect size for shoulder function compared to placebo, −0.35 (−0.69, −0.01); effect size for shoulder function compared to exercise alone, −0.32 (−0.62, −0.01) | Low (Cochrane risk-of-bias tool) | Moderate (GRADE approach) |

*Abbreviations: GRADE, Grading of Recommendations Assessment, Development and Evaluation; PEDro, Physiotherapy Evidence Database; SSP, subacromial shoulder pain.*
[a]*Values in parentheses are 95% confidence interval.*
[b]*Reported in the original review.*

**TABLE 4** Systematic Reviews Relating to the Effectiveness of Multimodal Physical Therapy for SSP

| Study | Sample Size | Patients Included | Results | Risk of Bias[a] | Level of Evidence[a] |
| --- | --- | --- | --- | --- | --- |
| Dong et al[11] | 33 | 2300 | Evidence suggests that most combined treatments based on exercise demonstrated better effects than exercise alone<br>No effect sizes reported | Low (Cochrane risk-of-bias tool) | Low |
| Goldgrub et al[14] | 19 | 1217 | Little evidence to support that multimodal care provides superior effectiveness compared with individual interventions for the management of SSP or nonspecific shoulder pain. For SSP, multimodal care may be associated with small and non–clinically important improvement in pain and function compared with corticosteroid injections<br>No effect sizes reported | Low (SIGN criteria) | Low |
| Saracoglu et al[30] | 4 | 135 | Low evidence that clinical taping in addition to other physical therapy interventions (exercise, manual therapy, electrotherapy) provides superior effectiveness for the initial stage of the treatment<br>No effect sizes reported | High (PEDro scale) | Low |

*Abbreviations: PEDro, Physiotherapy Evidence Database; SIGN, Scottish Intercollegiate Guidelines Network; SSP, subacromial shoulder pain.*
[a]*Reported in the original review.*

over isolated interventions in the management of SSP. The clinical significance of multimodal physical therapy remains unclear, possibly due to the variety of different treatment modalities. Currently, only a weak recommendation for including multimodal therapy in the management of SSP can be made.

### Corticosteroid Injection for SSP

Four systematic reviews relating to the effectiveness of corticosteroid injection for SSP were retrieved (**TABLE 5**). The systematic reviews were of variable quality (AMSTAR range, 5-8/11). Steuri et al[35] (moderate-level evidence) reported that in the short term (immediately after the intervention), corticosteroid injection was superior to negative control (no therapy) and physical therapy modalities for reducing pain and improving shoulder function. Ultrasound-guided corticosteroid injections were superior to blind injections for both pain and overall shoulder function. Dong et al[11] (low-level evidence) recommended corticosteroid injection as a second-line treatment, in addition to exercise-based therapies. In another review, there was moderate-level evidence regarding the usefulness of corticosteroid injections compared to placebo in the short and the long term.[38] There was low-level evidence that corticosteroid injection and exercise both led to similar outcomes as multimodal physical therapy for the treatment of nonspecific shoulder pain.[14] Overall, a moderate recommendation can be made regarding the clinical significance of corticosteroid injection as a solitary treatment or in addition to exercise-based therapy.

### Laser Therapy for SSP

Six systematic reviews discussed the effect of laser therapy on SSP (**TABLE 6**). These systematic reviews were of variable quality (AMSTAR range, 5-9/11). Dong et al[11] (low-level evidence) and Haik et al[15] (high-level evidence) did not provide any evidence of the benefit of low-level laser therapy in the treatment of SSP. Haslerud et al[16] concluded, based on moderate-level evidence, that laser therapy could reduce pain and improve function when used as an adjunct therapy to exercise or in a physical therapy treatment program. Other reviews[35,40] (moderate-level evidence) reported that laser therapy, when combined with other therapies, was superior to a placebo, but showed no benefits alone. Page et al[27] suggested low-quality evidence for the effect of laser treatment on pain, shoulder function, active mobility, and strength. Overall, a strong recommendation can be made to not use laser therapy in the treatment of SSP, as there was no evidence supporting the effectiveness of laser therapy as a monotherapy compared to other interventions.

### Ultrasound for SSP

Five systematic reviews evaluating the effectiveness of ultrasound for SSP were reviewed (**TABLE 7**). The systematic reviews were of variable quality (AMSTAR range, 5-9/11). Although there is only a weak recommendation, the reviews consistently concluded that there was no evidence for the effectiveness of therapeutic ultrasound.[10,11,27,35,40]

### Extracorporeal Shockwave Therapy for SSP

Three systematic reviews relating to the effectiveness of extracorporeal shockwave therapy for SSP were reviewed (**TABLE 8**). The systematic reviews were of variable quality (AMSTAR range, 5/11-8/11). Although there is only a moderate recommendation, all 3 reviews consistently concluded that the evidence did not support the effectiveness of extracorporeal shockwave therapy.[11,35,40]

**TABLE 5** Systematic Reviews Relating to the Effectiveness of Corticosteroid Injection for SSP

| Study | Sample Size | Patients Included | Results[a] | Risk of Bias[b] | Level of Evidence[b] |
|---|---|---|---|---|---|
| Dong et al[11] | 33 | 2300 | Localized corticosteroid injection may be considered as second-line treatment. Exercise and exercise-based therapies are the first-line choices<br>No effect sizes reported | Low (Cochrane risk-of-bias tool) | Low |
| Goldgrub et al[14] | 19 | 1217 | Evidence that corticosteroid injection leads to a similar outcome to that of multimodal physical therapy in cases of nonspecific shoulder pain<br>No effect sizes reported | Low (SIGN criteria) | Low |
| Steuri et al[35] | 200 | 10529 | Evidence that corticosteroid injection is superior to active physical therapy modalities for improvement in pain and overall shoulder function, but only at short-term follow-up<br>Effect size for pain, −0.25 (−0.46, −0.05); effect size for shoulder function, −0.43 (−0.71, −0.15) | Low (Cochrane risk-of-bias tool) | Moderate (GRADE approach) |
| van der Sande et al[38] | 8 | 852 | Conflicting evidence was found in favor of the effectiveness of corticosteroid injection versus placebo in the short-term and long-term treatment of SSP<br>No effect sizes reported | Low (Furlan's 12 criteria) | Moderate |

*Abbreviations: GRADE, Grading of Recommendations Assessment, Development and Evaluation; SIGN, Scottish Intercollegiate Guidelines Network; SSP, subacromial shoulder pain.*
[a]*Values in parentheses are 95% confidence interval.*
[b]*Reported in the original review.*

### Pulsed Electromagnetic Energy for SSP

Four systematic reviews evaluated the effectiveness of pulsed electromagnetic energy for treating SSP (**TABLE 9**). The systematic reviews were of variable quality (AMSTAR range, 5-9/11). None of the reviews found a greater effect of pulsed electromagnetic energy on pain reduction or improvement of shoulder function than a placebo treatment. With a strong recommendation, the conclusion can be made that there is no evidence supporting the effectiveness of pulsed electromagnetic energy for treating SSP.[11,15,27,35]

## DISCUSSION

The aim of this review was to perform an updated review of systematic reviews to investigate the effectiveness of conservative physical therapy treatment for SSP. Littlewood et al[22] suggested that exercise and multimodal physical therapy were promising interventions for SSP, but the extent of their effectiveness remains unclear. The conclusions of the current update were able to support and strengthen the recommendation regarding exercise therapy. Evidence for exercise as an intervention for SSP is increasing and strengthening, although the optimal type, dose, and load still remain unclear.

A large group of the included reviews (7/16) included exercise therapy as a treatment for SSP, and all of them had high- or moderate-level evidence. A strong recommendation may be made for including exercise for those diagnosed with SSP. But because many RCTs and systematic reviews do not describe the exercise program in detail, what constitutes the most appropriate exercise regime is unclear. For example, whether treatment for patients with SSP should be designed around loading that can temporarily reproduce and aggravate patients' pain and symptoms is still a matter of debate.[34] Based on surveys concerning the instructions physical therapists give during the rehabilitation of a musculoskeletal shoulder problem, the following foundations are the most commonly used[4,36]: exercises may be performed at home and/or at a clinic, patients are permitted to perceive some discomfort (less than 5/10 on a visual analog scale), the exercises should include resistance, and the expected duration of therapy is 12 weeks.

A strong recommendation may be made regarding the effectiveness of manual therapy when combined with exercise. In 2013, Littlewood et al[22] reported no clear evidence regarding any benefits of manual therapy. Manual therapy was mainly described as joint mobilizations, specific soft tissue techniques, manipulations, neurodynamic mobilizations, and mobilizations with movement of the

**TABLE 6** Systematic Reviews Relating to the Effectiveness of Laser Therapy for SSP

| Study | Sample Size | Patients Included | Results[a] | Risk of Bias[b] | Level of Evidence[b] |
|---|---|---|---|---|---|
| Dong et al[11] | 33 | 2300 | Low-level laser therapy is not recommended for patients with shoulder pain syndrome<br>No effect sizes reported | Low (Cochrane risk-of-bias tool) | Low |
| Haik et al[15] | 64 | 6319 | Low-level laser therapy is ineffective in reducing pain and improving function in individuals with SSP<br>No effect sizes reported | Low (PEDro scale) | High |
| Haslerud et al[16] | 17 | 801 | Evidence that, for reducing pain, low-level laser therapy is significantly better than placebo or no therapy. Laser therapy reduces pain and accelerates improvement when used as an add-on therapy to exercise or in a physical therapy treatment regimen. No strong evidence was found for laser therapy alone regarding shoulder function<br>Effect size for pain compared to placebo, 23.54 (15.72, 31.36); effect size for pain as adjunct therapy, 10.00 (–19.74, 39.74) | Unclear (PEDro scale) | Moderate |
| Page et al[27] | 47 | 2388 | Little evidence with respect to pain, function, active mobility, and strength. Low-quality evidence for benefits of laser therapy combined with physical therapy interventions<br>No effect sizes reported | High (Cochrane risk-of-bias tool) | Low (GRADE approach) |
| Steuri et al[35] | 200 | 10529 | Evidence that laser therapy is superior to placebo. Evidence that laser therapy in combination with exercise is superior to placebo in combination with exercise<br>Effect size for pain compared to placebo, –0.88 (–1.48, –0.27); effect size for pain in combination with exercise, –0.65 (–0.99, –0.31) | Low (Cochrane risk-of-bias tool) | Moderate (GRADE approach) |
| Yu et al[40] | 22 | 1195 | Low-level laser is more effective than placebo or ultrasound in providing short-term pain reduction for patients with SSP. The effect is of variable duration<br>No effect sizes reported | Low (SIGN criteria) | Moderate |

*Abbreviations: GRADE, Grading of Recommendations Assessment, Development and Evaluation; PEDro, Physiotherapy Evidence Database; SIGN, Scottish Intercollegiate Guidelines Network; SSP, subacromial shoulder pain.*
[a]*Values in parentheses are 95% confidence interval.*
[b]*Reported in the original review.*

shoulder girdle or spine,[9] but other reviews defined manual therapy as "movement of the joints and other structures by a healthcare professional."[8] Lack of a well-described definition and the variety of included interventions make it difficult to draw a conclusion about which type of manual therapy would most benefit patients with SSP. As the evidence for exercise as an intervention for SSP is strengthening and the findings of this review suggest that manual therapy in addition to exercise may, in the short term, further reduce pain and improve function, this intervention may be considered. There is a clear need for research to investigate different types of both exercise and manual therapy in the management of SSP to provide clear instructions and recommendations.

With respect to the effectiveness of multimodal therapy, no clear conclusions may be provided, and only a weak recommendation can be made. Multimodal physical therapy appeared to provide outcomes superior to those of a placebo or no treatment, although the clinical significance of

**TABLE 7** Systematic Reviews Relating to the Effectiveness of Ultrasound for SSP

| Study | Sample Size | Patients Included | Results[a] | Risk of Bias[b] | Level of Evidence[b] |
|---|---|---|---|---|---|
| Desmeules et al[10] | 11 | 792 | Low-level evidence that ultrasound is not superior to a placebo and does not have an additional benefit when used in conjunction with exercise, in terms of pain reduction and self-reported function<br>Effect size, −0.26 (−3.84, 3.32) | Unclear (Cochrane risk-of-bias tool) | Low |
| Dong et al[11] | 33 | 2300 | Ultrasound can be considered as a second-line treatment. Exercise and exercise-based therapies are the first-line choices<br>No effect sizes reported | Low (Cochrane risk-of-bias tool) | Low |
| Page et al[27] | 47 | 2388 | Low-level evidence that ultrasound is not more effective than placebo with respect to pain, global treatment success, or shoulder function<br>No effect sizes reported | High (Cochrane risk-of-bias tool) | Low (GRADE approach) |
| Steuri et al[35] | 200 | 10529 | Nonsignificant results of ultrasound for pain, overall shoulder function, and active range of motion<br>No effect sizes reported | Low (Cochrane risk-of-bias tool) | Moderate (GRADE approach) |
| Yu et al[40] | 22 | 1195 | Ultrasound was not more effective than a placebo for the treatment of nonspecific shoulder problems<br>No effect sizes reported | Low (SIGN criteria) | Moderate |

*Abbreviations: GRADE, Grading of Recommendations Assessment, Development and Evaluation; SIGN, Scottish Intercollegiate Guidelines Network; SSP, subacromial shoulder pain.*
[a]*Values in parentheses are 95% confidence interval.*
[b]*Reported in the original review.*

**TABLE 8** Systematic Reviews Relating to the Effectiveness of Extracorporeal Shockwave Therapy for SSP

| Study | Sample Size | Patients Included | Results[a] | Risk of Bias[b] | Level of Evidence[b] |
|---|---|---|---|---|---|
| Dong et al[11] | 33 | 2300 | Low-level evidence that extracorporeal shockwave therapy does not have an additional benefit when used in conjunction with exercise, in terms of pain reduction and self-reported function<br>No effect sizes reported | Low (Cochrane risk-of-bias tool) | Low |
| Steuri et al[35] | 200 | 10529 | Nonsignificant results of extracorporeal shockwave therapy for pain, overall shoulder function, and active range of motion<br>Effect size for pain compared to a placebo, −0.39 (−0.78, −0.01) | Low (Cochrane risk-of-bias tool) | Moderate (GRADE approach) |
| Yu et al[40] | 22 | 1195 | Extracorporeal shockwave therapy was not more effective than placebo for the management of SSP<br>No effect sizes reported | Low (SIGN criteria) | Moderate |

*Abbreviations: GRADE, Grading of Recommendations Assessment, Development and Evaluation; SIGN, Scottish Intercollegiate Guidelines Network; SSP, subacromial shoulder pain.*
[a]*Values in parentheses are 95% confidence interval.*
[b]*Reported in the original review.*

any positive effect remained unclear. The heterogeneity of the different components defining multimodal therapy could explain the variety of conclusions. Multimodal therapy can include many different interventions, which makes it difficult to draw a conclusion about its effectiveness.

Regarding the effectiveness of corticosteroid injection, a moderate recommendation can be made regarding the clinical significance of corticosteroid injection as an isolated treatment or in addition to exercise-based therapy. More research is needed to draw definite conclusions on the effectiveness of corticosteroids for the management of SSP.

Other commonly prescribed interventions, including therapeutic ultrasound, low-level laser, extracorporeal shockwave therapy, and pulsed electromagnetic energy, lack evidence of effectiveness and should not be used when managing SSP.

The methodological quality of the systematic reviews we included was moderate. Littlewood et al[22] reported scores ranging from 3/11 to 9/11, with a mean of 6/11. The range of scores in the current review was between 5/11 and 9/11, with a mean of 7/11.

Future reviews and research should focus on the modalities of exercise therapy (eg, types, repetitions). Also, there is a clear lack of high-quality RCTs and reviews testing the potential added value of manual therapy and indicating when and how it should be applied. As multimodal physical therapy can cover a wide range of different treatment modalities, a clear and well-considered selection should be made to determine which treatment modalities should be used in addition to exercise therapy.

As this review is an umbrella review, only data (eg, comparison groups, follow-up assessments) provided in the original reviews could be used. There were no specific requirements or inclusion/exclusion criteria considering comparators. As in every review, different comparison groups are used, and as this review uses 16 different reviews, the comparison groups were too heterogeneous to present a clear overview.

### Potential Limitations of Our Umbrella Review

There is a risk of multiple counting of primary studies that are included in multiple systematic reviews. Hence, those interventions that have been studied the most can be overrepresented in umbrella reviews. We focused on nonsurgical interventions, but certain interventions may have been missed using this search strategy.

Because different terms are used to describe SSP,[31] the included reviews might have missed certain RCTs that used other terms to describe this shoulder problem.

## CONCLUSION

Evidence for exercise as the most important management strategy for SSP is increasing and strengthening. Ongoing research is necessary to identify whether there is an optimal dose and type of exercise. Currently, it is not possible to state that one exercise program is more appropriate than another. However, a strong recommendation may be made to include manual therapy as an adjunct intervention with exercise. Conflicting evidence surrounds the effectiveness of multimodal therapy and corticosteroid injection. Other commonly prescribed nonsurgical interventions, such as ultrasound, low-level laser, and extracorporeal shockwave therapy, lack evidence of effectiveness. ◉

### KEY POINTS

**FINDINGS:** Exercise therapy should be considered as a principal intervention in the management of subacromial shoulder pain. Manual therapy may provide further benefit if used as an adjunct therapy.

**IMPLICATIONS:** Exercise therapy should be prioritized as the primary treatment

**TABLE 9** Systematic Reviews Relating to the Effectiveness of Pulsed Electromagnetic Energy for SSP

| Study | Sample Size | Patients Included | Results | Risk of Bias[a] | Level of Evidence[a] |
|---|---|---|---|---|---|
| Dong et al[11] | 33 | 2300 | Pulsed electromagnetic energy can be considered as a second-line treatment. Exercise and exercise-based therapies are the first-line choices<br>No effect sizes reported | Low (Cochrane risk-of-bias tool) | Low |
| Haik et al[15] | 64 | 6319 | Pulsed electromagnetic energy was not effective to reduce pain and improve function in individuals with SSP<br>No effect sizes reported | Low (PEDro scale) | High |
| Page et al[27] | 47 | 2388 | Pulsed electromagnetic energy had no clinically important benefits compared to placebo<br>No effect sizes reported | High (Cochrane risk-of-bias tool) | Low (GRADE approach) |
| Steuri et al[35] | 200 | 10529 | Nonsignificant results of pulsed electromagnetic energy for pain, overall shoulder function, and active range of motion<br>No effect sizes reported | Low (Cochrane risk-of-bias tool) | Moderate (GRADE approach) |

*Abbreviations: GRADE, Grading of Recommendations Assessment, Development and Evaluation; PEDro, Physiotherapy Evidence Database; SSP, subacromial shoulder pain.*
[a]*Reported in the original review.*

option, due to its clinical effectiveness, cost-effectiveness, and other associated health benefits.

**CAUTION:** Continued research is needed to more fully understand the uncertainty around the optimal type, dose, and duration of exercise for subacromial shoulder pain. All possible effects of manual therapy are seen in the short term and in the initial phase of rehabilitation, and always in addition to an exercise program.

## STUDY DETAILS

**PATIENT AND PUBLIC INVOLVEMENT:** There was no patient-public involvement in the research.

**DATA SHARING:** All data relevant to the study are included in the article.

**AUTHOR CONTRIBUTIONS:** All authors contributed to the initial phase of writing the manuscript and to the review process. Final adaptations and approval were given by Drs Lewis and Struyf and Ms Pieters.

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## APPENDIX A

### BACKGROUND AND FINDINGS OF THE STUDY

| | |
|---|---|
| What is known about this subject | • Exercise and multimodal physical therapy might be effective in the management of rotator cuff tendinopathy<br>• Exercise therapy should be prioritized as the primary treatment option, due to its clinical effectiveness, cost-effectiveness, and other associated health benefits |
| What this study adds to existing knowledge | • The evidence for the use of exercise therapy in the management of subacromial shoulder pain is consistent, and exercise should be considered as a principal intervention in the management of those with subacromial shoulder pain<br>• Manual therapy may provide further benefit if used in addition to exercise therapy<br>• Conflicting evidence surrounds the effectiveness of multimodal therapy and corticosteroid injection<br>• Ultrasound, low-level laser, and extracorporeal shockwave therapy lack evidence of effectiveness |

## APPENDIX B

### SEARCH STRATEGY

| Search Type | Search Term |
|---|---|
| Abbreviated | (subacromial impingement syndrome OR painful arc syndrome OR shoulder impingement OR subacromial bursitis OR rotator cuff tendonitis OR rotator cuff tendinosis OR supraspinatus tendonitis OR contractile dysfunction) AND (conservative treatment OR exercise OR exercise combined with manual therapy OR multimodal physiotherapy OR corticosteroid injection OR laser OR ultrasound OR extracorporeal shock wave therapy OR pulsed electromagnetic energy) AND (systematic review OR meta-analysis) |
| Detailed | ((“shoulder impingement syndrome”[MeSH Terms] OR (“shoulder”[All Fields] AND “impingement”[All Fields] AND “syndrome”[All Fields]) OR “shoulder impingement syndrome”[All Fields] OR (“subacromial”[All Fields] AND “impingement”[All Fields] AND “syndrome”[All Fields]) OR “subacromial impingement syndrome”[All Fields]) OR ((“pain”[MeSH Terms] OR “pain”[All Fields] OR “painful”[All Fields]) AND (“Arthrogryposis renal dysfunction cholestasis syndrome”[All Fields] OR “arc syndrome”[All Fields])) OR ((“shoulder”[MeSH Terms] OR “shoulder”[All Fields]) AND impingement[All Fields]) OR (subacromial[All Fields] AND (“bursitis”[MeSH Terms] OR “bursitis”[All Fields])) OR ((“rotator cuff”[MeSH Terms] OR (“rotator”[All Fields] AND “cuff”[All Fields]) OR “rotator cuff”[All Fields]) AND (“tendinopathy”[MeSH Terms] OR “tendinopathy”[All Fields] OR “tendonitis”[All Fields])) OR ((“rotator cuff”[MeSH Terms] OR (“rotator”[All Fields] AND “cuff”[All Fields]) OR “rotator cuff”[All Fields]) AND (“tendinopathy”[MeSH Terms] OR “tendinopathy”[All Fields] OR “tendinosis”[All Fields])) OR (supraspinatus[All Fields] AND (“tendinopathy”[MeSH Terms] OR “tendinopathy”[All Fields] OR “tendonitis”[All Fields])) OR ((“muscle contraction”[MeSH Terms] OR (“muscle”[All Fields] AND “contraction”[All Fields]) OR “muscle contraction”[All Fields] OR “contractile”[All Fields]) AND (“physiopathology”[Subheading] OR “physiopathology”[All Fields] OR “dysfunction”[All Fields]))) AND ((conservative[All Fields] AND (“therapy”[Subheading] OR “therapy”[All Fields] OR “treatment”[All Fields] OR “therapeutics”[MeSH Terms] OR “therapeutics”[All Fields])) OR (“exercise”[MeSH Terms] OR “exercise”[All Fields]) OR ((“exercise”[MeSH Terms] OR “exercise”[All Fields]) AND combined[All Fields] AND (“musculoskeletal manipulations”[MeSH Terms] OR (“musculoskeletal”[All Fields] AND “manipulations”[All Fields]) OR “musculoskeletal manipulations”[All Fields] OR (“manual”[All Fields] AND “therapy”[All Fields]) OR “manual therapy”[All Fields])) OR (multimodal[All Fields] AND (“physical therapy modalities”[MeSH Terms] OR (“physical”[All Fields] AND “therapy”[All Fields] AND “modalities”[All Fields]) OR “physical therapy modalities”[All Fields] OR “physiotherapy”[All Fields])) OR ((“adrenal cortex hormones”[MeSH Terms] OR (“adrenal”[All Fields] AND “cortex”[All Fields] AND “hormones”[All Fields]) OR “adrenal cortex hormones”[All Fields] OR “corticosteroid”[All Fields]) AND (“injections”[MeSH Terms] OR “injections”[All Fields] OR “injection”[All Fields])) OR (“lasers”[MeSH Terms] OR “lasers”[All Fields] OR “laser”[All Fields]) OR (“ultrasonography”[Subheading] OR “ultrasonography”[All Fields] OR “ultrasound”[All Fields] OR “ultrasonography”[MeSH Terms] OR “ultrasound”[All Fields] OR “ultrasonics”[MeSH Terms] OR “ultrasonics”[All Fields]) OR (extracorporeal[All Fields] AND (“shock”[MeSH Terms] OR “shock”[All Fields]) AND wave[All Fields] AND (“therapy”[Subheading] OR “therapy”[All Fields] OR “therapeutics”[MeSH Terms] OR “therapeutics”[All Fields])) OR (pulsed[All Fields] AND (“electromagnetic radiation”[MeSH Terms] OR (“electromagnetic”[All Fields] AND “radiation”[All Fields]) OR “electromagnetic radiation”[All Fields] OR (“electromagnetic”[All Fields] AND “energy”[All Fields]) OR “electromagnetic energy”[All Fields]))) AND ((“review”[Publication Type] OR “review literature as topic”[MeSH Terms] OR “systematic review”[All Fields]) OR (“meta-analysis”[Publication Type] OR “meta-analysis as topic”[MeSH Terms] OR “meta-analysis”[All Fields])) AND ((systematic[sb] OR Meta-Analysis[ptyp]) AND (“2012/09/01”[PDAT]: “2018/10/01”[PDAT]) AND “humans”[MeSH Terms]) |

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# Landing Biomechanics, But Not Physical Activity, Differ in Young Male Athletes With and Without Patellar Tendinopathy



Patellar tendinopathy is prevalent in individuals who are physically active, particularly athletes who participate in sports with repetitive jumping maneuvers.[10,11,26,44] Excess load on the tendon is believed to be a key factor contributing to patellar tendinopathy development.[13,14]

Differences in patellar tendon force, a biomechanical measure that estimates tissue-specific load to the tendon, during various landing tasks have been identified between individuals with and without symptoms of patellar tendinopathy.[4,19,38] Determining whether biomechanical profiles are different between individuals at differing stages along the continuum of tendon pathology[13] may inform the development of enhanced impairment-based, individualized treatment programs. However, to date, no biomechanical studies have compared movement-profile characteristics while controlling for tendon structural status and symptoms, and simultaneously included a healthy control group and used robust inclusion criteria.

**OBJECTIVE:** To examine differences in biomechanical and physical activity load in young male athletes with and without patellar tendinopathy.

**DESIGN:** Cross-sectional cohort study.

**METHODS:** Forty-one young male athletes (15-28 years of age) were categorized into 3 distinct groups: symptomatic athletes with patellar tendon abnormalities (PTA) (n = 13), asymptomatic athletes with PTA (n = 14), and a control group of asymptomatic athletes without PTA (n = 14). Participants underwent a laboratory biomechanical jump-landing assessment and wore an accelerometer for 1 week of physical activity monitoring.

**RESULTS:** The symptomatic group demonstrated significantly less patellar tendon force loading impulse in the involved limb compared with both the control and asymptomatic groups ($P<.05$), with large effects ($d$ = 0.91-1.40). There were no differences in physical activity between the 3 groups ($P>.05$).

**CONCLUSION:** Young male athletes with symptomatic patellar tendinopathy demonstrated smaller magnitudes of patellar tendon force loading impulse during landing compared to both asymptomatic athletes with patellar tendinopathy and healthy control participants. However, these 3 distinct groups did not differ in general measures of physical activity. Future investigations should examine whether comprehensively monitoring various loading metrics may be valuable to avoid both underloading and overloading patterns in athletes with patellar tendinopathy. *J Orthop Sports Phys Ther 2020;50(3):158-166. Epub 6 Jan 2020. doi:10.2519/jospt.2020.9065*

**KEY WORDS:** *accelerometer, load, tendon*

A limitation of traditional biomechanical assessment is that it provides a snapshot of the individual's magnitude of loading in a controlled environment and does not consider the frequency and duration of repeated loading over a prolonged time period. Given the importance of load volume in the development of patellar tendinopathy, it may also be important to consider physical activity load measures, such as the number of steps (frequency) or amount of time (duration) in moderate to vigorous physical activity (MVPA). Considering these physical activity load measures may better inform the prevention and management of symptomatic patellar tendinopathy. Advances in wearable technology, specifically accelerometry, allow for quantification of physical activity metrics that provide objective insight into cumulative external loading in an individual's natural environment.[24,32] Accelerometry-based measurement of physical activity is superior to self-reported quantification, because it removes recall error bias and is able to objectively quantify the amount and intensity of various forms of physical activity.[5,37,39,40] Previous literature has reported associations between training and competition load and injury.[21,35] Visnes and Bahr[42] demonstrated that high training volume (hours per week) and match exposure (matches

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per week), measured via self-reported weekly training diaries, were risk factors for the development of tendinopathy in adolescent volleyball athletes (odds ratio = 1.72-3.38).

However, to date, no studies have investigated objective measures of physical activity in individuals with patellar tendinopathy. As the pathoetiology of tendinopathy is a continuum,[13,14] it is possible that individuals at different stages of the continuum (individuals with asymptomatic and symptomatic tendon pathology) may have different levels of physical activity, which may be important in the progression of tendinopathy. Additionally, though studies demonstrate that athletes with patellar tendinopathy report high levels of activity-related pain on subjective patient-reported outcomes,[15] it is unclear whether these measures are associated with objective measures of physical activity, or whether athletes reduce their physical activity at all. Quantifying physical activity load in addition to biomechanical load magnitude in this population would improve our understanding of the associations between altered loading and clinical manifestations of patellar tendinopathy (ie, tendon pathology and pain).

Therefore, the purpose of this study was to investigate differences in patellar tendon force loading impulse and physical activity load between male athletes with and without patellar tendinopathy. We hypothesized that, compared to healthy control participants, athletes with symptomatic patellar tendinopathy would demonstrate less patellar tendon force loading impulse and physical activity load, while athletes with asymptomatic patellar tendinopathy would demonstrate greater patellar tendon force loading impulse and physical activity load.

## METHODS

The study protocol was approved by the Biomedical Institutional Review Board at the University of North Carolina at Chapel Hill (IRB 17-1731) and registered at www.ClinicalTrials.gov (NCT03262181). An a priori sample-size estimate was calculated using G*Power Version 3.1.9.2 (Heinrich-Heine Universität, Düsseldorf, Germany) to determine the number of participants necessary to detect differences in key biomechanical variables between groups. Using an alpha of .05, a beta of .20, and data from previous literature demonstrating group differences in knee flexion angle and peak vertical ground reaction force with large effects ($d$ = 0.75-1.25),[18,19] between 13 and 15 participants per group would be necessary to adequately power this study.

### Participants

All participants provided written informed consent or parental consent prior to enrollment. Forty-three male participants with and without patellar tendinopathy were enrolled following screening (**FIGURE 1**). Participants were recruited from the local high school and university communities using e-mail correspondence and public flyers. All participants were 15 to 28 years of age and postpubertal, as quantified by Pubertal Development Scale stage 5 (score greater than 10).[6] Participants were required to be actively participating within an organized sport setting, quantified by a Tegner Activity Scale score of 5 or greater (**TABLE 1**, **TABLE 2**).

### Screening Protocol for Patellar Tendinopathy

All participants underwent a 2-part screening protocol to determine group assignment. Participants were recruited into the symptomatic patellar tendon

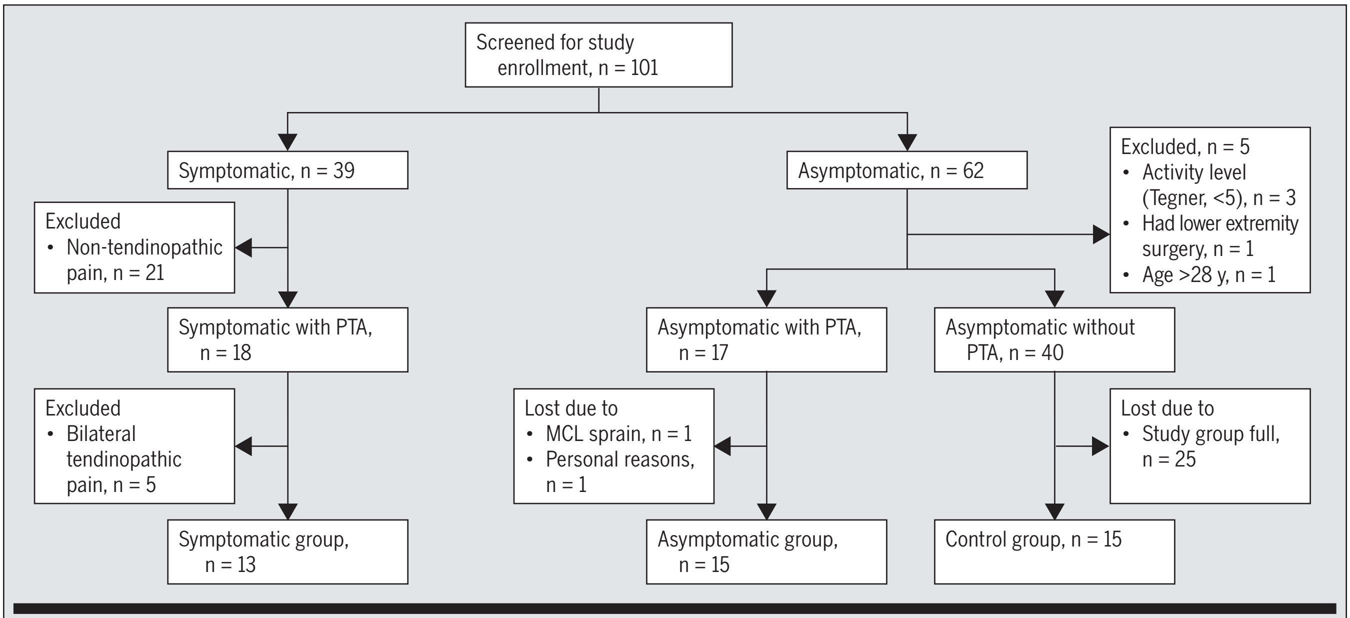


**FIGURE 1.** CONSORT diagram for study recruitment and enrollment. Abbreviations: MCL, medial collateral ligament; PTA, patellar tendon abnormality.

abnormality group if they exhibited (1) focal, isolated pain of 2/10 or greater on the numeric rating scale (identified by the participant on a pain map) during performance of the single-leg decline squat (SLDS) test,[33] and (2) ultrasonographic evidence of a structural proximal patellar tendon abnormality (a hypoechoic region 2 mm or greater, evident on both the longitudinal and transverse scans).[9,16] All ultrasonographic images were obtained by a single trained investigator (L.P.). If a participant noted bilateral SLDS pain, a criterion of 5/10 or greater on the "worse" limb and less than 2/10 on the contralateral limb was required. Participants were recruited into the asymptomatic patellar tendon abnormality group if they were free of SLDS pain but demonstrated ultrasonographic evidence of a patellar tendon abnormality. Finally, participants were recruited into the healthy control group if free of SLDS pain and patellar tendon abnormalities.

Participants were excluded if they had (1) known neurological disorders or cardiopulmonary diseases, (2) a history of any lower extremity surgery, (3) a history of a lower extremity injury in the prior 6 months, (4) an injection to the patellar tendon in the previous 3 months, (5) participation in formal rehabilitation for anterior knee pain in the prior 3 months, (6) presentation of non-tendinopathic knee pain during the SLDS test (ie, patellofemoral pain syndrome presentation), or (7) any other medical condition that would prevent them from participation in normal activities of daily living.

Following completion of the study period, 2 participants' physical activity data were not usable due to device malfunction. Therefore, 41 male participants with and without patellar tendinopathy had full data sets that were utilized for analysis in this study (**TABLE 1**).

## Patient-Reported Outcomes

The Victorian Institute of Sport Assessment-patellar tendon (VISA-P) questionnaire was used to quantify self-reported symptoms and knee function during the screening session (0-100, with 100 indicating no symptoms and full knee function).[15] All participants completed this questionnaire at the time of the screening session.

## Physical Activity Measurement

**Data Collection** Participants were outfitted with a GT9X Link accelerometer (ActiGraph, LLC, Pensacola, FL), a solid-state triaxial accelerometer with known validity and reliability for MVPA in young, active cohorts.[3,20]

Participants wore the accelerometer at the right anterior superior iliac spine for a period of 7 days.[3,20,30] A valid wear period was considered to be at least 4 total days (3 weekdays and 1 weekend day) and at least 480 minutes (8 hours) per day. The visual feedback display feature (ie, steps per day) on the screen of the accelerometer was disabled to avoid participant bias regarding daily performance. Participants kept daily physical activity logs, including both exercise and sport-specific activity, during the wear period. When insufficient data were obtained in the first period, participants were asked to rewear the accelerometer for an additional 7-day wear period (n = 2 participants).

**Data Analysis** The primary physical activity outcome variables for this study were average minutes in MVPA per day, average steps per day, and average steps in MVPA per day during the valid wear period. The GT9X Link accelerometer (ActiGraph, LLC) measured accelerations in the range of ±8 *g* at a 30-Hz sampling frequency in raw acquisition mode, with a 60-second epoch parameter (data written to memory every 60 seconds). After participant use, data were processed and analyzed using proprietary actigraphy data analysis software (ActiLife Version 6.0.0; ActiGraph, LLC). Wear time validation was performed using algorithms from Choi et al,[7] which differentiate between periods of valid wear and nonwear time. Next, Freedson adult triaxial vector magnitude cut points were applied to classify physical activity as light, moderate, vigorous, and very vigorous, based on the number of activity counts per 60-second epoch.[36] The number of steps per day was calculated within ActiLife, based on the vertical acceleration data measured with the GT9X Link monitor. All variables of interest were normalized to the number of valid wear days (**FIGURE 2**) prior to analysis.

**TABLE 1** PARTICIPANT CHARACTERISTICS[a]

| | Healthy Control (n = 14) | Asymptomatic Tendinopathy (n = 14) | Symptomatic Tendinopathy (n = 13) |
|---|---|---|---|
| Age, y | 19.64 ± 1.60 | 21.00 ± 1.96 | 19.62 ± 1.61 |
| Height, m | 1.84 ± 0.09 | 1.84 ± 0.07 | 1.82 ± 0.05 |
| Mass, kg | 79.91 ± 12.95 | 81.63 ± 13.03 | 83.46 ± 5.12 |
| Tegner Activity Scale (0-10) | 8.00 ± 0.88 | 8.00 ± 1.04 | 8.00 ± 1.00 |
| Pubertal Development Scale (0-12) | 11.57 ± 0.65 | 11.86 ± 0.53 | 11.39 ± 0.87 |
| VISA-P (0-100) | 97.64 ± 3.41 | 94.07 ± 7.85 | 76.15 ± 13.37 |

*Abbreviation: VISA-P, Victorian Institute of Sport Assessment-patellar tendon.*
[a]*Values are mean ± SD.*

## Three-Dimensional Landing Assessment

**Testing Protocol** On a separate testing day following the 7-day accelerometer wear period, participants visited the laboratory for a 3-D biomechanical landing assessment. Participants performed a 5-minute warm-up on a stationary bicycle at a self-selected pace.

**Double-Limb Jump-Landing Task** Participants wore their own athletic shoes. Participants performed 5 trials of a jump-landing task from a 30-cm box that was positioned from the front edge of the force plates at a distance of half the participant's height.[22] The participants were instructed to jump forward off the box to a double-leg landing, with one foot on each force plate, and immediately perform a maximal vertical jump upon landing.[22] Participants performed a minimum of 1 practice trial and subsequent practice trials necessary to ensure correct performance of the jump-landing task. A total of 5 successful jump-landing trials were collected, and the middle 3 trials were averaged for data analysis. A successful trial required the participant to leave the box with both feet at the same time, land on the force plates, and jump straight up in the air as high as possible.

Participants were outfitted with 20 retroreflective markers bilaterally on the following bony landmarks: acromion process, anterior superior iliac spine, greater trochanter, medial and lateral femoral condyles, medial and lateral malleoli, calcanei, and the first and fifth metatarsal heads.[27] A single marker was placed on the manubrium of the sternum and at the L4-5 vertebral space. Rigid clusters of 3 or 4 markers were placed at the sacrum and on the thigh, shank, and foot segments bilaterally.

**Data Acquisition** Three-dimensional kinematic data were collected using a 10-camera motion-capture system (Vicon; Oxford Metrics, Yarnton, UK) sampled at 120 Hz and filtered using a fourth-order, low-pass Butterworth filter with a 12-Hz cutoff frequency. Kinetic data were sampled at 1200 Hz using 2 floor-embedded force plates (Bertec Corporation, Columbus, OH). Knee and ankle joint center coordinates were defined using the centroid method,[22] and hip joint center coordinates were estimated using the Bell method.[2] Joint angles were defined based on the position of the distal segment relative to the proximal segment using a Cardan angle sequence in the following order of rotation: sagittal ($y$-axis), frontal ($x$-axis), and transverse ($z$-axis).

**Data Processing and Reduction** The lower extremity biomechanics of the involved (symptomatic and asymptomatic groups) and dominant (control group) limbs were evaluated during the descending phase of the jump-landing task (initial contact to peak knee flexion angle).[22] Ground reaction force and internal sagittal and frontal plane knee and hip joint moments were calculated using inverse dynamics procedures.[43] Patellar tendon force (body weight) was estimated using the internal knee extension moment and patellar tendon moment arm, following a previous methodology.[23,31] Patellar tendon force impulse (body weight times milliseconds) and internal knee extension moment impulse (Newton meters times milliseconds) were calculated as the area under the patellar tendon force and knee extension moment curves, respectively. Knee power, as measured in Joules per second, was calculated as the product of the internal sagittal plane knee moment (Newton meters divided by kilogram meters) and knee flexion velocity (degrees per millisecond). Negative knee work, as measured in Joules, was calculated as the negative area under the knee power curve.

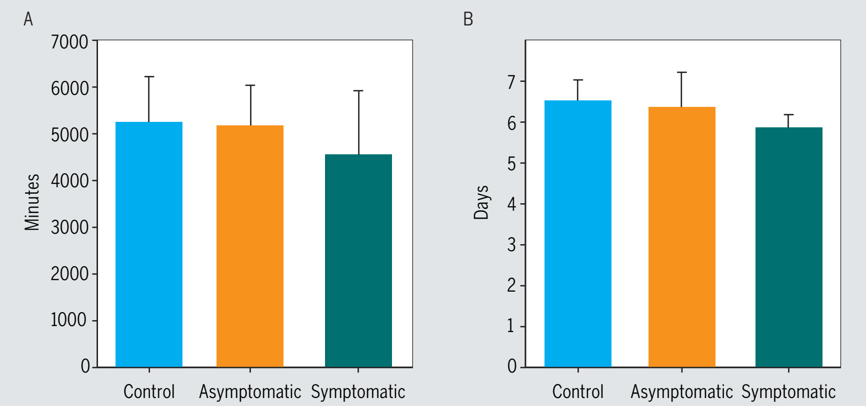


**FIGURE 2.** Comparison of wear-time metrics between groups: (A) total wear time and (B) valid wear time.

**TABLE 2** SPORT TYPE FOR EACH PARTICIPANT GROUP[a]

| Sport | Healthy Control (n = 14) | Asymptomatic Tendinopathy (n = 14) | Symptomatic Tendinopathy (n = 13) |
|---|---|---|---|
| Basketball | 6 | 8 | 6 |
| Volleyball | 2 | 1 | 3 |
| Ultimate frisbee | 3 | 2 | 2 |
| Soccer | 1 | 2 | 0 |
| Lacrosse | 1 | 0 | 1 |
| Handball | 1 | 0 | 1 |
| Football | 0 | 1 | 0 |

[a]*Values are n.*

## Statistical Analysis

Descriptive characteristics (means, SDs, 95% confidence intervals) were calculated for all dependent variables (**TABLE 1**). Our primary biomechanical load variable of interest, patellar tendon force impulse, was compared between the 3 groups using a 1-way analysis of variance, and a Tukey post hoc test was used for pairwise comparisons of means for significant findings. Our primary physical activity load variables, steps in MVPA per day and minutes in MVPA per day, were also assessed using a 1-way analysis of variance, with

Bonferroni correction ($\alpha$ = .05/2 = .025) to account for the potential relationship between these 2 variables. Separate 1-way analysis-of-variance models were utilized to compare the variables of exploratory biomechanical load (knee extension moment impulse, patellar tendon force, negative knee work, and knee power) and physical activity load (steps per day) across the 3 groups. Mean differences between groups and associated 95% confidence intervals were calculated. Cohen's *d* effect sizes were used to evaluate the magnitude of between-group differences for loading volume variables, classified as weak ($d \leq 0.2$), small (*d* = 0.2-0.5), moderate (*d* = 0.5-0.8), or large ($d \geq 0.8$).[8] Pearson product-moment correlations were utilized to examine the relationship between objective physical activity measures and VISA-P score. Statistical significance was set a priori at $\alpha$<.05. All statistical analyses were completed in SPSS Version 22 (IBM Corporation, Armonk, NY).

## RESULTS

No significant differences in height, mass, or age were observed between groups (*P*>.05) (**TABLE 1**). The VISA-P score was significantly lower in the symptomatic group compared to both the asymptomatic and control groups (*P*<.001).

The symptomatic group demonstrated significantly less patellar tendon force impulse than the control (*P*<.01) and asymptomatic (*P*<.05) groups (**FIGURE 3**). The magnitude of the effect for the symptomatic group compared to controls was considered to be strong and significant (Cohen's *d* = 1.40). Additionally, the exploratory variables of knee extension moment impulse and negative knee work were smaller in the symptomatic group compared to the control (*P*<.01) and asymptomatic (*P*<.05) groups, and patellar tendon force was smaller in the symptomatic group compared to the control group only (*P*<.05) (**FIGURE 3**). There were no statistically significant differences in knee power between any groups (*P*>.05). There were no statistically significant differences in any biomechanical load magnitude variables between the control and asymptomatic groups (*P*>.05).

There were no significant differences between the 3 groups for the primary physical activity variables of interest

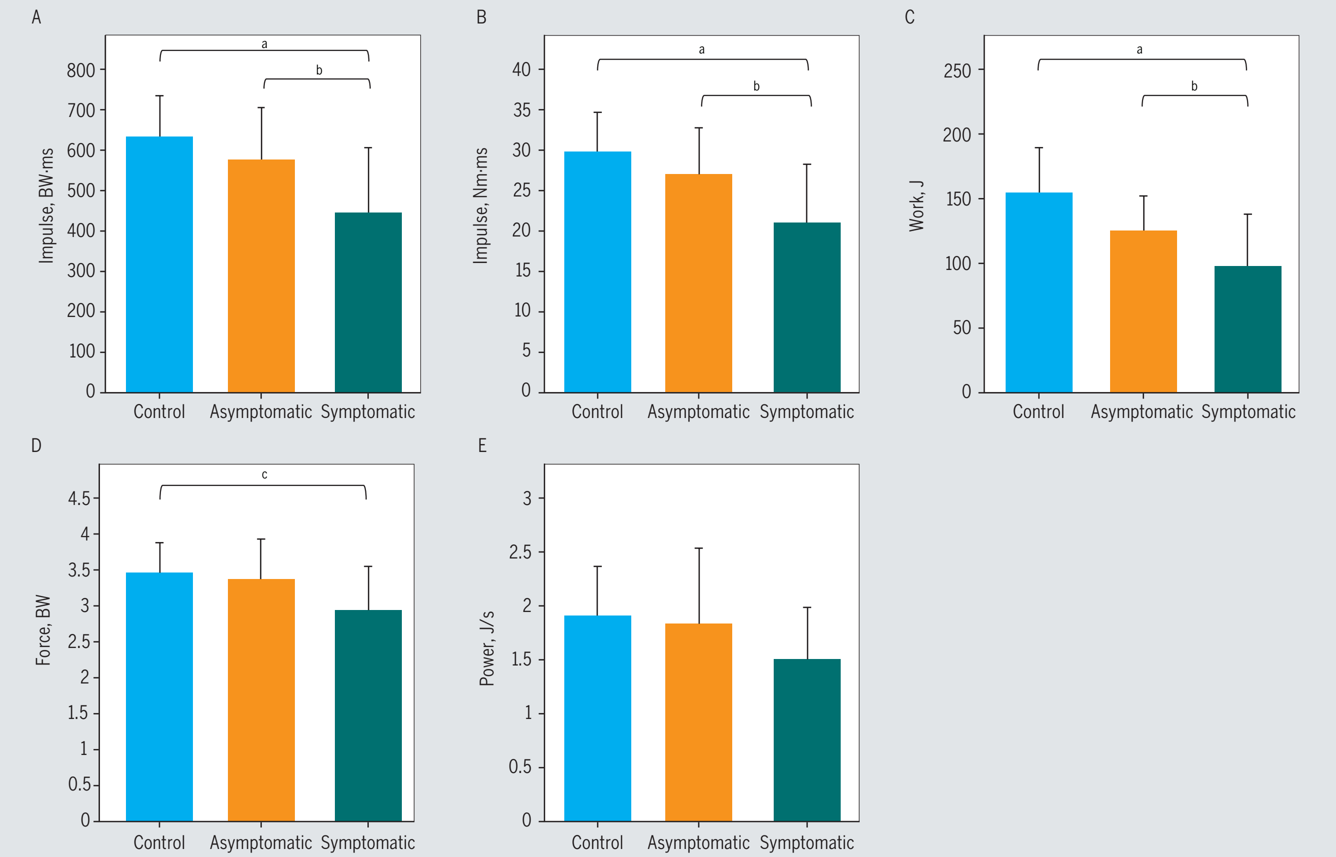


**FIGURE 3.** Biomechanical load magnitude variable comparisons between groups: (A) patellar tendon force impulse, (B) knee extension moment impulse, (C) negative knee joint work, (D) patellar tendon force, and (E) knee power. [a]Statistically significant difference between the control and symptomatic groups (*P*<.01). [b]Statistically significant difference between the asymptomatic and symptomatic groups (*P*<.05). [c]Statistically significant difference between the control and symptomatic groups (*P*<.05). Abbreviation: BW, body weight.

($P$>.025) (**FIGURE 4**). Neither total wear time ($P$ = .205) nor valid wear days ($P$ = .134) was significantly different between groups (**FIGURE 2, TABLE 3**). All group comparisons were conducted before and after controlling for total wear time, and neither model demonstrated statistical significance ($P$>.05).

## DISCUSSION

Symptomatic participants displayed significantly smaller patellar tendon force loading impulse on the involved limb compared to the healthy control and asymptomatic participants. In contrast to our hypothesis, patellar tendon force loading impulse was not greater in the asymptomatic participants compared to the healthy controls. Interestingly, there were no differences in measures of physical activity load between the 3 groups. To the best of our knowledge, this is the first study to objectively measure both biomechanical and physical activity load metrics in individuals with patellar tendinopathy.

Symptomatic participants demonstrated lower magnitudes of involved-limb patellar tendon force loading impulse than both the asymptomatic and control groups. Although numerous factors play a role, this movement pattern may reflect a load-avoidance behavior driven by pain, whereby individuals reduce extensor mechanism loading during the descending phase of the landing task. In the present study, we saw large effects for patellar tendon force impulse ($d$ = 1.40) between the control and symptomatic groups. Chronic reduction in eccentric stimulus to the patellar tendon tissue over the course of a landing task may reduce the effectiveness of the stretch-shortening cycle and lead to other compensatory movement strategies.[25]

The rate of load across the patellar tendon (patellar tendon force impulse) represents lesser tissue loading in the symptomatic group. Interestingly, though an exploratory variable, we also saw less peak patellar tendon force during the landing task in the symptomatic group compared to the control group. Edwards et al[18] found that normalized peak patellar tendon forces were significantly greater than peak vertical ground reaction forces during the horizontal phase of a stop-jump task in healthy men, suggesting that using vertical ground reaction forces to represent patellar tendon load may underestimate the specific load across the tissue. Estimating the patellar tendon tissue load during landing was a unique feature of the current study. For individuals with soft tissue or joint injury conditions, chronic tissue underloading may fail to provide the mechanical stimulus needed to maintain tissue homeostasis within its envelope of function.[17] There may be long-term consequences, as chronic reductions in patellar tendon force may facilitate decreased tissue capacity. Over time, this pattern may initiate a cycle of repeated bouts of pain in response to decreased loading levels. Identifying individuals with patellar tendinopathy who underload the patellar tendon during common sport-related movements, like jumping and landing, may be valuable in clinical practice to develop safe and progressive load-related exercise interventions.[14]

Though only exploratory in nature, our finding of lesser knee extension moment impulse and negative knee work in the

**TABLE 3** WEAR TIME COMPLIANCE FOR ACTIGRAPHY PHYSICAL ACTIVITY MEASURES[a]

| | Healthy Control (n = 14) | Asymptomatic Tendinopathy (n = 14) | Symptomatic Tendinopathy (n = 13) |
|---|---|---|---|
| Total wear time, min | 5298 ± 968 (4739, 5859) | 5217 ± 881 (4708, 5725) | 4598 ± 1375 (3767, 5428) |
| Valid wear time, d | 6.58 ± 0.51 (6.28, 6.87) | 6.43 ± 0.85 (5.94, 6.92) | 5.92 ± 0.31 (5.25, 6.60) |

[a]*Values are mean ± SD (95% confidence interval). There were no statistically significant differences between groups (P>.05).*

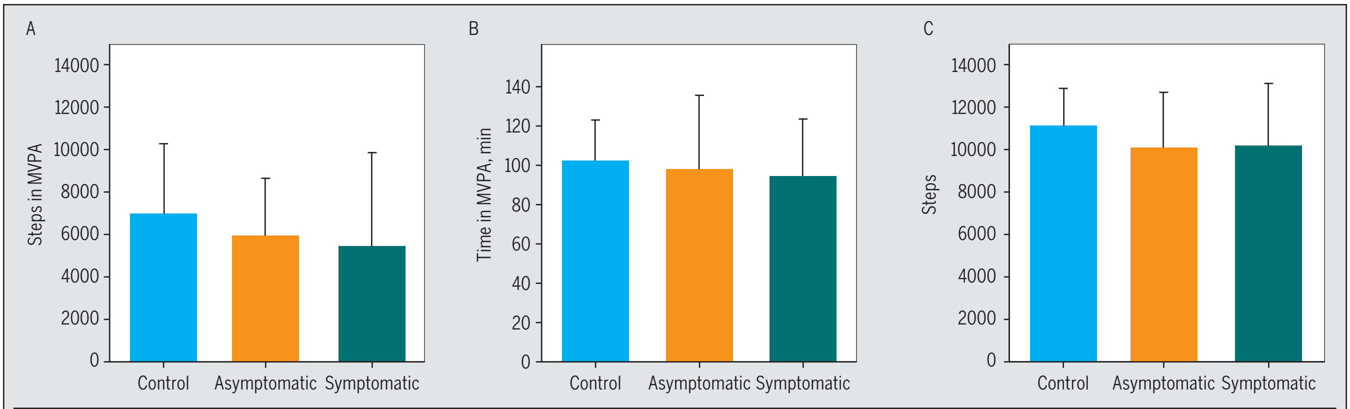


**FIGURE 4.** Comparison of physical activity load metrics between groups: (A) total steps per day spent in MVPA ($P$ = .323), (B) total time per day spent in MVPA ($P$ = .691), and (C) total steps per day ($P$ = .481). Abbreviation: MVPA, moderate to vigorous physical activity.

symptomatic group compared to both the asymptomatic and control groups is consistent with previous literature examining energetic variables during landing tasks in individuals with patellar tendinopathy. Bisseling et al[4] demonstrated lesser knee joint power and work and lower peak knee moments in athletes with symptomatic tendinopathy. Mechanical power and work reflect the interaction of load and displacement, which are highly relevant to the sagittal plane demand on the patellar tendon during jumping maneuvers. Future biomechanical research in patellar tendinopathy should continue to evaluate mechanical energy absorption during landing.

Interestingly, there were no differences in physical activity load between our 3 groups. These findings were in contrast to our hypotheses that the symptomatic group would demonstrate lesser, and the asymptomatic group would demonstrate greater, physical activity load than the control group, respectively. The development and progression of patellar tendinopathy in athletes are thought to be related to the excessive external load over time.[12-14,28,29] Though multifactorial, the load-related pathoetiology of tendinopathy stems from a discrepancy between the tendon tissue's load capacity and imposed external load.[12,14] Our findings may have important clinical implications for how clinicians design, prescribe, and manage load exposure in athletes.

A study conducted by Visnes and Bahr[42] tracked training volume prospectively for 4 years via self-reported training diaries in young, elite volleyball players, and found that the development of symptomatic patellar tendinopathy was associated with higher overall training characteristics, specifically number of hours and matches played. It is possible that the specificity of the activity-related measures to the sport of volleyball (hours and matches played) used by Visnes and Bahr[42] better captured the type of load related to tendinopathy development than the general measures of steps or time in MVPA per day used in the current study. Tendinopathy is most prevalent in athletes participating in jumping sports,[26] and the risk of patellar tendinopathy is associated with jumping performance.[26,34,41,42] However, while there is evidence of sex and interindividual differences in jumping frequency,[1] little is known about how jumping frequency may influence the risk or progression of patellar tendinopathy, or how jumping frequency differs once symptoms are present. Over time, chronic underloading may lead to reduced tissue capacity through stress shielding, and limit the adaptive potential of the tissue when exposed to the high loading demands of sport.[13,28] Future work should seek to develop feasible, implementable strategies to identify changes in physical activity or, more specifically, tissue load that may be reflective of trends in either overloading or underloading that may result in deleterious outcomes. In light of current gaps in existing evidence and the current study's findings, an important next step in load management should include serial monitoring of sport-specific movements, such as tracking jump counts over time, which may be more helpful in understanding the effect of real-world load volume on patellar tendinopathy.

Additionally, we hypothesized that individuals with symptoms would self-restrict their physical activity due to pain-avoidance behavior. However, despite worse VISA-P scores, the symptomatic group did not differ from the other groups in physical activity. Additionally, VISA-P score was not correlated with the physical activity measures ($P$>.05). The VISA-P scores in the symptomatic group (mean ± SD, 76.15 ± 13.37 points) were comparable to symptomatic cohorts of similar ages and activity levels in previous studies.[4,38,41] This finding may have important clinical implications, as it suggests that individuals who report high levels of pain-related disability do not necessarily limit their physical activity. Additionally, our results indicate that patient-reported outcomes may not accurately reflect the influence of pain on physical activity if used in isolation. Longitudinal studies that regularly monitor both physical activity and patient-reported function are needed to better understand the effects of tendinopathy on sport participation.

These combined findings suggest that individuals with symptomatic patellar tendinopathy do not significantly limit physical activity compared to their healthy counterparts. Additionally, there was no evidence of overloading in asymptomatic participants, as neither biomechanical nor physical activity load was higher in this group. However, a lesser magnitude of loading on the involved limb during landing in the symptomatic group is an important finding when considering interventions to manage patellar tendinopathy. Progressive loading protocols designed to increase the capacity of healthy tendon tissue may be critical for this cohort of patients with tendinopathy.[14] Future research should seek to study the effects of using comprehensive strategies, including both load magnitude and volume measurements, to determine how to appropriately manage load in individuals at different stages of the tendinopathic continuum.

### Limitations

This study is not able to offer cause-and-effect evidence that biomechanical movement strategies or physical activity levels preceded the development of tendinopathy or resulted in response to the pathologic condition. There are currently no prospective longitudinal studies that assess biomechanical profiles and adaptations around the initial development of patellar tendinopathy. It is possible that chronicity of symptoms may influence movement-pattern development; however, we do not have this information from the symptomatic cohort. It is common for tendon pain to fluctuate across activities or time periods, particularly in competitive athletes, which contributes to the challenge of managing this condition.[12,13] All athletes in the symptomatic group met our inclusion criterion of pain of at least 2/10 during the SLDS at the screening session (mean ± SD, 3.23 ± 1.21); however, it is possible that the low levels of pain in our symptomatic group resulted in the ability to tolerate and participate in larger amounts and/or higher intensity of physical activity.

We are also unable to account for other factors that may have influenced the participants' physical activity levels during the 7-day monitoring period, such as motivation, academic demand, environmental factors related to their sport, or the specific types of activity that may have differed between groups. There are obvious limitations to extrapolating 7 days of measured physical activity as a reflection of an individual's actual physical activity over a protracted time frame. However, a 7-day monitoring period is an accepted duration commonly utilized in physical activity literature, and has been shown to improve reliability and decrease variability of objective physical activity data.[3,20,30] Additionally, there were no statistically significant differences between groups in wear-time compliance (total wear time [minutes per week] or valid wear days) (**TABLE 3**). Finally, we did not take a daily pain assessment during the 7 days of physical activity monitoring, so we are unable to determine whether daily fluctuations in pain may have influenced physical activity participation in the symptomatic group.

## CONCLUSION

Young male athletes with symptomatic patellar tendinopathy demonstrated lesser magnitudes of patellar tendon force loading impulse during landing compared to both asymptomatic athletes with patellar tendinopathy and healthy control participants. However, young male athletes at varying stages of the patellar tendinopathy continuum did not differ in general measures of physical activity load. This study's findings highlight the importance of a comprehensive approach to load monitoring in individuals with patellar tendinopathy, including biomechanical movement profiles, loading volume, and patient-reported outcomes. ◉

## KEY POINTS

**FINDINGS:** Young male athletes with symptomatic patellar tendinopathy demonstrated lesser patellar tendon force loading impulse on the involved limb compared to both individuals with asymptomatic patellar tendinopathy and healthy controls. However, despite self-report of pain during activity, these individuals did not differ in weekly objective physical activity load.
**IMPLICATIONS:** Assessing landing biomechanics in jumping athletes at risk for and with symptoms of patellar tendinopathy may be important to detect aberrant knee loading profiles that can be addressed through structured rehabilitation programs.
**CAUTION:** The results of this study can only be applied to young male athletes. Further work is needed to evaluate loading patterns in females with and without patellar tendinopathy, as well as to develop the use of wearable accelerometers to estimate joint and tissue loads in individuals' real-world environments.

## STUDY DETAILS

**CLINICAL TRIAL REGISTRATION:** Registered at www.ClinicalTrials.gov (NCT03262181) on August 25, 2017.
**PATIENT AND PUBLIC INVOLVEMENT:** Patients and the public were not involved in the design, conduct, interpretation, or translation of this research.
**DATA SHARING:** All data relevant to the study are included in the article.
**AUTHOR CONTRIBUTIONS:** All authors contributed to the design, conduct, analysis, and interpretation of this study.

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# Pain, Sports Participation, and Physical Function in Adolescents With Patellofemoral Pain and Osgood-Schlatter Disease: A Matched Cross-sectional Study



Knee pain affects 1 in 3 adolescents, making it one of the most common sites of pain.[26] Persistent knee pain is associated with reduced quality of life and physical activity.[6] Knee pain is sometimes considered self-limiting, with no long-term impact. However, data indicate that this assumption is not correct, with many continuing to have pain into adulthood.[3,4]

**OBJECTIVE:** To compare pain, physical activity, quality of life, strength, and knee function in adolescents with patellofemoral pain (PFP) and Osgood-Schlatter disease (OSD) to those in pain-free controls.

**DESIGN:** Cross-sectional study.

**METHODS:** Self-report questionnaires were used to describe pain, physical activity, knee function, and quality of life in participants with PFP (n = 151) or OSD (n = 51) and in pain-free controls (n = 50) between 10 and 14 years of age. Hip and knee strength were measured by handheld dynamometry. Physical activity levels were measured using wearable accelerometers.

**RESULTS:** Adolescents were highly active (accumulating greater than 120 minutes of vigorous physical activity per day), with no differences between the OSD, PFP, and control groups. Adolescents with PFP or OSD scored 22 to 56 points lower ($P<.001$) on the Knee injury and Osteoarthritis Outcome Score subscales compared with controls, with the lowest scores on the "sport and recreation" and "quality of life" subscales. Adolescents with OSD had lower knee extension strength compared to controls ($P<.05$; effect size, 1.25). Adolescents with PFP had lower hip extension strength compared to controls ($P<.05$; effect size, 0.73).

**CONCLUSION:** Adolescents with PFP or OSD had high physical activity levels, despite reporting long-standing knee pain and impaired knee function that impacted on their sports participation and quality of life. Clinicians treating adolescents with PFP or OSD may use these findings to target treatment to the most common deficits to restore sports-related function and sports participation. *J Orthop Sports Phys Ther 2020;50(3):149-157. Epub 6 Jan 2020. doi:10.2519/jospt.2020.8770*

**KEY WORDS:** *adolescents, anterior knee pain, knee function, musculoskeletal pain*

There is a 4-fold increase in the years lived with disability due to musculoskeletal conditions during the transition from childhood to adolescence.[18] In the same period, there is an 8-fold increase in the number of contacts with general practitioners due to knee symptoms.[1,21] Approximately 6% to 7% of the adolescent population is affected (with varying severity) by patellofemoral pain (PFP),[17,25] while around 10% is affected by Osgood-Schlatter disease (OSD).[9] Despite the high prevalence, there is limited information regarding the impact of these impairments on associated deficits in adolescents. This lack of knowledge hinders the development of evidence-informed treatment strategies for young adolescents with PFP or OSD.

The incidence of OSD, which is thought to be related to maturation of the tibial tuberosity, peaks between 12 and 13 years of age.[19] The incidence of PFP is also highest during maturation.[12] Despite this, there are few data about knee conditions in this age group.[25] Both PFP and OSD are characterized by anterior knee pain

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during knee joint loading and aggravated by physical activity and sport.[8,13] Patellofemoral pain often has a diffuse presentation of pain around the patella, and OSD presents with pain localized to the tibial tuberosity.[8,13] Nearly half of adolescents who have had PFP for more than 5 years report knee pain that is severe enough to impact sports participation.[23] In comparison, OSD has often been described as lasting between 12 and 24 months, with more than 90% of cases having no residual symptoms at all.[13] Understanding the differences between adolescents with these conditions and those without knee pain may help to identify treatment targets.

The aim of this study was to evaluate pain, physical activity, quality of life, strength, and physical function in adolescents 10 to 14 years of age who were diagnosed with PFP or OSD, compared to pain-free controls.

## METHODS

### Study Design

This exploratory cross-sectional study was embedded within 2 cohort studies of PFP and OSD (ClinicalTrials.gov identifiers NCT02402673 and NCT02799394, respectively), and included a group of pain-free adolescents who served as a control group. The study was approved by the Ethics Committee of the North Denmark Region (N-2014-0100) and the Danish Data Protection Agency. Participants were required to have parental written informed consent. The study was conducted according to the Declaration of Helsinki. The reporting of the study follows the Strengthening the Reporting of Observational Studies in Epidemiology statement.[31] Data from the 2 prospective cohort studies were collected at inclusion specifically for the purpose of this cross-sectional investigation. Baseline pretreatment measures were collected when the intervention was initiated (2 weeks after inclusion) and are not presented in the current study. Baseline data from participants with PFP were published in a prospective study investigating the effect of activity modification and load management.[22] Pain drawings for those with PFP have been included as part of a larger study investigating pain patterns in patients from 10 to 40 years of age.[2]

### Recruitment

Between March 2015 and April 2017, students (10-14 years of age) from local schools were invited to answer an online questionnaire on musculoskeletal pain, including knee pain. This was supplemented by social media and general practice offices to recruit adolescents with knee pain and controls without knee pain. Potentially eligible adolescents (ie, those reporting knee pain via the questionnaire or in response to recruitment advertisements) were subsequently screened by telephone, and invited for a clinical examination if PFP or OSD could not be excluded by the phone interview.

### Participants and Diagnostics

The clinical examination was conducted by 1 of 2 physical therapists with 4 and 7 years of clinical experience, respectively. Diagnosis of PFP was made according to established criteria[7,12]—insidious onset of anterior or retropatellar knee pain for more than 6 weeks; pain provoked by at least 2 of prolonged sitting or kneeling, squatting, running, hopping, and stair climbing; tenderness on palpation of the patella; or pain with stepping down or double-leg squatting. In addition, participants were required to report more than 30 mm on a 0-to-100-mm visual analog scale for worst pain during the previous week.

The criteria used to diagnose OSD were consistent with the literature, and included participants reporting current pain and tenderness at the tibial tuberosity, pain on palpation of the tibial tuberosity, and pain with resisted isometric knee extension.[13] Exclusion criteria for both PFP and OSD were determined through patient medical history and clinical examination, and included Sinding-Larsen-Johansson disease; concomitant injury or pain from the hip, lumbar spine, or other structures of the knee (eg, tendinopathy); previous knee surgery; patellofemoral instability; knee joint effusion; and contraindications to magnetic resonance imaging (used to rule out pathology in the PFP group).

Inclusion criteria for the pain-free controls were no current self-reported musculoskeletal pain, no self-reported prior surgery on the lower extremity, no self-reported neurological or medical conditions, and no contraindications to magnetic resonance imaging. At the time of screening, controls were required to have sports participation levels similar to those of participants with knee pain, to prevent differences being detected due to comparison to a population with lower levels of sports participation. The aim was to have groups that were comparable regarding whether or not they were active in sports (yes/no) and regarding the approximate amount of weekly sports participation. This was done to the best of the ability of the 2 assessors during the telephone screening. Control participants were also matched by age (10-14 years). The proportion of girls included in the control group was targeted to be approximately between that of those with PFP and OSD.

### Data Collection

The testers (L.W. and K.K.) had previous experience testing adolescents and were not blinded to the status of the participant (PFP, OSD, or control). Information from previous nonstructured interviews with adolescents and parents informed the choice of outcome domains. Based on this, limitations in sports and physical activity were considered to be the most important domains. Additional domains of interest were pain and knee function, quality of life, and knee and hip strength. All procedures were pilot tested on adolescents (with and without knee pain) before initiation of the study.

**Height and Weight** Body weight was measured using a weighing scale. Height was measured using a tape measure fixed to a wall, with participants standing barefoot against the wall. Body mass index was calculated based on these measurements.

**Sports Participation** Participants with PFP and OSD were asked to report their sports participation (type, duration, and frequency per week) at present and prior to onset of knee pain. Participants who reported reduced or no sports participation due to knee pain were asked whether they desired to return to their previous level of sport.

**Physical Activity Data** Objective measures of physical activity were captured by a wrist-worn GT3X+ watch (ActiGraph, LLC, Pensacola, FL) recording at 30 Hz.[16] Participants were instructed to wear the device on the wrist of their nondominant arm for a week after inclusion, and not to remove it unless deemed unsafe during specific activities (eg, taekwondo, water polo). Data were analyzed using ActiLife (ActiGraph, LLC), and the full description of analysis can be seen in Rathleff et al.[22] The Evenson et al[11] cut points were used to categorize the intensity of participants' physical activity as sedentary (0-100 counts per minute), light (101-2295 counts per minute), moderate (2296-4011 counts per minute), or vigorous (4012 or more counts per minute).[16] In addition, we compared the physical activity levels to the recommendations by the World Health Organization.

**Pain, Symptoms, and Quality of Life** To assess pain and symptoms, the respective subscales from the Knee injury and Osteoarthritis Outcome Score (KOOS) were used (pain, other symptoms, function in daily living, function in sport and recreation [sport/rec], and knee-related quality of life).[28] This questionnaire was chosen because it has previously been used in young adolescents with knee pain.[20,25] Health-related quality of life was measured by the youth version of the European Quality of Life-5 Dimensions (EQ-5D-Y).[4] Participants also reported their worst pain in the past week on a numeric rating scale (0 to 10, where 0 is "no pain" and 10 is the "worst pain imaginable"). Pain duration was determined by the question, "For how long have you experienced knee pain?" (open ended, and subsequently calculated in months). If participants with PFP or OSD had bilateral pain, they were instructed to answer about their most painful knee.

**Hip and Knee Muscle Strength** Isometric knee extension and hip abduction strength were recorded for all adolescents. Hip extension strength was assessed in those with PFP and in controls only. Strength was measured in the symptomatic knee or most symptomatic knee in cases with bilateral pain. In pain-free adolescents, the right or left leg was randomly chosen as the test leg. Three consecutive strength measurements were taken for all participants. Muscle strength was tested using a PowerTrack Commander handheld dynamometer (JTECH Medical, Midvale, UT), fixed to the examination bed by a belt. All strength tests were conducted isometrically and have previously been shown to be reliable.[20,29] Average force output of the 3 tests (Newtons) was subsequently multiplied by lever length to calculate torque and normalized to body weight. Lever length for hip abduction was measured from the anterior superior iliac spine to the position of the dynamometer at the lateral side of the lower leg (5 cm above the lateral malleolus). Lever length for knee extension was measured as the distance from the knee joint line to the position of the dynamometer 5 cm above the medial malleolus. Lever length for hip extension was measured from the trochanter major to the position of the dynamometer 5 cm above the popliteal fossa.

During knee extension, the dynamometer strap was positioned 5 cm proximal to the medial malleolus, perpendicular to the anterior or posterior aspect of the tibia. Knee extension was tested in 60° of knee flexion. For hip abduction, participants were lying supine on an examination table, with the leg in 0° of flexion and 0° of abduction. The strap was positioned 5 cm proximal to the medial malleolus and perpendicular to the medial or lateral aspect of the tibia. Hip extension was measured using the short lever version,[29] with a strap to fix the dynamometer at the posterior thigh. After receiving standardized instructions, participants performed 2 submaximal practice trials. Afterward, the individual test was administered 3 times, with approximately 1 minute between each test.

## Sample-Size Considerations

No formal sample-size calculation was conducted for this cross-sectional study, as there are no data about young adolescents with PFP and OSD compared to pain-free controls. The final sample size was a convenience sample, determined by the number of adolescents with PFP and OSD who were enrolled in 1 of 2 prospective cohort studies (NCT02402673 and NCT02799394).

## Statistical Analysis

Data were visually inspected for approximate normality using a Q-Q plot. Mean values and SDs are reported for normally distributed data. Nonnormally distributed data are presented as median and interquartile range. Data on physical activity and sport are described descriptively. Scores on the KOOS and EQ-5D-Y were analyzed using a 1-way analysis of variance and the least-significant-difference post hoc test to test the differences between groups (control versus OSD versus PFP). A 2-way analysis of variance was used to investigate the effects of group (control versus PFP versus OSD) and sex (male versus female) and the group-by-sex interaction on isometric strength measures. Effect sizes of the differences in isometric hip and knee strength were calculated using Cohen's *d*, with effect sizes greater than 0.80 being considered large.[7] Sex was included in the model for strength measures due to previously documented sex-specific differences in strength.[24]

Based on peer-review comments, a regression model was used to assess the association between strength measures and the KOOS sport/rec subscale. This was done using a linear regression to estimate the association between sex, worst pain in the last week, isometric strength, diagnosis, and KOOS sport/rec score. Univariable analyses were initially performed, and variables with $P<.15$ were included in the multivariable model.[3] A separate regression model was also developed for the PFP group only to allow for the inclusion of hip extension strength data. All calculations were performed using Stata Version 11 (StataCorp LLC, College Station, TX) and SPSS Version 21 (IBM Corporation, Armonk, NY). Significance was accepted for $P$ values less than .05.

## RESULTS

### Demographics

Two hundred fifty-two adolescents (151 with PFP, 51 with OSD, and 50 pain-free controls) ranging in age from 10 to 14 years were included and tested (**FIGURE 1**). We assessed 85 controls for eligibility, of whom 35 were excluded: 34 due to not being a match and 1 for reporting knee pain during phone screening. One third of those with knee pain had previously received treatment for knee pain (**TABLE 1**). The most common reported treatments were treatment by physical therapist (14/51), acupuncture (3/51), and shockwave (2/51) in those with OSD, and treatment by physical therapist (34/151), acupuncture (4/151), and painkillers (2/151) in adolescents with PFP.

### Sports Participation and Objective Physical Activity

More than 50% reported reducing their sports participation, with the most common causes being "pain" and "I am afraid to damage my knee." Nine percent of adolescents with PFP reported a complete stop of sports due to knee pain, compared with 26% of adolescents with OSD. All adolescents except 1 had a desire to return to sport (**TABLE 2**). There were no differences in physical activity, measured with the GT3X+ watch (ActiGraph, LLC), between groups in average time spent in sedentary, light, moderate, or vigorous physical activity (**TABLE 2**). Due to device malfunction, not all data could be properly extracted from the GT3X+ or excluded as nonwear-time data; the included GT3X+ data were from 132 participants with PFP, 36 with OSD, and 48 controls.

### Pain, Symptoms, and Quality of Life

Adolescents with PFP and OSD reported pain for an average of 21 months (**TABLE 3**). There was a significant difference between groups for KOOS function in daily living (F = 55, $P<.001$), KOOS sport/rec (F = 52, $P<.001$), and KOOS quality-of-life (F = 217, $P<.001$) scores. Post hoc pairwise comparisons revealed that adolescents with OSD or PFP had lower scores compared to pain-free controls ($P<.001$) (mean differences in **TABLE 4**). Adolescents with OSD had significantly lower KOOS scores compared to adolescents with PFP

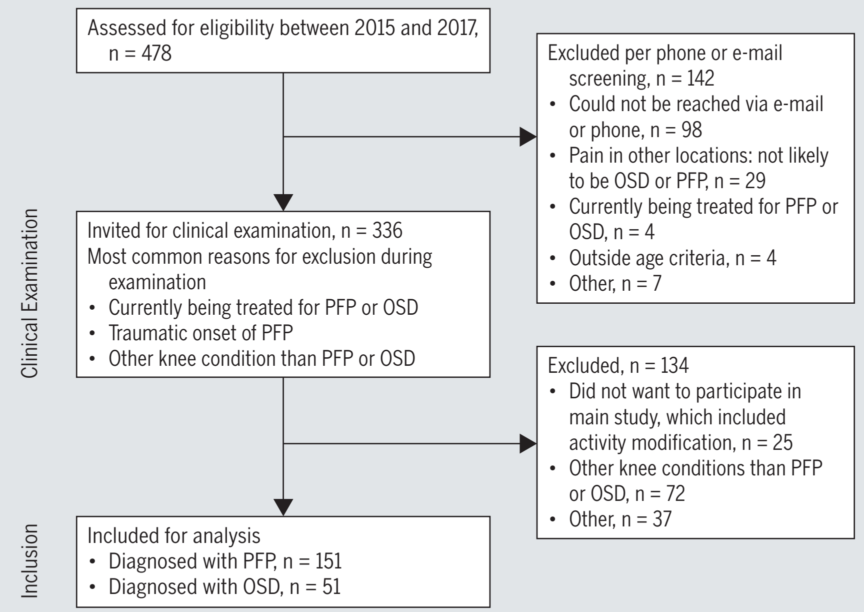


**FIGURE 1.** Flow chart. Abbreviations: OSD, Osgood-Schlatter disease; PFP, patellofemoral pain.

**TABLE 1** DEMOGRAPHICS[a]

| | Patellofemoral Pain (n = 151) | Osgood-Schlatter (n = 51) | Pain-Free Controls (n = 50) |
|---|---|---|---|
| Age, y | 12.6 ± 1.2 | 12.7 ± 1.1 | 12.3 ± 1.4 |
| Sex (female), % | 76 | 51 | 62 |
| Weight, kg | 50.4 ± 9.4 | 55.8 ± 10.1 | 48.0 ± 10.4 |
| Height, cm | 162.0 ± 9.6 | 165.5 ± 8.4 | 159.8 ± 10.5 |
| Body mass index, kg/m²[b] | 19.0 (17.2-20.8) | 20.2 (17.6-22.0) | 18.0 (17.1-20.0) |
| Previously treated for knee pain (yes), % | 28 | 37 | NA |
| Pain medication for knee pain (yes), % | 24 | 12 | NA |
| Current sports participation in leisure-time sports (yes), % | 91 | 74 | 88 |

*Abbreviation: NA, not applicable.*
[a]*Values are mean ± SD unless otherwise indicated.*
[b]*Values are median (interquartile range).*

for the quality-of-life domain ($P$<.05) (**TABLE 4**), but not for the function in daily living and sport/rec domains ($P$>.05).

Scores on the EQ-5D-Y were significantly different between groups (F = 56, $P$<.001). Compared to controls, the EQ-5D-Y index score was significantly lower in both the PFP (mean difference, 0.38; 95% confidence interval [CI]: 0.31, 0.45; $P$<.001) and OSD (mean difference, 0.38; 95% CI: 0.28, 0.45; $P$<.001) groups (**TABLE 4**). There was no difference between the OSD and PFP groups ($P$ = .762) (**TABLE 4**).

## Hip and Knee Muscle Strength

There was a significant sex-by-group interaction for hip abduction strength (F = 3.9, $P$ = .02). Post hoc testing revealed a simple main effect of group on hip abduction scores, which was statistically significant for girls (F = 7.7, $P$ = .001) but not

**TABLE 2** Sports Participation and Physical Activity Levels

| | Patellofemoral Pain (n = 151) | Osgood-Schlatter (n = 51) | Pain-Free Controls (n = 50) |
|---|---|---|---|
| Did you participate in sport before onset of knee pain? (yes), % | 98 | 100 | NA |
| Did you play competitive sport before onset of knee pain? (yes), % | 55 | 49 | NA |
| Did you reduce the amount of sports participation because of your knee pain? (yes), % | 64 | 49 | NA |
| If you don't participate in sport currently, do you desire to return to sport? (yes), % | 100 | 98 | NA |
| How many times per week do you currently participate in sport (training and competition)?[a] | 3 (2-5) | 4 (3-5) | 3 (1-4.5) |
| Physical activity levels[b] | | | |
| Sedentary | 346.6 (333.8, 359.4) | 344.2 (330.3, 358.1) | 353.9 (330.3, 377.6) |
| Average light | 334.0 (326.8, 341.2) | 333.8 (315.7, 351.9) | 318.0 (304.0, 331.9) |
| Average moderate | 113.1 (109.2, 116.9) | 115.5 (106.4, 124.6) | 109.0 (102.2, 115.7) |
| Average vigorous | 127.4 (120.0, 134.8) | 133.1 (117.5, 148.7) | 142.5 (128.0, 157.0) |
| Moderate to vigorous | 240.5 (229.9, 252.1) | 248.7 (225.1, 272.2) | 251.5 (231.3, 271.7) |
| Reached WHO minimum physical activity per day, % | 94.7 | 91.7 | 91.7 |

*Abbreviations: NA, not applicable; WHO, World Health Organization.*
[a]*Values are median (interquartile range).*
[b]*Based on GT3X+ data from 132 with patellofemoral pain, 36 with Osgood-Schlatter disease, and 48 controls. Values are mean (95% confidence interval) minutes per day.*

**TABLE 3** Pain and Symptoms[a]

| | Patellofemoral Pain (n = 151) | Osgood-Schlatter (n = 51) | Pain-Free Controls (n = 50) | Patellofemoral Pain Versus Controls[b] | Osgood-Schlatter Versus Controls[b] | Patellofemoral Pain Versus Osgood-Schlatter[b] |
|---|---|---|---|---|---|---|
| Age when knee pain started, y[c] | 11 (10-12) | 11 (10-12) | NA | | | 0 |
| Pain duration, mo | 21.3 ± 17.0 | 20.8 ± 12.5 | NA | | | 0.5 (–4.7, 5.7) |
| Duration of symptoms, n (%)[d] | | | | | | |
| 3-6 mo | 6 (4) | 4 (8) | NA | | | |
| 6-12 mo | 31 (22) | 2 (4) | NA | | | |
| >12 mo | 107 (74) | 44 (88) | NA | | | |
| Bilateral pain (yes), % | 73.5 | 71.4 | NA | | | 2.1 (–12.3, 16.5) |
| Worst pain in last week (NRS, 0-10) | 6.5 ± 2.0 | 6.4 ± 2.3 | NA | | | 0.1 (–0.6, 0.8) |
| KOOS pain (0-100)[c] | 66 (63-70) | 67 (63-68) | 100 (100-100) | –22 (–18, –26) | –26 (–21, –31) | –1 (–5, 3) |
| KOOS symptoms (0-100)[c] | 77 (75-80) | 73 (69-78) | 98 (96-99) | –32 (–28, –37) | –31 (–26, –37) | 4 (0, 8) |

*Abbreviations: KOOS, Knee injury and Osteoarthritis Outcome Score; NA, not applicable; NRS, numeric rating scale.*
[a]*Values are mean ± SD unless otherwise indicated.*
[b]*Values are mean difference (95% confidence interval).*
[c]*Values are median (interquartile range).*
[d]*One participant with Osgood-Schlatter disease and 7 with patellofemoral pain were not able to remember when their knee pain started and did not respond to the question.*

for boys. Compared to girls in the control group, hip abduction strength was significantly lower for girls with OSD (mean difference, 0.41; 95% CI: 0.20, 0.61; *P*<.001; effect size, 1.16; 95% CI: 0.57, 1.73) (**FIGURE 2**) and PFP (mean difference, 0.21; 95% CI: 0.06, 0.36; *P*<.01; effect size, 0.49; 95% CI: 0.08, 0.88). For boys, there were no differences in hip abduction strength between groups (*P* = .398).

For knee extension strength, there was no significant interaction (*P*>.05), but there was a significant main effect for group (F = 19, *P*<.001). The group with OSD had significantly reduced knee extension strength compared to controls (mean difference, 0.65; 95% CI: 0.39, 0.92; *P*<.001; effect size, 1.25; 95% CI: 0.82, 1.68) and those with PFP (mean difference, 0.65; 95% CI: 0.43, 0.87; *P*<.001; effect size, 0.99; 95% CI: 0.64, 1.32) (**FIGURE 2**). There were no differences between PFP and controls for knee extension strength (*P* = .986).

For hip extension strength, there was no sex-by-group interaction. There was a significant difference between groups, with lower strength in the PFP group compared to controls (F = 17, *P*<.001; mean difference, 0.36; 95% CI: 0.18, 0.53; effect size, 0.73; 95% CI: 0.40, 1.05) (**FIGURE 2**).

### Factors Associated With the KOOS Sport/Rec Subscale

In the univariable analyses, higher knee extension torque was associated with higher KOOS sport/rec score and higher "worst pain in the last week" was significantly associated with lower KOOS sport/

**TABLE 4** KOOS (ADL, Sport/Rec, and QoL) and EQ-5D-Y

| | Patellofemoral Pain (n = 151)[a] | Osgood-Schlatter (n = 51)[a] | Pain-Free Controls (n = 50)[a] | Patellofemoral Pain Versus Controls[b] | Osgood-Schlatter Versus Controls[b] | Patellofemoral Pain Versus Osgood-Schlatter[b] |
|---|---|---|---|---|---|---|
| KOOS ADL (0-100) | 77 (75-80)[c] | 78 (75-82)[c] | 100 (100-100) | −23 (−19, −27) | −22 (−19, −27) | −1 (−3, 6) |
| KOOS sport/rec (0-100) | 54 (50-58)[c] | 43 (37-49)[c] | 100 (100-100) | −48 (−38, −58) | −56 (−44, −68) | 8 (−2, 18) |
| KOOS QoL (0-100) | 50 (47-53)[cd] | 44 (39-48)[c] | 100 (100-100) | −50 (−45, −55) | −56 (−50, −62) | 6 (1, 11) |
| EQ-5D-Y (0-1) | 0.72 (0.63-0.78)[c] | 0.72 (0.44-0.78)[c] | 1 (1-1) | −0.38 (−0.31, −0.45) | −0.38 (−0.28, −0.45) | −0.01 (−0.08, 0.06) |

*Abbreviations: ADL, activities of daily living; EQ-5D-Y, European Quality of Life-5 Dimensions (Youth); KOOS, Knee injury and Osteoarthritis Outcome Score; QoL, quality of life; sport/rec, sport and recreation.*
[a]*Values are median (interquartile range).*
[b]*Values are mean difference (95% confidence interval).*
[c]*Significantly different from control group.*
[d]*Significantly different from Osgood-Schlatter disease group.*

**TABLE 5** Univariable and Multivariable Models Testing the Association Between Worst Pain in the Last Week, Strength, Diagnosis, and KOOS Sport/Recreation Score

| | Unadjusted Coefficient[a] | *P* Value | Adjusted Coefficient[a] | Adjusted *P* Value |
|---|---|---|---|---|
| All participants[bc] | | | | |
| Knee extension torque | 4.6 (0.1, 9.1) | .04 | 3.1 (−1.3, 7.6) | .17 |
| Hip abduction torque[d] | 3.2 (−5.6, 12.1) | .47 | | |
| Worst pain in last week (NRS) | -3.7 (−5.0, −2.4) | <.001 | −4.1 (−5.4, −2.8) | <.001 |
| Sex[d] | 2.0 (−4.7, 8.8) | .55 | | |
| Diagnosis (Osgood-Schlatter disease versus patellofemoral pain) | 6.0 (−1.1, 13.2) | .10 | 9.34 (1.9, 16.8) | .01 |
| Only participants with patellofemoral pain[e] | | | | |
| Knee extension torque[d] | 1.7 (−3.4, 6.9) | .50 | | |
| Hip abduction torque[d] | 2.9 (−6.5, 12.3) | .55 | | |
| Hip extension torque | 12.5 (4.3, 20.7) | .003 | 10.9 (3.7, 18.0) | .003 |
| Worst pain in last week (NRS) | −4.2 (−5.6, −2.9) | <.001 | −4.2 (−5.5, −2.9) | <.001 |
| Sex | 6.2 (−1.9, 14.4) | .13 | 6.1 (−1.0, 13.3) | .09 |

*Abbreviations: KOOS, Knee injury and Osteoarthritis Outcome Score; NRS, numeric rating scale.*
[a]*Values in parentheses are 95% confidence interval.*
[b]*From the univariable analysis.*
[c]*Association with the KOOS sport/recreation score among all participants with knee pain.*
[d]*Not included in the multivariable model because the P<.15 threshold was not met.*
[e]*Association with the KOOS sport/recreation score among adolescents with patellofemoral pain.*

rec score (**TABLE 5**). After adjustment in the multivariable model, higher "worst pain in the last week" and OSD diagnosis remained significantly associated with lower KOOS sport/rec scores. Knee extension torque was not significantly associated with KOOS sport/rec score in the multivariable model (**TABLE 5**).

When examining PFP only, univariable analyses indicated that sex, hip extension torque, and "worst pain in the last week" were associated with KOOS sport/rec scores (**TABLE 5**). Female sex, higher "worst pain in the last week," and lower hip extension torque were associated with lower KOOS sport/rec scores in the PFP group. Except for sex, these associations remained significant in the multivariable model. **TABLE 5** demonstrates the unadjusted coefficients from the univariable models, as well as the adjusted coefficients and *P* values for the variables that remained significant in the multivariable model, after accounting for other factors.

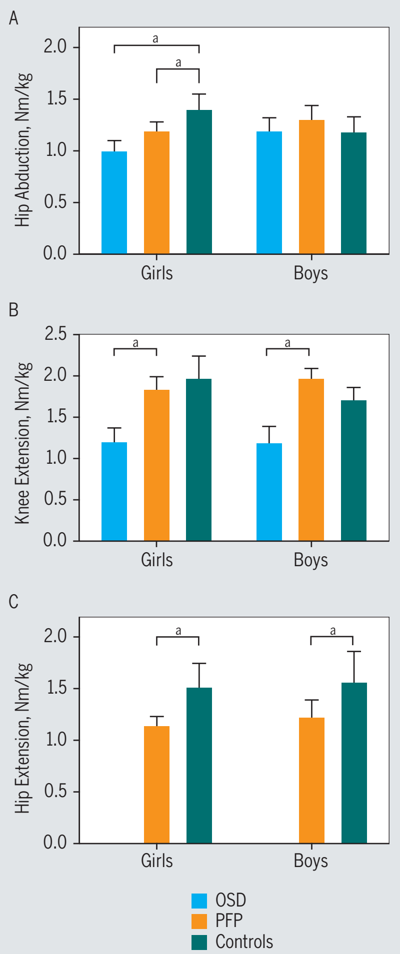


**FIGURE 2.** Comparison (to controls) of isometric (A and C) hip and (B) knee strength among adolescent girls and boys with OSD and PFP. Values are mean and 95% confidence interval. [a]Statistically significant difference. Abbreviations: OSD, Osgood-Schlatter disease; PFP, patellofemoral pain.

## DISCUSSION

This is the first study to characterize pain, physical activity, and knee function in 10- to 14-year-old adolescents diagnosed with PFP or OSD. We found that these 2 common knee pain complaints impact pain, self-reported sports participation, physical function, and quality of life to a similar extent, with no clinically relevant difference between OSD and PFP. While participants reported having to stop or reduce sport due to knee pain, the GT3X+ (ActiGraph, LLC) data demonstrated that the participants were still very physically active, accumulating approximately 2 hours of vigorous physical activity per day. Adolescents with PFP demonstrated reduced hip extension strength compared to pain-free controls; however, only girls with PFP and OSD had lower hip abduction strength compared to female controls. Adolescents with OSD demonstrated reduced knee extension strength compared to their matched healthy counterparts.

Despite the young age of the participants, the impact of pain on sports and physical function was similar to that in older adolescents and young adults with PFP (aged 15-19 years).[25] Almost all adolescents reported participating in sport prior to the onset of their knee pain, and the majority reduced their participation due to pain. In contrast, in older adolescents and young adults with PFP, only 2 of 3 adolescents with PFP participated in sports.[25] As older adolescents and young adults with PFP also reported a longer duration of symptoms, this may explain the differences in sports participation.

In this study, 1 in every 4 adolescents with PFP used painkillers. Use of pain medication among adolescents with OSD was half that of those with PFP, despite worse symptoms and larger reductions in sports participation. The reason for the difference is unclear and may warrant further examination.

In PFP, higher hip extension torque was associated with higher KOOS sport/rec scores. Hip abduction torque was not associated with KOOS sport/rec scores. A recent systematic review, including both adolescents and adults, highlighted that low hip muscle strength may be a consequence of PFP rather than the cause.[24] A previous smaller study found no difference in quadriceps strength between young people between the ages of 11 and 18 years with OSD and 13-year-old soccer players. However, these groups were not matched by age, and there was no mention of sex, height, weight, or other patient demographics, making a comparison to the current study difficult.[15] There were large deficits in knee extension torque for those with OSD. Girls with OSD also displayed significant hip abduction strength deficits. While knee extension torque was significantly associated with KOOS sport/rec subscale score, this relationship did not exist in the multivariable model after accounting for diagnosis (PFP or OSD). Further, there was no relationship between knee extension torque and KOOS sport/rec score in the model examining only PFP. Although we cannot infer cause and effect in this population, knee- and hip-strengthening exercises may be worth considering as part of management to improve function and performance, and to help ensure that adolescents return to sport without large strength deficits. Rest, stretching, or other passive modalities are unlikely to improve knee extension strength or hip abduction strength for girls with OSD.[5,9,13]

Both PFP and OSD are considered overuse musculoskeletal pain complaints caused by exposure to high repetitive loads.[13,27] Despite the pain and significant self-reported difficulties on the KOOS sport/rec subscale, the majority of adolescents with PFP and OSD continued to participate in physical activity. Our results indicate that despite their knee pain, young people with PFP and OSD were as physically active as the controls, even after they had decreased their sports participation as a result of knee pain. On average, they accumulated more than 2 hours of vigorous activity per day, which is 4 times the average of the International Children's Accelerometry Database.[10] They accumulated more than 4 hours of moderate to vigorous physical activity per day, which is 6 to 8 times as much as the average in the International Children's Accelerometry Database and twice as much as male players aged 10 to 14 years who participate in grassroots football in 3 European countries.[30] Adolescents reported participating in sports 3 to 4 times per week. This does not account for all the objectively measured vigorous activity, suggesting that these adolescents also participate in a lot of vigorous activity during school and leisure time. More research is needed to understand whether continued sports participation should be advised, or whether it will impede recovery through persistent loading of the painful knee.

Early specialization in a single sport has been associated with an increased risk of suffering from PFP, OSD, and Sinding-Larsen-Johansson disease/patellar tendinopathy in adolescent girls.[14] This is likely due to repetitive sports-specific loading, with OSD demonstrating a 4-fold greater relative risk in single-sport compared with multisport athletes.[14] The challenge for this population may be to find the right type and amount of physical activity and sport that will keep the adolescents active without aggravating their knee pain or hampering long-term recovery. Modifying or changing loading on specific structures may be a relevant target for future treatments in this population.

### Clinical Implications

In adolescents with OSD, we found large strength deficits in knee extension, which may suggest a rationale for including knee extension strengthening in this group of adolescents. Recommendations for OSD are diverse but often include rest, stretching, and return to sports after pain has settled, despite a lack of evidence to support this recommendation.[13] The desire to return to sport and high activity despite long-standing knee pain warrant future research to develop load-management and return-to-sport algorithms for those with OSD or PFP.

### Limitations

The 2 assessors were not blinded to the status of participants (PFP, OSD, or control). This may increase the risk of detection bias and increase potential between-group differences. However, the main conclusion of the severe impact of PFP and OSD is unlikely to be affected by the lack of blinding. As hip extension was not collected in those with OSD, we cannot evaluate whether hip extension strength deficits exist in adolescents with OSD. The smaller group numbers when stratifying by sex may make sex differences in strength difficult to detect. Further, we did not assess biomechanics, which might have indicated differences between these 2 patient populations. The use of the KOOS adult version is a potential limitation, as it is not validated for this patient population. As this is a cross-sectional study, strong conclusions on clinical implications cannot be drawn, and thus suggestions based on the results of this study are speculative.

## CONCLUSION

Adolescents from 10 to 14 years of age with PFP or OSD are characterized by high levels of vigorous physical activity, even in the presence of long-standing knee pain. They report difficulties with sports participation and impaired knee function, relative to pain-free controls. Clinicians treating adolescents with PFP or OSD may use these findings to target treatment for the most common deficits to restore sports-related function and sports participation. ◉

### KEY POINTS

**FINDINGS:** Adolescents with patellofemoral pain (PFP) and Osgood-Schlatter disease (OSD) are characterized by impairments in sports participation, knee function, and quality of life. Despite these impairments, adolescents continue with high levels of physical activity. Adolescents with PFP demonstrated reduced hip extension strength. However, only girls with PFP and OSD had lower hip abduction strength compared to female controls. Adolescents with OSD demonstrated reduced knee extension strength compared to their matched healthy counterparts.

**IMPLICATIONS:** Clinicians treating adolescents with PFP or OSD may use these findings to target treatment to the most common deficits to restore sports-related function and sports participation.

**CAUTION:** This was a cross-sectional analysis, and no cause-and-effect relationships can be inferred.

### STUDY DETAILS

**TRIAL REGISTRATION:** The data on which this cross-sectional study is based are registered at www.ClinicalTrials.gov (NCT02402673, NCT02799394).

**PATIENT AND PUBLIC INVOLVEMENT:** Information from previous nonstructured interviews with adolescents and parents informed the choice of outcome domains. Based on this, limitations in sports and physical activity were considered to be the most important domains. Additional domains of interest were pain and knee function, quality of life, and knee and hip strength.

**DATA SHARING:** All data presented in the manuscript are available, with a reasonable request, by contacting the corresponding author. Data will be shared in anonymized form and can be used for meta-analytical purposes. For those trying to answer new research questions on the data from this study, a formal request must be made.

**AUTHOR CONTRIBUTIONS:** All authors made substantial contributions to the conception or design of the work, or the acqui-

sition, analysis, or interpretation of data for the work. All authors were involved in drafting the work or revising it critically for important intellectual content, and gave final approval of the version to be published. All authors also agree to be accountable for all aspects of the work to ensure that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.



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# Comparing the Performance of Comorbidity Indices in Predicting Functional Status, Health-Related Quality of Life, and Total Health Care Use in Older Adults With Back Pain

**OBJECTIVE:** To determine how well the functional comorbidity index (FCI) predicts outcomes in older adults with back pain compared to Quan's modification of the Charlson comorbidity index (Quan-Charlson comorbidity index) and the Elixhauser comorbidity index.

**DESIGN:** Secondary analysis of a prospective cohort study.

**METHODS:** We included 5155 adults 65 years of age or older with new primary care visits for back pain. Comorbidity was measured using diagnosis codes 12 months prior to the new visit. Outcomes of functional limitation (Roland-Morris Disability Questionnaire), health-related quality of life (European Quality of Life-5 Dimensions [EQ-5D]), and total health care use (sum of relative value units) were measured 12 months after the new visit. We compared multivariable models containing preselected prognostic factors.

**RESULTS:** Spearman correlation coefficients among the indices were 0.70 or greater. Multivariable models for the Roland-Morris Disability Questionnaire had similar $R^2$ and root-mean-square error (RMSE) of prediction when using the FCI ($R^2$ = 0.190; RMSE, 6.19), Quan-Charlson comorbidity index ($R^2$ = 0.185; RMSE, 6.20), or Elixhauser comorbidity index ($R^2$ = 0.189; RMSE, 6.19). Multivariable models for the EQ-5D score showed small differences in $R^2$ and RMSE when using the FCI ($R^2$ = 0.157; RMSE, 0.163), Quan-Charlson comorbidity index ($R^2$ = 0.148; RMSE, 0.164), or Elixhauser comorbidity index ($R^2$ = 0.154; RMSE, 0.163). Multivariable models for health care use had similar Akaike information criterion (AIC) values when using the FCI (AIC = 10.04), Quan-Charlson comorbidity index (AIC = 10.04), or Elixhauser comorbidity index (AIC = 10.01).

**CONCLUSION:** All indices performed similarly in predicting outcomes. There does not seem to be an advantage to using one index over another for older adults with back pain. There is still a need to develop better function-based risk-adjustment models that improve prediction of functional outcomes versus standard comorbidity indices.
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**KEY WORDS:** *comorbidity measures, risk adjustment, spine*

Developing valid risk-adjustment models is an important priority for physical therapy–related policy and health services research. As health care transitions from fee-for-service to value-based payment models,[3] physical therapists are increasingly participating in clinical registries.[1,9] Comparing outcomes among providers and clinics is a core part of these recent developments. High-quality prognostic research is vital to informing risk adjustment, because these methods help make more fair and accurate comparisons between providers when the expected outcomes for groups of patients may differ.[19] Better risk adjustment allows clinicians to view their outcomes in comparison to those of other providers or a benchmark with greater confidence that the comparisons are accurate. It minimizes the risk of clinicians being unfairly penalized

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for treating patients who would have a worse prognosis in a value-based payment model.

Difference in comorbidity burden is an important variable to account for when adjusting functional outcomes of patients with chronic conditions such as back pain. Several measures of comorbidity burden are available to use as risk-adjustment variables.[18,20] However, the most common comorbidity indices used for risk adjustment were developed to predict mortality, hospital charges, length of stay, or in-hospital complications,[20] and may not be ideal for functional outcomes and patients with chronic conditions in outpatient settings. The functional comorbidity index (FCI) is a comorbidity measure designed to predict functional status. It captures more chronic conditions (eg, arthritis, hearing impairment, and degenerative disc disease) than existing comorbidity indices, and these conditions may have stronger associations with patients' functional outcomes.[10] However, the FCI has not been compared to other common comorbidity indices for patients with back pain or in outpatient settings.

The purpose of this analysis was to determine how well the FCI can predict outcomes in older adults with back pain compared to Quan's modification of the Charlson comorbidity index (Quan-Charlson comorbidity index) and to the Elixhauser comorbidity index for use in risk-adjustment models.

## METHODS

We conducted a secondary analysis using the Back pain Outcomes using Longitudinal Data registry, a prospective cohort study of patients 65 years of age and older with new primary care visits for back pain, which included thoracic, low back, or sacroiliac symptoms. We recruited 5239 participants from 3 integrated health systems across the United States. We defined a new visit as primary care or emergency department visits for back pain with no other back-related visits or procedures within the prior 6 months. We excluded individuals with prior lumbar spine surgeries or conditions suggestive of serious pathologies that may result in back pain. We also excluded participants without complete electronic health record data 12 months before and 12 months after their new visit. All participants provided informed consent, and the University of Washington Human Subjects Division approved this study. The study settings, recruitment, participants, and data collection have been well described in detail elsewhere.[11,12]

Demographic variables and health characteristics were collected at baseline via questionnaires. The 3 comorbidity measures were created using electronic health record data from the 12 months prior to participants' new back pain visit. All comorbidity measures were created using International Classification of Dis-

**TABLE 1** Baseline Characteristics of Older Adults With New Visits for Back Pain[a]

| Variable | Value |
|---|---|
| Demographics | |
| Age, y | 73.8 ± 6.9 |
| Sex (male), n (%) | 1819 (35.3) |
| Ethnicity (Hispanic), n (%) | 304 (5.9) |
| Race, n (%) | |
| Black | 785 (15.2) |
| Native American/Alaskan/Hawaiian or Pacific Islander | 44 (0.9) |
| Asian | 196 (3.8) |
| White | 3776 (73.2) |
| Other | 297 (5.8) |
| NA | 57 (1.1) |
| Education, n (%) | |
| Less than high school graduate | 311 (6.0) |
| High school graduate/GED or vocational/technical/trade school | 1431 (27.8) |
| Some college | 1264 (24.5) |
| Four-year college graduate | 1255 (24.3) |
| Professional or graduate degree | 879 (17.1) |
| NA | 15 (0.3) |
| Marital status, n (%) | |
| Married or partner | 3125 (60.6) |
| Separated or divorced | 598 (11.6) |
| Never married and single | 253 (4.9) |
| Widowed | 1164 (22.6) |
| NA | 15 (0.3) |
| Employment, n (%) | |
| Working full-time/part-time | 583 (11.3) |
| Retired (not due to ill health) | 4187 (81.2) |
| Retired or disabled because of ill health | 145 (2.8) |
| Other | 219 (4.2) |
| NA | 21 (0.4) |
| Study site, n (%) | |
| Detroit | 953 (18.5) |
| Northern California | 3164 (61.4) |
| Boston | 1038 (20.1) |

*Table continues on page 145.*

eases, Ninth Revision (ICD-9) codes. The FCI is made up of 18 health conditions, and it was scored as a count from 0 to 18. The FCI was developed to predict functional status.[10] The Quan-Charlson comorbidity index contains 17 conditions that are weighted to create a final score from 0 to 29.[17] The Elixhauser comorbidity index provides a summary score (0-30) of 30 health conditions.[6]

For this analysis, we used patient-reported outcome measures collected at baseline and 12 months after the new visit. We measured functional status using the Roland-Morris Disability Questionnaire (RMDQ). The RMDQ is a valid measure of back-related function and is scored from 0 (no disability) to 24 (maximum disability).[16] Health-related quality of life was assessed using the European Quality of Life-5 Dimensions (EQ-5D). The EQ-5D is a utility score based on 5 domains, with final values from 0 (death) to 1 (best health).[2] We measured total health care use after a new visit by summing the relative value units for all visits and procedures from baseline through 12 months.[8]

**TABLE 1** BASELINE CHARACTERISTICS OF OLDER ADULTS WITH NEW VISITS FOR BACK PAIN[a] (CONTINUED)

| Variable | Value |
|---|---|
| Back pain characteristics | |
| Symptom duration, n (%) | |
| <1 mo | 1727 (33.5) |
| 1-3 mo | 999 (19.4) |
| 3-6 mo | 339 (6.6) |
| 6-12 mo | 308 (6.0) |
| 1-5 y | 764 (14.8) |
| >5 y | 1014 (19.7) |
| NA | 4 (0.1) |
| Back pain intensity (NRS) | 5.0 ± 2.8 |
| Leg pain present (yes), n (%) | 3258 (63.2) |
| Functional status (RMDQ) | 9.6 ± 6.4 |
| Pain interference with activity | 3.3 ± 2.5 |
| General health status (EQ-5D index score) | 0.76 ± 0.18 |
| Health characteristics | |
| Smoking, n (%) | |
| Never | 2852 (55.3) |
| Quit >1 y ago | 1973 (38.3) |
| Smoker or quit <1 y ago | 315 (6.1) |
| NA | 15 (0.3) |
| Expectation for recovery | 5.5 ± 3.7 |
| Positive anxiety screen, n (%) | 639 (12.4) |
| Positive depression screen, n (%) | 429 (8.3) |
| Diagnosis category at index, n (%) | |
| Axial pain | 3499 (67.9) |
| Back and leg pain | 1081 (21.0) |
| Lumbar spinal stenosis | 280 (5.4) |
| Other | 295 (5.7) |
| Total RVUs before | 38.4 ± 90.7 |

*Abbreviations: EQ-5D, European Quality of Life-5 Dimensions; GED, general education diploma; NA, not answered; NRS, numeric rating scale; RMDQ, Roland-Morris Disability Questionnaire; RVU, relative value unit.*
[a]*Values are mean ± SD unless otherwise indicated.*

We characterized the cohort at baseline and described the distribution of each comorbidity index using descriptive statistics. We examined correlations among the comorbidity indices using Spearman rank-order correlation coefficients. The association of each comorbidity measure with baseline and 12-month outcomes was assessed using linear regression for the RMDQ and EQ-5D and generalized linear models for relative value units. We compared model fit using the $R^2$ or Akaike information criterion from each model, and we determined predictive accuracy using the root-mean-square error (RMSE) of prediction. No set criteria were used to compare the difference in model performance; instead, we qualitatively compared the $R^2$, Akaike information criterion, and RMSE of the models. All models included covariates of age, sex, race, education, index back diagnosis, symptom duration, and study site. Few participants were excluded for not having complete electronic health record data (n = 84, 1.6%). These exclusions were mostly due to data not being sent for these patients by the study site or an insurance company refusing to release billing data (n = 65). We did not account for this, because we think these data are missing completely at random and would not introduce bias. All analyses were conducted using Stata Version 14.1 (StataCorp LLC, College Station, TX). Statistical significance was set using a standard 2-sided alpha of .05.

## RESULTS

BASELINE CHARACTERISTICS OF THE 5155 participants included in this analysis are presented in **TABLE 1**. We examined the distribution of comorbidities for each comorbidity index using counts and proportions. For the FCI, 2563 (49.7%) had no comorbidities, 1194 (23.2%) had 1 comorbidity, and 1398 (27.1%) had 2 or more comorbidities. For the Quan-Charlson comorbidity index, 3195 (62.0%) had no comorbidities, 878 (17.0%) had 1 comorbidity, and 1082 (21.0%) had 2 or more comorbidities. For the Elixhauser comorbidity index, 802 (15.6%) had no comorbidities, 889 (17.2%) had 1 comorbidity, and 3464 (67.2%) had 2 or more comorbidities. The correlation coefficient between the FCI and the Quan-Charlson comorbidity index was 0.70, that between the FCI and the Elixhauser comorbidity index was 0.75, and that between the Elixhauser and Quan-Charlson comorbidity indices was 0.74.

Estimates from multivariable models testing the association of each comorbidity index with baseline and 12-month outcomes are presented in **TABLE 2**. The FCI and the Quan-Charlson and Elixhauser indices each explained a similar amount of variance for baseline and 12-month function (18.1% to 18.4% at baseline and 18.5% to 19.0% at 12 months) and health-related quality of life (8.0% to 8.5% at baseline and 14.8% to 15.7% at 12 months). Each model had similar performance for estimating total health care use. The RMSEs for estimated baseline and 12-month function and health-related quality of life were similar for all models.

**TABLE 2** Model Performance of Each Index for Estimating Baseline and 12-Month Outcomes[a]

| Time Point/Outcome/Index | $\beta$[b] | $R^2$ | AIC | RMSE |
|---|---|---|---|---|
| Baseline | | | | |
| RMDQ (n = 5086) | | | | |
| FCI | 0.66 (0.53, 0.80) | 0.184 | 32373.46 | 5.82 |
| Elixhauser | 0.38 (0.30, 0.46) | 0.183 | 32380.19 | 5.83 |
| Quan-Charlson | 0.54 (0.42, 0.66) | 0.181 | 32387.63 | 5.83 |
| EQ-5D index score (n = 5072) | | | | |
| FCI | −0.015 (−0.019, −0.011) | 0.085 | −3693.39 | 0.168 |
| Elixhauser | −0.008 (−0.010, −0.006) | 0.084 | −3685.08 | 0.168 |
| Quan-Charlson | −0.010 (−0.013, −0.006) | 0.080 | −3665.54 | 0.168 |
| Total RVUs (n = 5086) | | | | |
| FCI | 1.39 (1.34, 1.44) | 0.051 | 9.05 | 89.05 |
| Elixhauser | 1.34 (1.31, 1.37) | 0.122 | 8.83 | 86.60 |
| Quan-Charlson | 1.27 (1.22, 1.31) | 0.044 | 9.10 | 89.30 |
| 12 mo | | | | |
| RMDQ (n = 4351) | | | | |
| FCI | 0.80 (0.64, 0.95) | 0.190 | 28228.20 | 6.19 |
| Elixhauser | 0.46 (0.37, 0.56) | 0.189 | 28230.13 | 6.19 |
| Quan-Charlson | 0.62 (0.48, 0.76) | 0.185 | 28252.84 | 6.20 |
| EQ-5D index score (n = 4306) | | | | |
| FCI | −0.020 (−0.024, −0.015) | 0.157 | −3380.81 | 0.163 |
| Elixhauser | −0.011 (−0.013, −0.008) | 0.154 | −3365.52 | 0.163 |
| Quan-Charlson | −0.013 (−0.016, −0.009) | 0.148 | −3337.29 | 0.164 |
| Total RVUs (n = 5086) | | | | |
| FCI | 1.13 (1.09, 1.17) | 0.030 | 10.04 | 131.48 |
| Elixhauser | 1.11 (1.09, 1.14) | 0.040 | 10.01 | 130.78 |
| Quan-Charlson | 1.12 (1.08, 1.15) | 0.030 | 10.04 | 131.45 |

*Abbreviations: AIC, Akaike information criterion; EQ-5D, European Quality of Life-5 Dimensions; FCI, functional comorbidity index; RMDQ, Roland-Morris Disability Questionnaire; RMSE, root-mean-square error; RVU, relative value unit.*
[a]*Covariates included age, sex, race, education, index back diagnosis, symptom duration, and study site.*
[b]*Values in parentheses are 95% confidence interval.*

## DISCUSSION

We compared the performance of 3 comorbidity indices in predicting function, health-related quality of life, and total health care use among a cohort of older adults with new visits for back pain. The FCI, Quan-Charlson comorbidity index, and Elixhauser comorbidity index all performed similarly in predicting outcomes. Consequently, there does not seem to be an advantage to using one index over another for older adults with back pain in outpatient settings. Overall, risk-adjustment models that included a comorbidity index, age, sex, race, education, index back diagnosis, symptom duration, and study site explained only 18% of the variance in baseline and 19% of the variance in 12-month RMDQ scores. These models were less useful in explaining variance in quality of life (about 8% at baseline and 15% at 12 months). For every 1-unit increase on the comorbidity indices, the mean total health care use increased by 11% to 13%.

These results suggest that there is a need to develop better risk-adjustment models for predicting functional and quality-of-life outcomes. All of the models accounted for less than 20% of the variance for outcomes that are important to rehabilitation providers[4] and patients,[7] which is considered relatively low. Although measures of comorbidity are an important variable to include in risk-adjustment models, the ability of these models to sufficiently adjust for differences in case mix between providers or clinics is limited, as shown by the low amount of explained variance.

Comorbidities were included in the FCI based on their relationship to function, but in this study, the FCI did not have an advantage over the Quan-Charlson comorbidity index and the Elixhauser comorbidity index in predicting function. These findings are consistent with recent research from inpatient settings[13,14] and support the notion that comorbidity measures function as an indicator of allostatic load, with the individual comorbidities included being less important than the total number of health conditions an individual accumulates.[5] To improve the prediction of function for use in risk-adjustment models, additional variables such as baseline functional status,[12] pain severity, and number of pain sites[15] may need to be regularly collected and reported for all patients. The increasing availability of clinical registries presents the opportunity to regularly collect patient-reported data as part of usual clinical care. Future health services research can leverage these data to develop better risk-adjustment models that include more important prognostic factors than are typically available in administrative claims data.

Even though the models performed similarly, the indices measured different sets of comorbidities, and the proportion of patients categorized with zero comorbidities varied considerably, from 16% for the Elixhauser comorbidity index to 62% for the Quan-Charlson comorbidity index. The number of conditions in each index likely affects this. The FCI and Quan-Charlson comorbidity index include 18 or 17 conditions, respectively, and the Elixhauser comorbidity index includes 30 conditions. The different comorbidities included for each index also seem to contribute to the different comorbidity scores for each patient. These differences in type and number of comorbidities led us to initially hypothesize that there may be differences in the predictive ability of the 3 indices, but this did not seem to be the case.

Strengths of this study include the availability of electronic health record data and the availability of patient-reported outcomes that are important for rehabilitation settings and providers. Limitations of this study include potential misclassification of health conditions when using diagnosis codes. Measurement error may diminish the ability of a comorbidity index to accurately predict an outcome. International Classification of Diseases, Ninth Revision codes are also no longer used in clinical practice within the United States. Additionally, the exclusion of patients who had serious pathologies (eg, cancer) might have attenuated the association of comorbidity indices with outcomes. Similarly, the exclusion of patients with back procedures or visits in the prior 6 months might also have attenuated the association for the FCI, as it includes a category of degenerative disc disease and spinal stenosis. However, the Back pain Outcomes using Longitudinal Data cohort was designed to be very pragmatic, and patients with serious pathology would be treated very differently from the population to which this study is generalizing. These results may not generalize to other patient populations or health conditions that rehabilitation providers may treat.

## CONCLUSION

The FCI, Quan-Charlson comorbidity index, and Elixhauser comorbidity index performed similarly in predicting function, health-related quality of life, and total health care use. There does not seem to be an advantage to using one index over another for older adults with back pain in outpatient settings. All models explained a relatively low proportion of variance in the outcomes. These findings may not generalize to other health conditions, and future research can investigate the performance of risk-adjustment models that include commonly used patient-reported outcomes. ◉

### KEY POINTS

**FINDINGS:** The functional comorbidity index did not have an advantage over Quan's modification of the Charlson comorbidity index and the Elixhauser comorbidity index in risk-adjustment models for older adults with back pain in outpatient settings. All models explained a relatively low proportion of variance in the outcomes.

**IMPLICATIONS:** There is a critical need to develop better function-based risk-adjustment models to optimally compare outcomes among providers and clinics.

**CAUTION:** There is likely misclassification of health conditions when using diagnostic codes.

### STUDY DETAILS

**TRIAL REGISTRATION:** The Back pain Outcomes using Longitudinal Data study was registered at www.ClinicalTrials.gov (NCT01776242).

**PATIENT AND PUBLIC INVOLVEMENT:** Patient and public engagement was not a part of this research.

**DATA SHARING:** Data from the Back pain Outcomes using Longitudinal Data cohort are available on request through the University of Washington Clinical Learning, Evidence and Research Center for Musculoskeletal Disorders (theclearcenter@uw.edu).

**AUTHOR CONTRIBUTIONS:** All authors contributed to the conception or design of the work, interpreted the data, were involved in drafting the work or revising it critically for important intellectual content, approved the final version to be published, and are accountable for all aspects of the work. Drs Jarvik and Heagerty were responsible for data acquisition. Dr Rundell performed the data analysis.

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# EDITORIAL

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# Overcoming Overuse: Improving Musculoskeletal Health Care



Care for musculoskeletal conditions is evolving. For more than 2 decades, clinical practice guidelines for conditions such as knee pain and low back pain recommended medication as first-line care, then surgery for selected patients who did not respond. Current recommendations now prioritize nonpharmacological interventions. Advice and exercise for musculoskeletal conditions, such as low back pain and hip and knee osteoarthritis, have replaced medication as first-line care, and some surgical procedures are actively discouraged.[11] What prompted the changes to recommendations? An increase in high-quality research evidence and awareness of the harms of overuse.[2,10]

Overuse of health care is the use of services that have no net benefit or cause harm.[2,10] Overuse includes overlapping concepts of low-value care and overtreatment (**TABLE**). Changes in clinical practice guidelines provide an unprecedented opportunity for physical therapists to prevent overuse and lead the evidence-based management of musculoskeletal conditions. In the "Overcoming Overuse" series, we explore the evidence of overuse in musculoskeletal health care and propose potential solutions.

## Global Awareness of Overuse in Musculoskeletal Care

Greater awareness of the enormous waste due to overuse (estimated to be as high as 30% of total health care spending)[1] has spurred global initiatives to tackle the issue. For example, Choosing Wisely (http://www.choosingwisely.org) aims to reduce overuse by engaging with professional bodies to publish their own "do-not-do" lists of tests and treatments. There are over 150 Choosing Wisely recommendations that focus on musculoskeletal conditions (eg, low back pain, knee osteoarthritis, shoulder pain, rheumatoid arthritis).

**SUMMARY:** This is the first article in a series on "Overcoming Overuse" in musculoskeletal health care. *Overuse* is the use of services that are unlikely to improve patient outcomes, result in more harm than benefit, and would not be desired by an informed patient. The Overcoming Overuse series explores the myriad ways diagnostic tests and treatments are overused in musculoskeletal health care, and proposes ways to ensure patients receive appropriate care. We focus on strategies to promote guideline-concordant care in rehabilitation practice and strategies to overcome overuse.
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**KEY WORDS:** *musculoskeletal, overuse, physical therapy*

Opportunity cost is an important consequence of overuse. Today, finite health care resources are being used to fund ineffective (eg, knee arthroscopy) and unproven health services for musculoskeletal conditions (eg, opioids for acute low back pain).[1] These funds could be better spent on services known to improve musculoskeletal health (eg, exercise and weight-loss programs for knee osteoarthritis). Overuse compounds when ineffective or unproven health services crowd out recommended care.

The CareTrack study in Australia monitored 35 573 health care encounters and found that only 43% of patients with osteoarthritis and 72% with low back pain received recommended care when they visited a health care professional.[6] There were similar results in the United States (57% for osteoarthritis and 68% for low back pain).[5] We found that 1 in every 3 physical therapists across 19 countries did not provide recommended care for common musculoskeletal conditions, such as back pain, knee osteoarthritis, and ankle sprains.[11] However, it is difficult to disentangle overuse from these numbers. We will explore the challenge of directly measuring overuse later in this series.

## Physical Therapy: Friend or Foe?

As the physical therapy profession grows and clinical practice guidelines increas-

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ingly encourage people to seek nonpharmacological care,[11] it is vital to consider how physical therapists can help prevent overuse. In the United States, there are nearly 250 000 physical therapists, and the profession is estimated to grow 28% within the next 10 years. In Australia, there are now more practicing physical therapists than general practitioners, and 1 in 10 Australians visit a physical therapist each year. Growth in the physical therapy workforce will undoubtedly raise awareness of the profession, and may drive use of physical therapy services. This is an important opportunity for physical therapists to draw from the large evidence base that underpins the profession to improve the quality of the musculoskeletal health care they provide.

While physical therapy treatment may be less expensive and carry fewer risks than imaging, surgery, and opioids, the value of the care provided is critical. The annual cost of physical therapy is estimated at $1 billion in Australia and over $25 billion in the United States.[11] If physical therapists do not provide recommended care, it is possible that increased emphasis on nonpharmacological care could reduce overuse in one area (eg, surgery) but create overuse in another (eg, electrophysical agents for low back pain).

One in 4 physical therapists provide treatments for musculoskeletal conditions that guidelines recommend against, and nearly half provide treatments that have not been well researched.[11] Not all agree with recommendations to reduce some services (eg, only 52% of physical therapists agree that electrotherapy should not be provided for low back pain).[12] Without considering the type or amount of treatment, blind advocacy for physical therapy as a blanket alternative to medication or surgery could lead to overuse.

## Understanding the Drivers of Overuse in Musculoskeletal Care

Although data on the drivers of overuse in physical therapy are scarce, the 2017 *Lancet* Right Care series highlighted several relevant drivers of overuse in medicine.[7] Economic incentives, such as fee-for-service and volume-based payments, likely influence clinicians' decisions. In countries where physical therapists bill for specific treatments, health insurance coverage and payment models could encourage the use of profitable, yet ineffective or untested, treatments. The knowledge, beliefs, expectations, assumptions, and biases of physical therapists and their patients can also drive overuse. Any strategy to overcome overuse will therefore require understanding of a diverse set of contributors to the problem.

## The Overcoming Overuse Series

We are optimistic that physical therapists can seize the opportunity to "overcome overuse" and lead evidence-based health care for musculoskeletal conditions. In this series, we will explore the many facets of overuse in musculoskeletal

**TABLE** Definitions of Overuse and Related Concepts, Adapted From Traeger et al[10] and the 2017 *Lancet* Right Care Series[2]

| Term | Definition | Example |
|---|---|---|
| Overuse | Provision of a service that is unlikely to increase quality or quantity of life, that poses more harm than benefit, or that patients who were fully informed of its potential benefits and harms would not have wanted | Despite clinical practice guidelines recommending against knee arthroscopy for degenerative meniscal tears or osteoarthritis, over 33 000 surgeries are performed in Australia each year[10] |
| Overdiagnosis | An (asymptomatic) person is diagnosed with a condition; the diagnosis does not produce a net benefit for that person | An asymptomatic child diagnosed with a mild scoliosis |
| Overdetection | A health-related finding is detected in an asymptomatic person, probably by testing technology. The finding does not produce a net benefit for that person | Findings on shoulder imaging that are common in asymptomatic people (when there is no way to reliably link imaging findings to symptoms). Rotator cuff tears are more common in asymptomatic people (compared to symptomatic people) from ages 20 to 29 (7% versus 4%) and 30 to 39 (21% versus 14%) years[9] |
| Overtreatment | Provision of treatment with no net benefit by individual clinicians to patients | Use of ineffective therapies for knee osteoarthritis. In 2017, half of the 284 Belgian physical therapists surveyed advocated treatments shown to have no net benefit for patients with knee osteoarthritis, such as ultrasound and electrical stimulation[8] |
| Overmedicalization | Altering the meaning or understanding of experiences, so that human problems are reinterpreted as medical problems requiring medical treatment, without net benefit to patients | Professional associations promoting early management of acute low back pain, despite its positive natural history and a randomized controlled trial showing that 4 sessions of physical therapy delivered within 2 weeks of pain onset provide little to no benefit for patients with acute low back pain[3]<br>Professional associations promoting regular check-ups with a physical therapist despite no evidence of benefit |
| Low-value care | An intervention that confers no or very little benefit on patients, or the risk of harm exceeds probable benefit, or the added costs of the intervention do not provide proportional added benefits | Subacromial decompression surgery for shoulder pain provides similar effects to placebo surgery and is not recommended in guidelines. Nearly 20 000 surgeries are performed in England each year[4] |

diagnosis and treatment. We will propose solutions to support evidence-based, patient-centered, safe, and appropriate musculoskeletal care.

The Overcoming Overuse series has 5 key objectives:

1. Define and measure overuse of diagnostic tests and treatments in musculoskeletal health care
2. Outline the potential drivers of overuse
3. Explore how vested interests can increase the risk of overuse
4. Discuss funding arrangements that foster quality care delivery
5. Consider the evidence base for using shared decision making to reduce overuse

We hope to engage the *JOSPT* community on a variety of themes relevant to avoiding overuse of musculoskeletal health care. We encourage users to follow the series using the #overcomeoveruse hashtag. Suggest further ideas for the Overcoming Overuse series by e-mailing jospt@jospt.org or via social media (@JOSPT). ◉



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