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# Hamstring Strain Injury in Athletes

*Clinical Practice Guidelines Linked to the International Classification of Functioning, Disability and Health From the Academy of Orthopaedic Physical Therapy and the American Academy of Sports Physical Therapy of the American Physical Therapy Association*

*J Orthop Sports Phys Ther. 2022;52(3):CPG1-CPG44. doi:10.2519/jospt.2022.0301*



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# Summary of Recommendations

### REINJURY RISK AND RETURN TO PLAY

**B** Clinicians should use the history of a hamstring strain injury (HSI) in return-to-play (RTP) progression, as a previous HSI is a risk factor for a future reinjury.

**B** Clinicians should use caution in RTP decisions for individuals who did not complete an appropriately progressed, comprehensive impairment-based functional exercise program that specifically included eccentric training.

**B** Clinicians should use hamstring strength, pain level at the time of injury, number of days from injury to pain-free walking, and area of tenderness measured on initial evaluation to estimate time to RTP.

### DIAGNOSIS/CLASSIFICATION

**B** Clinicians should make a diagnosis of HSI when an individual presents with a sudden onset of posterior thigh pain during activity, with pain reproduced when the hamstring is stretched and/or activated, muscle tenderness with palpation, and loss of function.

### EXAMINATION: PHYSICAL IMPAIRMENT MEASURES

**A** Clinicians should quantify knee flexor strength following HSI by using either a handheld or isokinetic dynamometer.

**A** Clinicians should assess hamstring length by measuring the knee extension deficit with the hip flexed to 90°, using an inclinometer.

**C** Clinicians may use the length of muscle tenderness and proximity to the ischial tuberosity to assist in predicting timing of RTP.

**F** Clinicians may assess for abnormal trunk and pelvic posture and control during functional movements.

### EXAMINATION: ACTIVITY LIMITATION AND PARTICIPATION RESTRICTION

**B** Clinicians should include objective measures of an individual's ability to walk, run, and sprint when documenting changes in activity and participation over the course of treatment.

### EXAMINATION: OUTCOME MEASURES

**B** Clinicians should use the Functional Assessment Scale for Acute Hamstring Injuries before and after interventions, intended to alleviate the impairments of body function and structure, activity limitations, and participation restrictions in those diagnosed with an acute HSI.

### INTERVENTIONS: INJURY PREVENTION

**A** Clinicians should include the Nordic hamstring exercise as part of an HSI prevention program, along with other components of warm-up, stretching, stability training, strengthening, and functional movements (sport specific, agility, and high-speed running).

### INTERVENTIONS: AFTER INJURY

**B** Clinicians should use eccentric training to the patient's tolerance, added to stretching, strengthening, stabilization, and progressive running programs, to improve RTP time after an individual sustains an HSI.

**B** Clinicians should use progressive agility and trunk stabilization, added to a comprehensive impairment-based treatment program of stretching, strengthening, and functional exercises, to reduce reinjury rate after an individual sustains an HSI.

**F** Clinicians may perform neural tissue mobilization after injury to reduce adhesions to surrounding tissue and therapeutic modalities to control pain and swelling early in the healing process.



# List of Abbreviations

**AASPT:** American Academy of Sports Physical Therapy
**AKE:** active knee extension
**AOPT:** Academy of Orthopaedic Physical Therapy
**APTA:** American Physical Therapy Association
**CI:** confidence interval
**CPG:** clinical practice guideline
**FASH :** Functional Assessment Scale for Acute Hamstring Injuries
**FIFA:** International Federation of Association Football (Fédération Internationale de Football Association)
**HaOS:** hamstring outcome score
**HHD:** handheld dynamometer

**H/Q:** hamstring-quadriceps
**HR:** hazard ratio
**HSI:** hamstring strain injury
**ICC:** intraclass correlation coefficient
**ICF:** International Classification of Functioning, Disability and Health
***JOSPT*:** *Journal of Orthopaedic & Sports Physical Therapy*
**MDC:** minimal detectable change
**MRI:** magnetic resonance imaging
**NHE:** Nordic hamstring exercise
**OR:** odds ratio
**RCT:** randomized controlled trial
**ROM:** range of motion
**RR:** relative risk
**RTP:** return to play
**SEM:** standard error of measurement
**SLR:** straight leg raise
**US:** ultrasound

# Introduction

## AIM OF THE GUIDELINES

The Academy of Orthopaedic Physical Therapy (AOPT) and the American Academy of Sports Physical Therapy (AASPT) of the American Physical Therapy Association (APTA) has an ongoing effort to create evidence-based clinical practice guidelines (CPGs) for orthopaedic and sports physical therapist management of patients with musculoskeletal impairments described in the World Health Organization's International Classification of Functioning, Disability and Health (ICF).[108] The purposes of these CPGs are as follows:

- Describe evidence-based physical therapist practice, including diagnosis, prognosis, intervention, and assessment of outcome, for musculoskeletal disorders commonly managed by orthopaedic physical therapists
- Classify and define common musculoskeletal conditions using the World Health Organization's terminology related to impairments of body function and structure, activity limitations, and participation restrictions
- Identify interventions supported by current best evidence to address impairments of body function and structure, activity limitations, and participation restrictions associated with common musculoskeletal conditions
- Identify appropriate outcome measures to assess changes resulting from physical therapist interventions in body function and structure, as well as in activity and participation of these individuals
- Provide a description to policy makers, using internationally accepted terminology, of the practice of orthopaedic physical therapists
- Provide information for payers and claims reviewers regarding the practice of orthopaedic physical therapy for common musculoskeletal conditions
- Create a reference publication for orthopaedic physical therapy clinicians, academic instructors, clinical instructors, students, interns, residents, and fellows regarding the best current practice of orthopaedic physical therapy

## STATEMENT OF INTENT

These guidelines are not intended to be construed or to serve as a standard of medical care. Standards of care are based on all clinical data available for an individual patient and are subject to change, as scientific knowledge and technology advance and patterns of care evolve. These parameters of practice should be considered guidelines only. Adherence to them will not ensure a successful outcome in every patient, nor should they be construed as including all proper methods of care or excluding other acceptable methods of care aimed at the same results. The ultimate judgment regarding a particular clinical procedure or treatment plan must be made based on clinician experience and expertise, considering the clinical presentation of the patient, the available evidence, available diagnostic and treatment options, and the patient's values, expectations, and preferences. However, we suggest that significant departures from accepted guidelines should be documented in the patient's medical records at the time the relevant clinical decision is made.

## SCOPE AND RATIONALE OF THE GUIDELINE

The hamstring muscle group consists of 3 muscles in the posterior thigh: the semitendinosus, semimembranosus, and biceps femoris. Hamstring strain injury (HSI) may result in considerable impairment, activity limitation, and participation restriction, including time lost from competitive sports. In professional sports, HSIs may be associated with significant financial costs.[18] The high reinjury rate is also an important issue.[55] Typically, HSIs are classified by the involved muscle, anatomical location, and severity of damage.[3,18] Classifications also may consider whether there is myofascial, musculotendinous, and/or intratendinous involvement.[3,18] A variety of injury mechanisms for HSIs have been described and typically involve some type of eccentric overloading and/or overstretching in a position of hip flexion and knee extension.[4] Different mechanisms of injury may be associated with unique injury locations and

specific structural impairments. For example, overloading injuries typically occur in a lengthened position, as in high-speed running, when the hamstring is eccentrically contracting across the hip and knee, and late in swing phase/early heel strike.[11] This overload injury usually involves the biceps femoris and surrounding tissue. In contrast, overstretching injuries occur with combined hip flexion and knee extension movements, as in kicking or reaching to pick up and lift something off the ground with the knee extended. This overstretching injury typically involves the proximal semimembranosus.[6] This CPG includes sports-related overloading and overstretching injuries to myofascial or musculotendinous structures in any combination of the 3 hamstring muscles. Injuries exclusive to the proximal or distal hamstring tendons with primarily intratendinous involvement are different from HSIs that involve the myofascial and musculotendinous structures with respect to incidence, mechanism of injury, pathoanatomical features, clinical course, and treatment strategies.[3] Given these differences, this CPG will exclude isolated tendon injuries. While the effect of interventions for those with an HSI can be measured in a variety of ways, including but not limited to strength, range of motion (ROM), and pain levels, the ultimate success of the rehabilitation process is determined by the individual's ability to return to sports participation while preventing reinjury. Therefore, only studies that directly assessed time to return to play (RTP) and reinjury rates were included when discussing interventions for HSIs.

# Methods

The AOPT and AASPT appointed content experts to conduct a review of the literature and develop an HSI CPG. The aims of this review were to provide a concise summary of the contemporary evidence and to develop recommendations to support evidence-based practice. The authors of this guideline worked with the CPG editors and medical librarians for methodological guidance. The research librarians were chosen for their expertise in systematic review and rehabilitation literature searching and to perform systematic searches for concepts associated with classification, examination, and intervention strategies for HSI. Briefly, the following databases were searched from database inception to June 2021: PubMed, Embase, CINAHL, Cochrane Library, Ovid, and SPORTDiscus (see **APPENDIX A** for full search strategies, dates, and results, available at www.jospt.org).

The authors declared relationships and developed a conflict management plan, which included submitting a conflict-of-interest form to the AOPT. Articles authored by a reviewer were assigned to an alternate reviewer. The CPG authors did not draft recommendations when their research was included in that topic area. The AOPT and AASPT funded the CPG development team for travel and CPG development training. The CPG development team maintained editorial independence.

Articles used to support recommendations were reviewed based on prespecified inclusion and exclusion criteria, with the goal of identifying evidence relevant to clinical decision making for managing adults with HSI. Two members of the CPG development team independently reviewed the title and abstract of each article for inclusion (see **APPENDIX B** for inclusion and exclusion criteria, available at www.jospt.org). Full-text review was then similarly conducted to obtain the final set of articles used to make the recommendations. The team leader (R.L.M.) provided the final decision for discrepancies that were not resolved by the review team (see **APPENDIX C** for flow charts of articles, available at www.jospt.org). Articles for selected relevant topics that were not sufficient for developing recommendations (eg, incidence and imaging) were not subject to the systematic review process and were not included in the flow chart. Evidence tables for this CPG are available on the CPG page of the AOPT and AASPT of the APTA websites (www.orthopt.org and www.aaspt.org).

This guideline was issued in 2022, based on the published literature through June 2021, and will be considered for review in 2026, or sooner if important evidence becomes available. Any updates to the guideline in the interim period will be noted on the AOPT and AASPT of the APTA websites (www.orthopt.org and www.aaspt.org).

## LEVELS OF EVIDENCE

Individual clinical research articles were graded according to criteria adapted from the Centre for Evidence-Based Medicine (Oxford, UK) for diagnostic, prospective, and therapeutic studies. In teams of 2, each reviewer independently assigned a level of evidence and evaluated the quality of each article using a critical appraisal tool (see **APPENDICES D** and **E** for the levels-of-evidence table and details on procedures used for assigning levels of evidence, available at www.jospt.org). The evidence update was organized from the highest level of evidence to the lowest level of evidence. An abbreviated version of the grading system is provided in **TABLE 1**.

**TABLE 1** LEVELS OF EVIDENCE

| | |
|---|---|
| I | Evidence obtained from high-quality diagnostic studies, prospective studies, systematic reviews, or randomized controlled trials |
| II | Evidence obtained from lesser-quality diagnostic studies, systematic reviews, prospective studies, or randomized controlled trials (eg, weaker diagnostic criteria and reference standards, improper randomization, no blinding, less than 80% follow-up) |
| III | Case-control studies or retrospective studies |
| IV | Case series |
| V | Expert opinion |

## STRENGTH OF EVIDENCE AND GRADES OF RECOMMENDATION

The strength of the evidence supporting the recommendations was graded according to the established methods provided below (**TABLE 2**). Each team developed recommendations based on the strength of evidence, including how directly the studies addressed the question relating to HSIs. In developing their recommendations, the authors considered the strengths and limitations of the body of evidence and the health benefits, side effects, and risks of tests and interventions.

**TABLE 2** GRADES OF RECOMMENDATION

| Grades of Recommendation | | Strength of Evidence | Level of Obligation |
|---|---|---|---|
| A | Strong evidence | A preponderance of level I and/or level II studies support the recommendation. This must include at least 1 level I study | Must or should |
| B | Moderate evidence | A single high-quality randomized controlled trial or a preponderance of level II studies support the recommendation | Should |
| C | Weak evidence | A single level II study or a preponderance of level III and IV studies, including statements of consensus by content experts, support the recommendation | May |
| D | Conflicting evidence | Higher-quality studies conducted on this topic disagree with respect to their conclusions. The recommendation is based on these conflicting study results | |
| E | Theoretical/ foundational evidence | A preponderance of evidence from animal or cadaver studies, from conceptual models/principles, or from basic sciences/bench research support this conclusion | May |
| F | Expert opinion | Best practice based on the clinical experience of the guidelines development team supports this conclusion | May |

## GUIDELINE REVIEW PROCESS AND VALIDATION

Identified reviewers who are experts in HSI management and rehabilitation reviewed the CPG draft for integrity and accuracy, and to ensure that it fully represented the current evidence for the condition. The guideline draft was also posted for open review on www.orthopt.org, and a notification of this posting was sent to the members of the AOPT. In addition, reviewers were invited from a panel including consumer/patient representatives and external stakeholders, claims reviewers, medical coding experts, academic educators, clinical educators, physician specialists, researchers, and CPG methodologists. All comments, suggestions, and feedback from the reviews were provided to the authors and editors for consideration and revision. The AOPT Clinical Practice Guideline Advisory Panel reviews guideline development methods, policies, and implementation processes on a yearly basis.

## DISSEMINATION AND IMPLEMENTATION TOOLS

In addition to publishing this CPG in the *Journal of Orthopaedic & Sports Physical Therapy* (*JOSPT*), it will be posted on the CPG pages of the *JOSPT, AASPT,* and AOPT websites, which are free-access website areas, and submitted for free access on the ECRI Guidelines Trust (guidelines.ecri.org) and the Physiotherapy Evidence Database (www.PEDro.org.au). The planned implementation tools for patients, clinicians, educators, payers, policy makers, and researchers, and the associated implementation strategies, are listed in **TABLE 3**.

## ORGANIZATION OF THE GUIDELINE

When systematic reviews were conducted to support specific recommendations, summaries of studies with the corresponding evidence levels are followed by a synthesis of the literature and rationale for the recommendation(s), discussion of gaps in the literature when appropriate, and the recommendation(s). Topics for which a systematic review was conducted and recommendations provided include RTP and reinjury risk, examination, injury prevention, and interventions. For other topics where a systematic review was outside the scope of this CPG, a summary of the literature is provided. This includes incidence/prevalence, pathoanatomical features, risk factors, clinical course, differential diagnosis, and imaging.

## CLASSIFICATION

The primary International Classification of Diseases-10th Revision codes associated with an HSI are as follows:

1. **S76.01** Strain of muscle, fascia and tendon of hip

2. **S76.302A** Unspecified injury of muscle, fascia and tendon of the posterior muscle group at thigh level, left thigh, initial encounter
   a. **S76.312** Strain of muscle, fascia and tendon of the posterior muscle group at thigh level, left thigh
   b. **S76.311** Strain of muscle, fascia and tendon of the posterior muscle group at thigh level, right thigh
3. **S76.319D** Strain of muscle, fascia and tendon of the posterior muscle group at thigh level, unspecified thigh, subsequent encounter

The primary ICF body function codes associated with HSI are **b28015** Pain in lower limb and **b7301** Power of muscles of one limb.

The primary ICF body structure code associated with HSI is **S75002** Muscles of thigh.

The primary ICF activities and participation codes associated with HSI are **d4105** Bending, **d4153** Maintaining a sitting position, **d4351** Kicking, **d4509** Walking, unspecified, **d4551** Climbing, **d4552** Running, **d4553** Jumping, and **d9201** Sports.

**TABLE 3** Planned Strategies and Tools to Support the Dissemination and Implementation of This CPG

| Tool | Strategy |
|---|---|
| *JOSPT*'s "Perspectives for Patients" and "Perspectives for Practice" articles | Patient- and clinician-oriented guideline summaries available at www.jospt.org |
| Mobile app of guideline-based exercises for patients/clients and health care practitioners | Marketing and distribution of app via www.orthopt.org and www.aaspt.org |
| Clinician's Quick-Reference Guide | Summary of guideline recommendations available at www.orthopt.org and www.aaspt.org |
| JOSPT's Read for Credit℠ continuing education units | Continuing education units available for physical therapists and athletic trainers at www.jospt.org |
| Webinars and educational offerings for health care practitioners | Guideline-based instruction available for practitioners at www.orthopt.org |
| Mobile and web-based app of guideline for training of health care practitioners | Marketing and distribution of app via www.orthopt.org |
| Non-English versions of the guidelines and guideline implementation tools | Development and distribution of translated guidelines and tools to JOSPT's international partners and global audience via www.jospt.org |
| APTA CPG+ | Dissemination and implementation aids |

CLINICAL PRACTICE GUIDELINES

# Incidence/Prevalence

Hamstring strain injuries are common in activities that involve high-speed running, jumping, kicking, and/or explosive lower extremity movements with rapid changes in direction, including lifting objects from the ground. Therefore, sports such as track and field, soccer, Australian rules football, American football, and rugby have the highest frequency of reported injuries.[8,50,89,93] The estimated incidence of HSIs per 1000 hours of exposure is 0.87 in noncontact sports and 0.92 to 0.96 in contact sports.[50] Incidence rate estimates are 3 to 4.1 per 1000 competition hours and 0.4 to 0.5 per 1000 training hours for professional male European soccer players.[29] Some groups have reported an increasing incidence of HSIs. For example, in professional male European soccer players between 2001 and 2014, there was an increase in HSIs per year of 2.3% (95% confidence interval [CI]: 0.6%, 4.1%) during competition and 4.0% (95% CI: 1.1%, 7.0%) during training.[25] Dalton et al[17] reported that 68.2% of HSIs occurred during practice in men's football, men's soccer, and women's soccer. A professional soccer team of 25 players can expect about 7 HSIs per season.[50] Australian rules football players have a 1.3-fold higher risk of HSI with each additional year of age, while soccer players have a 1.9-fold higher risk with each increasing year of age.[64] Hamstring strain injuries frequently cause a significant loss of time from competition, generally ranging from 3 to 28 days or more, depending on injury severity.[50] Reinjury rates are high and range between 13.9% and 63.3% across Australian rules football and track and field athletes.[21,50] Furthermore, those with a history of HSI have a 3.6-times higher risk of sustaining a future HSI.[55] The high incidence of recurrent HSIs may be attributable to inadequate rehabilitation or premature RTP.[17]

# Pathoanatomical Features

Skeletal muscle consists of slow (type I) and fast (type II) muscle fibers. It is believed that the hamstring muscle group has a higher percentage of type II fibers than other thigh muscles, making the muscle more susceptible to injury.[30,64] However, the actual percentage of type II fibers may vary, depending on age and other individual anatomical variations.[64] The long head of the biceps femoris muscle is the most commonly involved hamstring muscle in both first-time and recurrent injuries, being involved in 79% to 84% of HSIs.[23,86,103,106] Anatomically, an increased anterior pelvic tilt may place the hamstring muscle group in a more lengthened position and potentially increase the likelihood of an HSI.[49,64] Timmins et al[90] studied 20 recreationally active athletes with no history of HSI and 16 elite athletes with a history of a unilateral HSI and compared ultrasound (US) imaging measures of the biceps femoris muscle architecture (eg, muscle thickness, pennation angle, and fascicle length) during graded isometric contractions at 0°, 30°, and 60° of knee flexion. The researchers found (1) significantly shorter fascicle length and fascicle length relative to muscle thickness on the injured side compared to the uninjured side at all contraction intensities, and (2) significantly greater pennation angle on the injured biceps femoris compared to the uninjured side at all contraction intensities.[90]

## SUMMARY

Most HSIs occur in the long head of the biceps femoris. Evidence suggests that muscle architecture (eg, higher pennation angle and shorter fascicle length) may contribute to an HSI.

# Risk Factors

Risk factors for acute HSI are categorized as being nonmodifiable or modifiable. Nonmodifiable factors describe characteristics of an individual that cannot be changed, such as history of previous HSI and age. Modifiable factors are factors that can be altered, such as muscle characteristics, muscle performance, and performance characteristics.[38,98,100]

## NONMODIFIABLE RISK FACTORS

### Previous Injury

Systematic reviews have consistently identified previous injury as a risk factor for a subsequent HSI.[34,38,73] Studies within these reviews reported a 2- to 6-times higher rate of recurrence following a previous HSI.[27,35] A prospective study not included in these reviews found that male sprinters with a prior HSI had a significantly higher injury rate than those who had never sustained an HSI (odds ratio [OR] = 2.85, $P<.05$).[91] A recent HSI (within 8 weeks) was found to place individuals at greater risk for injury when compared to those with a nonrecent injury (OR = 13.1; 95% CI: 11.5, 14.9 versus OR = 3.5; 95% CI: 3.2, 3.9).[69] Also, Green et al[38] reported the risk of recurrent HSI to be greatest during the same season (relative risk [RR] = 4.8; 95% CI: 3.5, 6.6). Green et al[38] also reported a history of anterior cruciate ligament injury (RR = 1.7; 95% CI: 1.2, 2.4) and calf strain (RR = 1.5; 95% CI: 1.3, 1.7), as well as other knee injuries and ankle ligament sprains, to be risk factors for an HSI. A history of a quadriceps strain and chronic groin pathology were not identified as risk factors.[38]

### Physical Characteristics

Systematic reviews have identified increasing age to be a significant risk factor for HSI.[34,38,73] One study included in these reviews found that athletes older than 23 years of age were at greater risk than those 23 years of age or younger (RR = 1.34; 95% CI: 1.14, 1.57).[68] Another study found that Australian rules football athletes older than 25 years of age were at greater risk than those 25 years of age or younger (RR = 4.43; 95% CI: 1.57, 12.52).[35] While systematic reviews have found height[34,73] and preferred kicking leg[34] not to be risk factors, ethnicity represented a risk factor in African-American athletes and Aboriginal Australian rules footballers.[73]

## MODIFIABLE RISK FACTORS

### Weight and Body Mass Index

Findings from systematic reviews do not support weight or body mass index as risk factors for HSIs.[34,73]

### Muscle Characteristics

Findings from systematic reviews and meta-analyses found no relationship between hamstring flexibility and HSI.[34,38,73] In addition, Green et al[38] found no relationship between HSIs and passive knee extension ROM, active knee extension (AKE) ROM, passive straight leg raise (SLR), and slump tests. While flexibility does not play a role, lower-level studies suggest that biceps femoris fascicle length and hamstring muscle-tendon unit stiffness are related to HSIs.[38] Green et al[38] also found conflicting evidence regarding the effect of hip flexor tightness and limited ankle dorsiflexion ROM on HSIs.

### Muscle Performance

Green et al[38] reported limited evidence for hamstring weakness as a risk factor for HSI, a finding potentially influenced by the method and timing of measurement. They included a summary of previously published meta-analyses and noted no association between HSI and reduced knee flexor strength measured during the Nordic hamstring exercise (NHE) or with isokinetic testing.[38] Similar findings were noted by Opar et al[63] in their meta-analysis. The meta-analysis by Freckleton and Pizzari[34] identified increased peak quadriceps torque as a risk factor for HSIs. Conflicting results from systematic reviews existed when examining hamstring-to-quadriceps strength imbalances as a risk factor for HSI.[34,73] Study findings did not seem to be related to measurement, speed, or type of muscle contraction.[34,73] Based on lower-level studies, Green et al[38] found altered trunk and gluteus muscle activity and abnormal motor control to be potential risk factors for HSI.[38]

### Performance Characteristics

The meta-analysis by Green et al[38] found that increased positional high-speed running demands were a risk factor for HSIs, with moderate to strong evidence in soccer, American football, and rugby and lower levels of evidence in Gaelic football and cricket. Athletes with rapid increases in high-speed running exposure may be especially at risk. Findings from lower-level studies showed that sprinting characteristics, with increased anterior pelvic tilting and thoracic spine sidebending during the backswing, were also associated with HSIs. Within this meta-analysis, 1 study found a higher proportion (68%, $P<.001$) of HSIs sustained during running activities and more severe injuries during kicking.[8] Systematic reviews have included lower levels of evidence for predicting HSI using performance measures, such as the single-leg hop for distance and the jumping percentage difference between noncountermovement and countermovement jumping.[34,38] Freckleton and Piz-

zari[34] examined a variety of sports and found that workload, with time spent in games versus practice, as well as frequency of off-season running were not risk factors for HSI.

## SUMMARY

Previous HSI, age greater than 23 years, anterior cruciate ligament injuries, calf strains, and other knee and ankle ligament injuries represent nonmodifiable risk factors for HSI. Hamstring fascicle length and stiffness, but not flexibility, are modifiable risk factors. High-speed running demands with abnormal trunk and pelvic posture and motor control may be risk factors for HSI. However, further research is needed to better define performance characteristics, such as hamstring weakness, that might be risk factors.

# Clinical Course

An HSI can occur anywhere along the length of the muscle, but occurs most frequently in the proximal biceps femoris at the musculotendinous junction.[14] At the time of injury, an individual experiences a sudden, sharp pain in the posterior thigh. Additionally, an audible or palpable popping sensation[39] often occurs during an activity that overloads and/or overstretches the hamstring muscle.[2,4] The individual may stop the event or activity due to the pain and limited function. The recurrence rate of HSI ranges between 13.9% and 63.3% when followed over the same and subsequent seasons.[21] Also, injuries with more extensive myofascial damage extending into the tendon are more prone to reinjury and delayed RTP.[72]

The clinical course of an HSI depends on the extent and nature of the muscle damage. In mild injuries, only the myofibrils are damaged.[2] With greater injury severity, the extreme tensile and shear forces result in additional fascia, basal lamina, and blood vessel tearing.[49] Release of muscle enzymes, creatine kinase, and collagen, with proteoglycan degradation and inflammation, occurs following the injury. Blood vessel damage results in bleeding and clotting.[49] The most common type of HSI occurs within the biceps femoris, where the myofibers attach to the intramuscular fascia.[13,53,102]

The healing process includes 3 phases: inflammation, proliferation, and remodeling.[49] The inflammation phase occurs immediately after HSI and lasts approximately 3 to 5 days.[53] Vasodilation and increased capillary permeability during this phase cause fluid stasis, resulting in an ischemic local environment, causing further muscle damage and edema. Two to 4 days after injury, phagocytic cells enter the damaged area to activate local undifferentiated ("stem") cells that begin rebuilding the collagen and vascular infrastructure (eg, fibroblasts and endothelial cells).[53] Clinically, pain, swelling, bleeding, and loss of ROM typically characterize this phase.

The proliferation phase may overlap to varying degrees with the inflammation phase and last up to several weeks. During this phase, satellite cells contribute to repair damaged myofibers[61] as collagen and vascular infrastructures are rebuilt. At this time, individuals often experience muscle weakness, stiffness, swelling, and limited function.[109] Suboptimal outcomes occur when these symptoms and signs continue for an extended period.[53]

Depending on the extent of the HSI, the remodeling phase can continue for up to 2 years. This phase is characterized by final collagen formation, allowing for support to the injury site. A properly aligned extracellular matrix is required to maintain optimal myofibril orientation. With an intact or repaired basal lamina acting as a scaffold, myofibrils can regenerate. Early ROM and soft tissue mobilization after injury may help promote more organized scar formation, with fewer adhesions to surrounding tissue. As the remodeling phase progresses, the individual will have minimal complaints and can tolerate greater stress to the muscle.[53]

## SUMMARY

The normal healing process of an HSI is similar to other biological tissues and progresses through stages of inflammation, proliferation, and remodeling. The remodeling phase can last up to 2 years. Early hip and knee ROM may contribute to less disorganized scar formation and a lower reinjury rate.

# Return to Play and Reinjury Risk

## OVERVIEW

The high rates of recurrent HSIs are associated with substantial losses of time in training and competition for athletes and large costs to professional sports organizations. Optimizing reinjury risk assessment and RTP decision making is a high priority for all stakeholders. The importance of determining when the athlete can safely RTP while minimizing risk of reinjury remains high, especially following severe HSI that usually requires a longer recovery.

I In a meta-analysis that included 71 324 athletes, a previous HSI was a risk factor for future injury (RR = 2.7; 95% CI: 2.4, 3.1).[38] Multiple systematic reviews[31,34,95] and additional studies not included in these reviews supported this finding.[12,66] In Australian rules football players (n = 1932), those with a recent HSI (within 8 weeks) were at higher risk (OR = 13.1; 95% CI: 11.5, 14.9) for reinjury compared to those with a nonrecent injury (greater than 8 weeks) (OR = 3.5; 95% CI: 3.2, 3.9).[69] Green et al[38] noted that the risk of recurrent HSI was greatest during the same season (RR = 4.8; 95% CI: 3.5, 6.6).

II The systematic review by de Visser et al[21] noted a lower risk of hamstring strain reinjury when individuals performed agility and stabilization exercises after injury, compared to only stretching and strengthening exercises (7.7% versus 70%, respectively). In 48 semiprofessional soccer players, Mendiguchia et al[60] found that a comprehensive impairment-based treatment program reduced the risk of reinjury compared to a standard NHE program (RR = 6; 90% CI: 1, 35).

II A systematic review by Hickey et al[45] recommended a combination of clinical assessment (manual muscle testing, ROM, palpation), performance (sprinting, agility, hopping, sport-specific movements), and isokinetic dynamometry tests to inform RTP decision making. Four studies included in the Hickey et al[45] review used RTP criteria, based on a combination of clinical assessment and performance tests, and reported mean RTP times of 23 to 45 days and reinjury rates between 9.1% and 63.3%.[45] Two studies that implemented the Askling H-test as part of the decision-making criteria reported mean RTP times of 36 and 63 days, with reinjury rates of 1.3% and 3.6%.[45] The most practical findings were noted in 3 studies that used isokinetic dynamometry, in addition to clinical assessment and performance tests, with reported mean RTP times of 12 to 25 days and reinjury rates between 6.25% and 13.9%.[45] In their systematic review, Schut et al[84] found limited evidence for initial findings of visible bruising, muscle pain during everyday activities, a popping sound at injury, being forced to stop play within 5 minutes, width of palpation pain, pain on trunk flexion, and pain on active knee flexion in predicting RTP times. They also found limited evidence to support an association between RTP times and an individual's height and weight.[84]

II At the time of physical therapist initial evaluation, a combination of 3 demographic and 6 clinical variables explained 50% of the variance (±19 days) in predicting the time to RTP after grade I or II HSI.[48] However, a combination of clinical and demographic variables, obtained on physical therapy assessment 7 days after the initial evaluation, explained 97% of the variance (±5 days) in predicting time to RTP. In order of importance, the following variables were most predictive for RTP: (1) change in strength during the first week for the "mid-range" test, (2) peak isokinetic knee flexion torque of the uninjured leg at day 1, (3) pain level at the time of injury, (4) days to walk pain free, (5) playing soccer, (6) "inner-range" hamstring strength at day 1, (7) the presence or absence of pain on a single-leg bridge at day 7, (8) delay in starting physical therapy, and (9) percentage of strength in the "outer-range" test compared to the healthy leg.[48]

II Cross et al[15] found no between-sex differences in the RTP time for first-time (median: men, 7.0 days; women, 6.0 days; $P = .07$) or recurrent (median: men, 11 days; women, 5.5 days; $P = .06$) HSIs. However, they reported that male soccer players had higher rates of reinjury compared to female players (men, 22%; women, 12%; $P = .003$).[15] Similarly, Schut et al[84] noted no association between RTP times and sex or previous HSI sustained within the last 12 months. Related to characteristics of sport and time to RTP, moderate evidence showed no association between the level of sport activity or the intensity of sport activity performed (3 or fewer times per week or more than 3 times per week).[84] Conflicting evidence existed for type of sport and time to RTP from injury.[84]

II Two lesser-quality randomized controlled trials (RCTs) identified in a meta-analysis found a significant reduction in time to RTP (hazard ratio [HR] = 3.22; 95% CI: 2.17, 4.77) when eccentric exercises were added to a conventional stretching, strengthening, and stabilization program after HSI.[70]

II Hamstring strain injuries categorized by deficits in AKE ROM with the hip flexed demonstrated longer bouts of rehabilitation as the ROM deficit increased. Grade I injuries had less than a 15° ROM deficit and required 25.9 days of rehabilitation. Grade II injuries had a 16° to 25° ROM deficit and required 30.7 days of rehabilitation, while grade III injuries had a 26° to 35° ROM deficit and required 75.0 days of rehabilitation.[86] Normalization of isokinetic strength was not required to successfully complete a soccer-specific rehabilitation program.[92]

IV The length of the area of tenderness measured on initial evaluation ($R^2$ = 0.58, $P$<.001), area of tenderness ($R^2$ = 0.36, $P$ = .006), and age ($R^2$ = 0.27, $P$ = .024) were significant predictors for RTP, while width of tenderness ($R^2$ = 0.006, $P$ = .75) and location of injury were not (proximal/distal $P$ = .62, medial/lateral $P$ = .64).[82] Combining the individual's age with length of injury into a multiple regression analysis improved the prediction of RTP ($R^2$ = 0.73, $P$<.001).[82]

IV A systematic review by Fournier-Farley et al[32] identified lower levels of evidence for the following risk factors: (1) stretching-type injuries, (2) recreational-level sport participant, (3) structural injuries (macroscopic muscle fiber damage), (4) a greater than 20° to 25° deficit of AKE, (5) a greater than 1-week time to first treatment consultation, (6) higher maximal pain score on a 0-to-10 visual analog scale, and (7) greater than 1 day to walk pain free after HSI. When specifically looking at criteria for RTP decisions, a systematic review by van der Horst et al[97] found a wide variety of function-related criteria, none of which have been validated.

### GAPS IN KNOWLEDGE

Despite some evidence, additional studies are needed to accurately predict the clinical course as well as identify factors that predict time to RTP and risk for reinjury. An important limitation in this area is lack of consistency, reliability, and validity in defining RTP.

### EVIDENCE SYNTHESIS AND RATIONALE

The CPG teams found the best evidence of a risk factor for reinjury to be the history of HSI, with those having sustained a more recent injury being at higher risk. Therefore, RTP decisions should consider a previous HSI. Moderate evidence supports the absence of an appropriately progressed, comprehensive impairment-based functional exercise program as a risk factor for reinjury. Moderate evidence also identifies rehabilitation programs that do not specifically include eccentric training as a risk factor for reinjury and delayed RTP. An objective assessment with a criterion-based functional exercise progression may allow injured athletes to effectively RTP in a time-sensitive manner, while minimizing the risk of reinjury. Allowing athletes to RTP before they are ready increases the risk of reinjury.

### RECOMMENDATIONS

B Clinicians should use the history of an HSI when implementing RTP progression, as a previous HSI is a risk factor for a future reinjury.

B Clinicians should use caution in RTP decisions for individuals who did not complete an appropriately progressed, comprehensive impairment-based functional exercise program that specifically included eccentric training.

B Clinicians should use hamstring strength, pain level at the time of injury, number of days from injury to pain-free walking, and area of tenderness measured at initial evaluation to estimate time to RTP.

# Diagnosis/Classification

### OVERVIEW

Early and accurate clinical diagnosis of an HSI is important for providing appropriate treatment, deciding on RTP, and preventing reinjury. Because HSIs are typically diagnosed and graded based on physical findings, clinicians should recognize both the clinical features and signs and symptoms associated with the different injury grades of HSI. It should be noted that detailed classification systems using diagnostic imaging have been described but are outside the scope of this CPG.

II In 83 Australian rules football athletes with posterior thigh pain, Verrall et al[103] found the clinical features of an HSI (n = 68) to be a sudden onset of pain, an injury associated with running/acceleration, posterior thigh tenderness, and pain on resisted hamstring muscle contraction. The report of a sudden onset of pain (91%) was the most useful finding.[103]

II In a prospective cohort of 180 male athletes, Schneider-Kolsky et al[83] found that clinical examination ($r$ = 0.69, $P$<.001) and magnetic resonance imaging (MRI) ($r$ = 0.58, $P$<.001) were associated with time to RTP in 58 Australian rules football athletes. Wangensteen et al[104,105] found that the addition of MRI to clinical examination alone explained only an additional 2.8% of the variance in time to RTP.

IV Zeren and Oztekin[111] defined the taking-off-the-shoe test for grade I and II biceps femoris injuries (n = 140) and found it to be 100% accurate compared to US diagnosis.

## GAPS IN KNOWLEDGE

Although a clinical examination represents the gold standard for diagnosing an HSI, evidence to define the accuracy of this examination is limited. A clinical examination traditionally describes an HSI as grade I, II, or III, representing severity ranging from mild muscle damage without loss of structural integrity to complete muscle tearing with fiber disruption. The following criteria are used to identify each grade of injury.[1,86,110]

### Grade I (Mild Strain)

1. Microtearing of a few muscle fibers
2. Local pain of smaller dimensions
3. Tightness and possible cramping in the posterior thigh
4. Slight pain with muscle stretching and/or activation
5. Stiffness that may subside during activity but returns following activity
6. Minimal strength loss
7. Less than a 15° deficit with the AKE test

### Grade II (Moderate Strain)

1. Moderate tearing of muscle fibers, but the muscle is still intact
2. Local pain covering a larger area than in a grade I strain
3. Greater pain with muscle stretching and/or activation
4. Stiffness, weakness, and possible hemorrhaging and bruising
5. Limited ability to walk, especially for 24 to 48 hours after injury
6. A 16° to 25° deficit with the AKE test

### Grade III (Severe Strain)

1. Complete tear of the muscle
2. Diffuse swelling and bleeding
3. A possible palpable mass of muscle tissue at the tear site
4. Extreme difficulty or inability to walk
5. A 26° to 35° deficit with the AKE test

The CPG team believes that clinicians practicing in a direct-access model should refer individuals with suspected grade III injuries to a physician.

While the above grading criteria are commonly used as part of the clinical examination, research is needed to support their reliability and validity. Also, these criteria do not consider the exact location of the injury, which can be identified with MRI and US imaging.

## EVIDENCE SYNTHESIS AND RATIONALE

Although evidence for the use of clinical examination to diagnose an HSI is limited, an individual with an acute injury typically presents with a sudden onset of well-localized posterior thigh pain, muscle tenderness, and loss of function. The mechanism of injury is commonly related to an overloading and/or overstretching of the hamstring muscle group. The injury may be associated with a popping and/or tearing sensation and result in localized ecchymosis. Hamstring group stretching and/or activation may reproduce the pain. However, these symptoms may be absent in some individuals with complete tears. When the area of maximal tenderness is at either the origin or insertion of the hamstring muscle group, tendon pathology should be considered as part of the differential diagnosis. When direct trauma to the posterior thigh is the mechanism of injury, the clinician should consider a different diagnosis, such as a contusion. Although it can occur on rare occasions in those with an HSI, an insidious onset of vague posterior symptoms should raise concerns for referred pain from the lumbar spine. The benefits of properly diagnosing an HSI would allow for appropriate injury management, including RTP decisions and injury prevention measures. The harms of not appropriately recognizing the clinical features of an HSI could result in further injury or reinjury if the individual is not removed from athletic participation.

## RECOMMENDATION

B Clinicians should make a diagnosis of HSI when an individual presents with a sudden onset of posterior thigh pain during activity, pain reproduced with hamstring stretching and/or activation, muscle tenderness with palpation, and loss of function.

## DIFFERENTIAL DIAGNOSIS

The differential diagnosis for those with primarily proximal or distal posterior thigh symptoms may need to include hip and knee pathologies, as well as isolated tendon lesions, apophysitis, and avulsion fractures. Specifically, for those with posterior thigh symptoms, differential diagnosis includes the following[52]:

- Lumbar radiculopathy

- Sacroiliac dysfunction
- Deep gluteal syndrome with nerve entrapment
- Ischial tunnel syndrome
- Adductor muscle strain
- Contusion
- Compartment syndrome
- Thrombosis

### Imaging

Imaging is typically not needed in those diagnosed with a grade I or II HSI, based on clinical examination. This may be especially true in those with less severe injuries, as studies have found that they may not be identifiable on MRI.[24,83] Magnetic resonance imaging assessment is recommended in those with a suspected grade III HSI.[67] Detailed systems to classify HSIs based on MRI findings are available, such as the British Athletics Muscle Injury Classification,[71] the modified Peetrons classification,[23] and the anatomically based system described by Chan et al.[9] However, the role of MRI in helping to determine the clinical course, including RTP and risk of reinjuries, is unclear. Evidence suggests that the addition of MRI does not improve the prediction of RTP beyond clinical examination.[83,105] However, with suspicion of a nonmusculoskeletal pain source, such as a thrombosis, imaging may be indicated. While the American College of Radiology Appropriateness Criteria do not specifically outline guidelines for those with an HSI, the criteria for chronic hip pain note that MRI and US are "usually appropriate" in those with chronic symptoms and suspected extra-articular noninfectious soft tissue abnormalities (www.acr.org/). Therefore, MRI or US imaging can be useful in decision making in individuals with an atypical presentation of symptoms or who do not have satisfactory results with nonsurgical care. Radiographs are usually not required, unless the symptoms are proximal and radiographs may be useful to rule out avulsion fractures.

# Examination

## PHYSICAL IMPAIRMENT MEASURES

### Overview

Activities that involve eccentric overloading of the hamstring muscles in a lengthened position are not only associated with HSI, but may also remain impaired after injury. Examples include high-speed running, jumping, kicking, and/or other explosive lower extremity movements. These activities are integral to sports such as track and field, soccer, Australian rules football, American football, and rugby. Therefore, a physical examination should include measures of hamstring-related impairments (strength and muscle length) and direct and self-reported assessments of sport-specific activities. An assessment of potential risk factors that may have contributed to injury also may be appropriate (**TABLES 4** though **10**).

### Gaps in Knowledge

Individuals with an HSI present with knee flexor weakness, hamstring tightness, and muscle tenderness. However, the best method for assessing hamstring muscle strength (eg, isometric, eccentric, or isokinetic) and the clinical interpretation of strength deficits remain undetermined. Future studies also should examine the reliability of measures other than using an inclinometer to assess hamstring muscle length with the hip flexed to 90°. Mapping hamstring muscle tenderness is a valuable component of a clinical examination, but more evidence is needed to define its usefulness in HSI management. While abnormal trunk and pelvic posture and control during movements may be risk factors for an initial HSI,[38,49,64] further evidence is needed to support the usefulness of assessing these impairments over the course of treatment.

### Evidence Synthesis and Rationale

There is strong evidence for strength and ROM measures after HSI. Current evidence suggests good reliability for measures of knee flexor weakness following HSI with isometric, isokinetic, and eccentric contractions, using a handheld dynamometer (HHD) or isokinetic dynamometer, as well as for hamstring muscle length (hip flexed to 90° and SLR methods) using an inclinometer. The degree of knee extension deficit measured with the hip flexed to 90° is potentially useful for grading the severity of injury. Weak evidence exists for mapping the location and area of muscle tenderness. Percentage length of tenderness and age are predictors of days to RTP; athletes with more proximal pain had a longer time to RTP. Proper assessment of knee flexor strength, hamstring flexibility, and muscle tenderness may be used in conjunction with a criterion-based functional activity progression. This approach allows injured athletes to effectively RTP in a time-sensitive manner, while minimizing the risk of reinjury. A harm of inadequate injury assessment is allowing the athlete to return to sport, which may put the athlete at risk for reinjury.

**TABLE 4** ISOMETRIC KNEE FLEXOR MUSCLE STRENGTH

| | |
|---|---|
| ICF category | Measurement of impairment of body function, power of isolated muscles and muscle groups |
| Description | Resistive measures of knee flexion strength with an isometric muscle contraction |
| Measurement method | While positioned in prone or supine, the individual performs an isometric knee flexion contraction against an HHD that is placed on the posterior aspect of the distal tibia. The highest force of 3 trials is recorded for each position. Pain level during the test can be recorded using a visual analog scale. The hip and knee positions may be altered to affect the length of the hamstring muscle group<br>Specific testing positions include:<br>• Inner range: strength is measured with the individual positioned in prone, with the knee in 90° of flexion. The athlete gradually builds up force to a maximum generated knee flexor force, against an HHD, that creates a "make" force[107]<br>• Midrange: strength is measured in prone, with the knee extended and the dorsum of the foot on the table. The therapist passively lifts the leg off the table to a height equal to the distance of the foot length. The individual pushes up against the HHD for 3 seconds. The examiner applies a "break" force once peak force is achieved[107]<br>• Outer range: strength is measured with the individual supine, with the hip and knee in 90° of flexion. The individual pushes against the HHD for 3 seconds. The examiner applies a "break" force once peak force is achieved[107]<br>• 15° of knee flexion: strength is measured with the individual positioned in prone, with the knee in 15° of flexion. The individual gradually builds up force to a maximum generated knee flexor force, against an HHD, that creates a "make" force[75] |
| Nature of variable | Continuous |
| Unit of measurement | Kilograms or Newtons |
| Measurement properties (reliability) | |
| Inner range | Intrarater[107]<br>• $ICC_{3,1}$ = 0.87; 95% CI: 0.84, 0.89; SEM, 1.78 kg; $MDC_{95}$, 4.9 kg<br>Interrater<br>• $ICC_{1,1}$ = 0.71; 95% CI: 0.62, 0.82; SEM, 26 N[75]<br>• $ICC_{2,1}$ = 0.69; 95% CI: 0.45, 0.83; SEM, 2.01 kg; $MDC_{95}$, 5.6 kg[107] |
| Midrange | Intrarater[107]<br>• $ICC_{3,1}$ = 0.89; 95% CI: 0.87, 0.90; SEM, 2.02 kg; $MDC_{95}$, 5.6 kg<br>Interrater[107]<br>• $ICC_{2,1}$ = 0.83; 95% CI: 0.68, 0.90; SEM, 1.05 kg; $MDC_{95}$, 4.1 kg |
| Outer range | Intrarater[107]<br>• $ICC_{3,1}$ = 0.90; 95% CI: 0.88, 0.92; SEM, 2.19 kg; $MDC_{95}$, 6.1 kg<br>Interrater[107]<br>• $ICC_{2,1}$ = 0.79; 95% CI: 0.62, 0.88; SEM, 2.17 kg; $MDC_{95}$, 6.0 kg |
| 15° of knee flexion | Interrater[75]<br>• $ICC_{1,1}$ = 0.83; 95% CI: 0.73, 0.90; SEM, 29 N |
| Measurement properties (validity) | Isometric strength deficits, when assessed less than 7 days post injury, were found in the injured limbs compared to the noninjured side (effect size, −1.72; 95% CI: −3.43, 0.00)[57]<br>Deficits in knee flexor strength were noted between the previously injured limb and the contralateral noninjured limb for mean force with an isometric contraction (effect size at 0°/0°, *d* = −1.06; 90% CI: −1.93, −0.19 and at 45°/45°, *d* = −0.88; 90% CI: −1.74, −0.02)[43]<br>Individuals with HSI generated significantly less isometric knee flexor force than those without HSI. Mean difference between groups: peak torque, −44.8 N; 95% CI: −86.3, −3 N; normalized, −22.2 Nm; 95% CI: −40.5, −3.7 Nm; normalized to body weight, −0.2; 95% CI: −0.4, 0.0[10] |

*Abbreviations: CI, confidence interval; HHD, handheld dynamometer; HSI, hamstring strain injury; ICC, intraclass correlation coefficient; ICF, International Classification of Functioning, Disability and Health; MDC, minimal detectable change; SEM, standard error of measurement.*

## Recommendations

**A** Clinicians should quantify knee flexor strength following HSI by using either an HHD or an isokinetic dynamometer.

**A** Clinicians should use an inclinometer to assess hamstring length by measuring knee extension deficit with the hip flexed to 90°.

**C** Clinicians may use the length of muscle tenderness and proximity to the ischial tuberosity to assist in predicting timing of RTP.

**F** Clinicians may assess for abnormal trunk and pelvic posture and control during functional movements.

**TABLE 5** ISOKINETIC KNEE EXTENSOR AND FLEXOR MUSCLE STRENGTH

| | |
|---|---|
| ICF category | Measurement of impairment of body function, power of isolated muscles and muscle groups |
| Description | Resistive measures of the strength of the knee extensors and flexors, using an isokinetic dynamometer |
| Measurement method | The individual is seated, with the hip and knee flexed to 90°. The distal tibia is fixed with a cuff attached to a load cell just proximal to the malleoli. Straps are used to secure the thigh just proximal to the knee. After a brief warm-up, the individual exerts a maximal contraction through an arc of motion for both knee extension and flexion at selected speeds |
| Nature of variable | Continuous |
| Unit of measurement | Newton meters, foot-pounds, or the H/Q ratio |
| Measurement properties (reliability) | Intratester (noninjured individuals)[54]<br>• $ICC_{2,1}$ = 0.82 for eccentric contractions; SEM, 2.84 Nm; MDC, 7.87 Nm |
| Measurement properties (validity) | Individuals with an HSI generated significantly less knee flexor force than controls at speeds of 60°/s ($P$<.0013) and 180°/s ($P$<.0036). When comparing knee flexor strength between the uninjured (within the previous 12 months) and injured sides, injured-side knee flexors were weaker at 60°/s during concentric ($P$<.038) and eccentric ($P$<.03) contractions. They were also weaker with eccentric contractions at 180°/s ($P$<.038)[65]<br>A between-limb eccentric knee flexor muscle strength imbalance of greater than 15% to 20% was associated with an increased risk of HSI by 2.4 times (95% CI: 1.1, 5.5) and 3.4 times (95% CI: 1.5, 7.6), respectively[7]<br>At 60°/s, individuals with HSI showed eccentric hamstring-to-concentric quadriceps asymmetry, with imbalances of H/Q ratios less than 0.60 being able to best identify those with a previous HSI[20]<br>Concentric isokinetic testing at 60°/s showed a difference in injured versus noninjured knee flexor strength, with an area under the receiver operating characteristic curve of 0.773 ($P$<.05). No significant differences were noted at 120°/s[46]<br>Isokinetic quadriceps-hamstring strength ratios (concentric and eccentric) were not predictive of HSI[19]<br>At 60°/s, individuals with an HSI demonstrated a 9.6% deficit in peak torque and a 6.4% deficit in work, compared to the uninjured side, at the time of RTP[81]<br>Injured individuals also generated significantly less peak torque and work than the contralateral side when tested at 240°/s. The H/Q ratio (eccentric, 30°/s and concentric, 240°/s) revealed that the injured limb had a lower ratio than the uninjured limb[81]<br>Individuals with prior HSI demonstrated significantly lower eccentric strength (at 25° to 5° of knee flexion, 81.2 Nm/kg versus 75.2 Nm/kg; $P$<.025)[87]<br>Greater peak quadriceps concentric torque, adjusted for body weight, at 300°/s (greater than 1 SD above the mean, 2.2-3.7 Nm/kg) was identified as a risk factor for injury (HR = 2.06; 95% CI: 1.21, 3.51)[99]<br>A significant small effect for a lower conventional H/Q ratio was found in previously injured legs compared to the uninjured contralateral legs at 60°/s:60°/s (effect size, −0.32; 95% CI: −0.54, −0.11) and 240°/s:240°/s (effect size, −0.43; 95% CI: −0.83, 0.03), but not 180°/s:180°/s or 300°/s:300°/s[57] |

*Abbreviations: CI, confidence interval; H/Q, hamstring-quadriceps; HR, hazard ratio; HSI, hamstring strain injury; ICC, intraclass correlation coefficient; ICF, International Classification of Functioning, Disability and Health; MDC, minimal detectable change; RTP, return to play; SEM, standard error of measurement.*

## ACTIVITY LIMITATION AND PARTICIPATION RESTRICTION

II Hickey et al[45] provided general guidelines for assessing activity limitations that include a progression sequence of pain-free walking, pain-free normal jogging, running at 70% perceived maximum speed, pain-free change of direction, and pain-free 100% running speed.

II Røksund et al[79] established excellent reliability (intraclass correlation coefficient [ICC] = 0.978; 95% CI: 0.96, 0.98; standard error of measurement [SEM], 0.008 seconds; minimal detectable change $[MDC]_{95}$, 0.022 seconds) for the repeated sprint test in 75 semiprofessional and professional soccer players (19 ± 3 years of age). Athletes with a previous HSI showed a significant decrease in speed with repeated sprinting (0.07 seconds versus 0.02 seconds, $P$ = .007).[79]

III Ishøi et al[47] found that 11 soccer players with a prior history of an HSI had a higher mean maximal sprinting velocity when compared to 33 controls (mean difference, 0.45 m/s; 95% CI: 0.06, 0.85 m/s).

### Gaps in Knowledge

Information is needed to allow clinicians to select and interpret scores from measures of activity and participation in those with HSI. Because athletes make up the population that typically sustains an HSI, evidence to support the validity, reliability, and responsiveness of sport-related functional activities, including high-speed running, jumping, kicking, and/or explosive lower extremity movements, would be useful.

### Evidence Synthesis and Rationale

Limited evidence exists regarding the most appropriate activity and participation measures that should be used to docu-

**TABLE 6** NORDIC ECCENTRIC KNEE FLEXOR MUSCLE STRENGTH TEST

| | |
|---|---|
| ICF category | Measurement of impairment of body function, power of isolated muscles and muscle groups |
| Description | Resistive measure of eccentric knee flexor strength |
| Measurement method | The individual is positioned in a tall kneeling position, with the arms across the chest and both ankles firmly secured to a load-cell instrumented device. The athlete performs a Nordic hamstring test by slowly lowering the trunk toward the floor, keeping the spine and hips in neutral |
| Nature of variable | Continuous |
| Unit of measurement | Kilograms or Newtons |
| Measurement properties (reliability) | |
| Intertester (noninjured individuals) | Left and right sides pooled[62]<br>• $ICC_{95}$ = 0.87-0.92; $MDC_{95}$, 55.6 N<br>Same day[22]<br>• ICC = 0.60; 95% CI: 0.38, 0.75 (left leg)<br>• ICC = 0.62; 95% CI: 0.41, 0.76 (right leg)<br>1 wk apart[22]<br>• ICC = 0.67; 95% CI: 0.38, 0.84 (left leg)<br>• ICC = 0.76; 95% CI: 0.53, 0.89 (right leg) |

*Abbreviations: CI, confidence interval; ICC, intraclass correlation coefficient; ICF, International Classification of Functioning, Disability and Health; MDC, minimal detectable change.*

**TABLE 7** KNEE FLEXOR MUSCLE STRENGTH: SINGLE-LEG BRIDGE TEST

| | |
|---|---|
| ICF category | Measurement of impairment of body function, power of isolated muscles and muscle groups |
| Description | Resistive measure of concentric knee flexor strength |
| Measurement method | The individual lies down on the ground, with one heel on a box measuring 60 cm high. The test leg is positioned in 20° of flexion. The individual crosses the arms over the chest and pushes down through the heel to lift the buttocks off the ground, with as many repetitions as possible until failure |
| Nature of variable | Continuous |
| Unit of measurement | Number of repetitions fully completed |
| Measurement properties (validity) | In 482 athletes tested prospectively, 28 developed an HSI. Those with a right HSI had a significantly lower mean right single-leg bridge test score ($P$ = .029)[33] |

*Abbreviations: HSI, hamstring strain injury; ICF, International Classification of Functioning, Disability and Health.*

ment progress over the course of treatment. Because injuries often occur with high-speed running, combined with the fact that gait, running, and change in direction/cutting movements are typically impaired after an HSI, it would seem appropriate that objective measures of activity and participation should include these activities in sport-specific task analysis.

### Recommendation

**B** Clinicians should include objective measures of an individual's ability to walk, run, and sprint when documenting changes in activity and participation over the course of treatment.

## OUTCOME MEASURES

**I** The Functional Assessment Scale for Acute Hamstring Injuries (FASH) is a reliable and valid 10-item questionnaire used to assess function after an acute HSI. The FASH has excellent test-retest reliability (ICC = 0.9), internal consistency (Cronbach's $\alpha$ = .98), and responsiveness (3.8 and 5.32 using baseline and pooled SDs). The FASH also has established face validity, content validity, and construct validity (eg, its ability to discriminate between acute HSI and noninjured hamstrings).[56]

**II** The hamstring outcome score (HaOS) is a 5-domain questionnaire that assesses an athlete's soreness, symptoms, pain, activities (sports), and quality of life. Questions on the HaOS are scored 0 to 4, from no complaints to maximum complaints. A score of 100% suggests no complaints in all domains. A score of 80% or more indicates a low risk for HSI, while below 80% indicates a high risk for HSI. Based on a study of 365 amateur soccer players, the scale is a predictor of new HSI in athletes with lower HaOS scores ($P$<.005).[28,96]

**TABLE 8** KNEE EXTENSION TEST FOR HAMSTRING LENGTH (HIP/KNEE: 90°/90°)

| | |
|---|---|
| ICF category | Measurement of impairment of body function, mobility of a single joint |
| Description | Measures knee flexor muscle length |
| Measurement method | The individual lies supine, with the hip and knee flexed to 90°; the knee is then maximally extended, either passively or actively, with the ankle in an open pack position. A goniometer or inclinometer can be used to measure the knee extension deficit. Comparisons are made with the uninjured side |
| Nature of variable | Continuous |
| Unit of measurement | Degrees |
| Measurement properties (reliability) | |
| Inclinometer interrater (same day) | With knee passive ROM[76]<br>• $ICC_{1,1}$ = 0.77; 95% CI: 0.63, 0.86; SEM, 7.6°; MDC, 21°<br>With knee active ROM[76]<br>• $ICC_{1,1}$ = 0.89; 95% CI: 0.81, 0.94; SEM, 5.3°; MDC, 15° |
| Measurement properties (validity) | AKE test: individuals with an HSI were categorized into grades based on the lack of full AKE compared to the uninjured side. Individuals with a grade I injury had less than a 15° deficit and required 25.9 days of rehabilitation. Those with a grade II injury exhibited a 16° to 25° deficit and required 30.7 days of rehabilitation. Athletes with a grade III injury demonstrated a 26° to 35° deficit and required 75.0 days of rehabilitation[86]<br>In those with a US-confirmed diagnosis of HSI, the AKE test found the injured limb to have a mean ± SD deficit of 12.8° ± 6.8° when compared to the uninjured side[86] |
| Modifications | Maximum hip flexion AKE assesses hamstring flexibility with the athlete positioned in maximum hip flexion<br>Intrarater reliability[107]<br>• $ICC_{3,1}$ = 0.83; 95% CI: 0.80, 0.86; SEM, 6.2°; MDC, 17.2°<br>Interrater reliability[107]<br>• $ICC_{2,1}$ = 0.96; 95% CI: 0.92, 0.98; SEM, 3.3°; MDC, 9.3° |

*Abbreviations: AKE, active knee extension; CI, confidence interval; HSI, hamstring strain injury; ICC, intraclass correlation coefficient; ICF, International Classification of Functioning, Disability and Health; MDC, minimal detectable change; ROM, range of motion; SEM, standard error of measurement; US, ultrasound.*

**TABLE 9** SLR FOR ASSESSING HAMSTRING LENGTH

| | |
|---|---|
| ICF category | Measurement of impairment of body function, mobility of a single joint |
| Description | Measures of knee flexor muscle length |
| Measurement method | The individual lies supine, with the hip and knee extended. The examiner passively flexes the hip to the individual's pain tolerance, while keeping the knee extended. A modification is to perform the maneuver and stop when the individual reports pain in the posterior thigh of 3/10 ("moderate") on a pain scale, with 0 as no pain and 10 as maximal pain |
| Nature of variable | Continuous |
| Unit of measurement | Degrees |
| Measurement properties (reliability) | |
| Inclinometer (to pain tolerance) | Intrarater[107]<br>• $ICC_{3,1}$ = 0.88; 95% CI: 0.86, 0.90; SEM, 4.7°; MDC, 13.0°<br>Interrater[107]<br>• $ICC_{2,1}$ = 0.74; 95% CI: 0.52, 0.86; SEM, 6.54°; MDC, 18.1° |
| Inclinometer (stopping point of pain rated at 3/10) | Intrarater[4]<br>• $ICC_{3,1}$ = 0.98; 95% CI: 0.95, 0.99 |
| Modification for determining RTP using an inclinometer (Askling H-test) | The clinician passively flexes the hip, with the knee extended, to the individual's tolerance. The individual then performs 3 SLRs as fast and as high as possible to the point of not sustaining reinjury. The examiner records the highest value of the 3 trials[5]<br>• $ICC_{1,1}$ = 0.96; 95% CI: 0.84, 0.99 |

*Abbreviations: CI, confidence interval; ICC, intraclass correlation coefficient; ICF, International Classification of Functioning, Disability and Health; MDC, minimal detectable change; RTP, return to play; SEM, standard error of measurement; SLR, straight leg raise.*

**TABLE 10** MUSCLE TENDERNESS

| | |
|---|---|
| ICF category | Measurement of impairment of body structure |
| Description | Assess the location of peak tenderness and the region of tenderness of the knee flexor muscles after an HSI<br>The individual lies prone on a treatment table, with the knee fully extended |
| Measurement method | The examiner palpates the muscle to identify the location of peak hamstring tenderness and measures the distance from the ischial tuberosity. Next, marks are placed at the most proximal and distal and medial and lateral points of tenderness (at the point that tenderness subsides) to establish the length and width of tenderness. The area is "mapped" by expressing the length and width of tenderness as a percentage of the posterior thigh length and width[82] |
| Nature of variable | Continuous |
| Unit of measurement | Centimeters or inches |
| Measurement properties (validity) | Percentage length of tenderness and age were the best predictors of days to RTP following HSI ($R^2$ = 0.73, $P$<.001), with the following predictive equation: [number of days before return to sport = (% length of tenderness × 2.1) + (age × 1.5) − 43.4][82]<br>Athletes who report more proximal pain have a longer time to RTP[6] |

*Abbreviations: HSI, hamstring strain injury; ICF, International Classification of Functioning, Disability and Health; RTP, return to play.*

### Evidence Synthesis and Rationale

The FASH and HaOS are the only evidence-based instruments designed to assess athletes with an HSI. While other potential instruments (eg, the Copenhagen Hip and Groin Outcome Score) are available, no evidence exists for their use in those with an HSI. Although the FASH has established reliability and validity, future works should determine the MDC and minimal clinically important difference for improved score interpretation and responsiveness. The HaOS has established construct validity for predicting HSI in athletes but does not have established reliability and is used primarily before athletic sport participation begins to identify athletes who may be susceptible to an HSI.

### Recommendation

**B** Clinicians should use the FASH before and after interventions to alleviate the impairments of body function and structure, activity limitations, and participation restrictions in those diagnosed with an acute HSI.

## INJURY PREVENTION

### Prevention of First-Time Injury

Hamstring injuries are common in sports that require high-speed running, jumping, kicking, explosive rapid changes in direction, and/or lifting objects from the ground. Prevention of a first-time HSI is important because of the considerable impairment, activity limitation, and participation restriction, including time lost from competitive sports, that may occur after injury. Prevention may be particularly important in professional sports, where HSIs can be associated with significant financial costs.[18]

**I** An umbrella review by Raya-Gonzalez et al[74] identified 8 systematic reviews and concluded that exercise prevention programs that included the NHE were effective in reducing the incidence of HSI. This included a systematic review and meta-analysis by van Dyk et al,[101] who noted that the NHE reduced HSI by 51% (RR = 0.49; 95% CI: 0.32, 0.74) in 15 studies with 8459 athletes. Also included was a systematic review by Goode et al[37] that found that the effectiveness of the NHE may be dependent on exercise compliance. A systematic review not in the umbrella review also concluded that the NHE may be effective in reducing the incidence of HSI.[80]

**I** When specifically looking at female soccer players, a systematic review by Crossley et al[16] found, in 5 studies, that exercise-based (single-component and multicomponent) strategies significantly reduced the incidence of HSIs (incidence rate ratio = 0.40; 95% CI: 0.17, 0.95). They concluded that although the evidence was not as robust in female soccer players, exercise-based strategies can reduce HSI by 40% to 60%, similar to the rate found in their male counterparts.[16]

**II** An RCT with 259 male high school soccer players found the time lost to injury to be lower in the NHE group (113.7/10000 hours) compared to the control group (1116.3/10000 hours) ($P$<.001).[40]

**III** Within the umbrella review by Raya-Gonzalez et al,[74] the systematic review by Rogan et al[78] reported inconclusive evidence in low-level studies to support the role of hamstring stretching. Hibbert et al[42] noted weak evidence for eccentric hamstring exercises other than the NHE in HSI prevention. Not included in the Raya-Gonzalez et al[74] review, a systematic review by McCall et al[59] also found weak evidence in 3 studies to support eccentric hamstring exercises other than the NHE. While evidence supports the NHE in HSI prevention, Elerian et al[26] did not find a significant difference in HSI rates between seasons when

34 soccer players performed the NHE and a season when they did not perform the NHE.

IV In 613 male collegiate sprinters followed over a period of 24 seasons by the same coach, the incidence of HSI decreased as agility and flexibility were added to strength training.[88] Results from a case series further supported the use of isokinetic strengthening exercises for reducing HSI rate.[41]

### Gaps in Knowledge

Further research is needed to specifically define the most effective prevention programs with warm-up, stretching, balance, strengthening, and functional movements, as well as potentially other eccentric hamstring exercises, that should be added to the NHE. Additionally, frequency and load progression of all preventive interventions need to be further defined. Recommendations regarding dosing of the NHE can vary, with volumes that range from 2 sets of 3 repetitions once per week to 3 sets of 10 repetitions twice a week and a gradual progression to 4 sessions per week. These exercises are generally performed after training and on days before a rest day to allow for adequate recovery.[36]

### Evidence Synthesis and Rationale

Evidence supports injury prevention exercise programs that include the NHE and other components of warm-up, stretching, stability training, strengthening, and functional movements (sport specific, agility, and high-speed running). The International Federation of Association Football (Fédération Internationale de Football Association [FIFA]) 11+, HarmoKnee, and "New Warm-up Program" are examples of specific injury prevention programs.[80] The FIFA 11+ and HarmoKnee programs include the NHE, as well as components of warm-up, stretching, stability training, strengthening, and functional movements (sport specific, agility, and high-speed running).

### Recommendation

A Clinicians should include the NHE as part of an HSI prevention program, along with other components of warm-up, stretching, stability training, strengthening, and functional movements (sport specific, agility, and high-speed running).

# Interventions

## INTERVENTION AFTER INJURY

Only studies of interventions within the scope of physical therapy that directly assessed time to RTP and reinjury rates were included in the review process. While clinicians measure intervention effectiveness in many ways (eg, strength, ROM, and pain levels), the ultimate success of the rehabilitation process is determined by the athlete's ability to RTP while preventing reinjury.

I A high-quality RCT found that individuals returning to play following a standardized progressive rehabilitation protocol, comprising hamstring-strengthening exercises and running performed within either pain-free (n = 21) or pain-threshold limits (n = 22), reported 2 reinjuries per group, with no difference in RTP time. The median time from HSI to RTP was 15 days (95% CI: 13, 17) for the pain-free group and 17 days (95% CI: 11, 24) for the pain-threshold group ($P$ = .37).[44]

II A systematic review and meta-analysis by Pas et al[70] identified 2 RCTs with fair evidence to support a program that added eccentric strengthening exercises to a conventional program of stretching, strengthening, and stabilization after an HSI. Participating in these programs resulted in a significantly reduced time to RTP (HR = 3.22; 95% CI: 2.17, 4.77) but had no effect on reinjury rate (RR = 0.25; 95% CI: 0.03, 2.20).

II A systematic review of 5 studies found that progressive agility and trunk stabilization, added to a rehabilitation program focusing on stretching and strengthening, did not improve RTP time but may decrease reinjury rate.[21] Included within this systematic review, Sherry and Best[85] specifically found a significant reduction in reinjury rates in favor of progressive agility and trunk stabilization exercises, as they found no reinjuries in 13 participants within 16 days after RTP and 1 reinjury within 1 year, versus 6 reinjuries in 11 athletes and 7 reinjuries in 10 athletes, respectively, in the static stretching, isolated progressive hamstring resistance exercise, and icing group ($P$<.001).

II Systematic reviews found insufficient evidence to support the use of stretching as an isolated treatment in the management of HSI.[21,58,70,73,77]

II An RCT (n = 48 male semiprofessional soccer players) found that an individualized criterion-based treatment program consisting of comprehensive impairment-based treatments reduced the risk of reinjury compared to a standard NHE program (RR = 6; 90% CI: 1, 35). However, there was no difference in RTP time (25.5 days versus 23.2 days, –13.8%; 90% CI: –34%, 3.4%).[60]

II A systematic review by Hickey et al[45] identified 9 studies (n = 601) that examined individuals diagnosed with an acute HSI and concluded that specific criteria for progression of rehabilitation were not well defined.

III In a case-control study that compared professional male soccer players (mean age, 24.3 years) over 2 seasons, reinjury rate was reduced from 7 of 35 to 1 of 34 in the season that the NHE was instituted.[26]

IV A study found that 50 of 54 athletes (mean age, 36 years; 30 male, 20 female) who were compliant with a rehabilitation program that emphasized eccentric hamstring strengthening in a lengthened position reported no reinjuries.[94]

IV A retrospective case series consisting of 48 consecutive HSIs in intercollegiate athletes found that early mobilization with progressive stretching and sport-related functional exercises were successful in allowing athletes to return to sport after HSI at an average of 11.9 days (range, 5-23 days), with 3 reinjuries.[51]

V It is the opinion of the CPG team that clinicians should incorporate neural tissue mobilization after injury to reduce adhesions to surrounding tissue and therapeutic modalities to control pain and swelling early in the healing process.

### Gaps in Knowledge

While evidence supports exercise in the treatment of HSI, future works should examine the benefits of other commonly used treatments, such as soft tissue mobilization, nerve glides, and therapeutic modalities. These commonly used treatments may assist in the healing process and shorten the period of disability after an HSI. Research is needed to determine the efficacy of these treatments in reducing time to RTP and decreasing reinjury rates.

### Evidence Synthesis and Rationale

Evidence supports initiating hamstring-strengthening exercises, including eccentrics, early in the rehabilitation process, guided by patient pain tolerance. Successful interventions included 6 to 12 repetitions, depending on the intensity of the exercise, with both load and ROM increased as tolerated. Patients should perform the exercises 2 to 3 times per week. The evidence behind eccentric hamstring exercises includes, but is not limited to, the NHE. Evidence also supports progressive agility and trunk stabilization exercises and a running program involving acceleration and deceleration phases, with a progressive increase in speed and distance, throughout the rehabilitation process as tolerated. The benefits of eccentric training, added to stretching, strengthening, stabilization, and progressive running programs, are improved RTP times and reduced reinjury rates. Although the harms of initiating and progressing exercise and running are poorly described, there is a potential to aggravate symptoms if the load of the activity is beyond the individual's tolerance. Potential harms may be mitigated if the clinician recognizes the primary phase of healing (inflammatory, proliferation, or remodeling) and uses a logical systematic method to begin, monitor, and progress tissue loading.

### Recommendations

B Clinicians should use eccentric training to patient tolerance, added to stretching, strengthening, stabilization, and progressive running programs, to improve RTP time after an individual sustains an HSI.

B Clinicians should use progressive agility and trunk stabilization, added to a comprehensive impairment-based treatment program with stretching, strengthening, and functional exercises, to reduce reinjury rate after an individual sustains an HSI.

F Clinicians may perform neural tissue mobilization after injury to reduce adhesions to surrounding tissue and use therapeutic modalities to control pain and swelling early in the healing process.

# Decision Tree

## MEDICAL SCREENING (CLASSIFY CONDITION AND ASSESS REINJURY RISK)

### Patient Examination

- Sudden onset of posterior thigh pain – B
- Reproduction of pain with hamstring stretching and activation – B
- Muscle tenderness with palpation – B
- Loss of function – B
- Use the following criteria to grade muscle injury – F
  - Grade I (mild strain): (1) microtearing of a few muscle fibers, (2) local pain of smaller dimensions, (3) tightness and possible cramping in the posterior thigh, (4) slight pain with muscle stretching and/or activation, (5) stiffness that may subside during activity but returns following activity, (6) minimal strength loss, and (7) less than a 15° deficit with the AKE test
  - Grade II (moderate strain): (1) moderate tearing of muscle fibers, but the muscle is still intact, (2) local pain covering a larger area than in grade I, (3) greater pain with muscle stretch and/or activation, (4) stiffness, weakness, and possible hemorrhaging and bruising, (5) limited ability to walk, especially for 24 to 48 hours after injury, and (6) a 16° to 25° deficit with the AKE test
  - Grade III (severe strain): (1) complete tear of the muscle, (2) diffuse swelling and bleeding, (3) possible palpable mass of muscle tissue at the tear site, (4) extreme difficulty or inability to walk, and (5) a 26° to 35° deficit with the AKE test
- Previous HSI – B
- Grade III HSIs are referred to a physician – F

## OUTCOME MEASURES TO DOCUMENT PROGRESS

- Knee flexor strength using either an HHD or isokinetic dynamometer – A
- Hamstring length and measuring knee extension deficit with the hip flexed to 90° using an inclinometer – A
- Measure the length of muscle tenderness to palpation and the location relative to the ischial tuberosity
- Clinicians may assess for abnormal trunk and pelvic posture and control during functional movements – F
- Objective measures to quantify and grade an individual's ability to walk, run, and sprint – B
- FASH – B

## MEASURES TO ESTIMATE TIME TO RTP

- Knee flexor strength using either an HHD or isokinetic dynamometer – B
- Pain level at the time of injury – B
- Number of days to walk pain free after injury – B
- Area of tenderness to palpation measured at initial evaluation – B

## INTERVENTION STRATEGIES

- Eccentric training to patient tolerance, added to an impairment-based treatment program with stretching, strengthening, stabilization, agility, and progressive running – B
- Nerve mobilization – F
- Therapeutic modalities for symptom management – F

## INJURY PREVENTION

- The NHE, with other components of warm-up, stretching, stability training, strengthening, and functional movements (sport specific, agility, and high-speed running) – A

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ACKNOWLEDGMENTS: *We thank the medical librarians at Augusta University for their assistance in researching the articles included in these guidelines.*

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## APPENDIX A

## SEARCH STRATEGIES AND RESULTS

### Physical Impairment Measures

All search results, n = 3610; original citations, n = 2686

### Patient-Reported Outcome Measures

All search results, n = 1433; original citations, n = 1112

*PubMed (June 7, 2020)*

| | Search Term | Result |
|---|---|---|
| 1 | "Hamstring Tendons"[Mesh] OR Biceps Femoris[tw] OR hamstring[tw] OR hamstrings[tw] OR Semimembranosus[tw] OR Semitendinosus[tw] OR thigh[tw] | 45670 |
| 2 | Myofascial pain syndromes[mh:noexp] OR soft tissue injuries[mh:noexp] OR strains[mh] OR myositis ossificans[mh] OR leg injuries[mh:noexp] OR Pain[mesh:noexp] OR Acute Pain[mesh] OR Chronic Pain[mesh] OR Musculoskeletal Pain[mesh:noexp] OR Pain[tiab] OR Painful[tw] OR Ache[tw] OR Injury[tw] OR Injuries[tw] | 1796745 |
| 3 | 1 AND 2 | 13942 |
| 4 | Hamstring strain[mesh] OR Hamstring strain[tw] OR Hamstring tear[tw] OR Torn Hamstring[tw] OR Hamstring injury[tw] OR Hamstring injuries[tw] OR Hamstring pain[tw] OR Hamstring ache[tw] OR Hamstring Myositis Ossificans[tw] | 829 |
| 5 | 3 OR 4 | 13956 |
| 6 | "Sensitivity and Specificity"[Mesh] OR sensitivity[tw] OR specificity[tw] OR "Evaluation Studies as Topic"[Mesh] OR evaluation indexes[tw] OR evaluation report[tw] OR evaluation reports[tw] OR evaluation research[tw] OR use-effectiveness[tw] OR use effectiveness[tw] OR preposttests[tw] OR pre post test[tw] OR preposttest[tw] OR pre post test[tw] OR qualitative evaluation[tw] OR qualitative evaluations[tw] OR quantitative evaluation[tw] OR quantitative evaluations[tw] OR theoretical effectiveness[tw] OR critique[tw] OR critiques[tw] OR evaluation methodology[tw] OR evaluation methodologies[tw] OR "Validation Studies as Topic"[Mesh] OR "Reproducibility of Results"[Mesh] OR reproducibility[tw] OR validity[tw] OR validation[tw] OR reliability[tw] OR "Data Accuracy"[Mesh] OR data accuracy[tw] OR data accuracies[tw] OR data quality[tw] OR data qualities[tw] OR precision[tw] OR responsiveness[tw] OR consistency[tw] OR consistencies[tw] OR consistent[tw] OR log-likelihood ratio[tw] OR likelihood-ratio[tw] OR likelihood ratio[tw] OR LR test[tiab] OR "Epidemiologic Research Design"[Mesh] OR "Research Design"[Mesh] OR research design[tw] OR research designs[tw] OR research strategy[tw] OR research strategies[tw] OR research techniques[tw] OR research technique[tw] OR research methodology[tw] OR research methodologies[tw] OR experimental design[tw] OR experimental designs[tw] | 4199739 |
| 7 | "Gait"[Mesh] OR "Gait Analysis"[Mesh] OR gait[tw] OR "strength test"[tw] OR isokinetic[tw] OR "range of motion"[tw] OR flexibility[tw] OR full movement[tw] OR "lower extremity alignment"[tw] OR "posture"[tw] OR movement pattern[tw] OR movement patterns[tw] OR "straight leg raise"[tw] OR "McConnell test"[tw] OR "dynamic horizontal side support"[tw] OR "dynamic valgus"[tw] OR "single leg bride" [tw] OR "Active hamstring test"[tw] OR "Hamstring 90/90 Test"[tw] OR "endurance test"[tw] OR "single leg squat"[tw] OR "single-leg stance"[tw] OR "single leg balance"[tw] OR "step down"[tw] OR Agility testing[tw] OR sprinting[tw] OR jumping[tw] OR "Timed hop for distance"[tw] OR "Star Excursion balance test"[tw] OR "step-down test"[tw] OR "cross-over"[tw] OR "Copenhagen five second squeeze test"[tw] OR "Double straight leg lower test"[tw] OR "Rehabilitation"[Mesh] OR rehabilitation[tw] OR physical function[tw] OR physical functions[tw] OR physical functioning[tw] OR performance status[tw] OR "Return to Sport"[Mesh] OR "back-to-sport"[tw] OR "return-to-sport"[tw] OR "back to sport"[tw] OR "return to sport"[tw] OR "back-to-sports"[tw] OR "return-to-sports"[tw] OR "back to sports"[tw] OR "return to sports"[tw] OR "sporting activity resumption"[tw] OR "recreational activities resumption"[tw] OR "return to recreation"[tw] OR "return to recreational"[tw] OR "return to play"[tw] | 874126 |
| 8 | "Pain"[Majr] OR pain rating[tw] OR pain scale[tw] OR visual analogue scale[tw] OR visual analog scale[tw] OR numerical rating scale[tw] OR number rating scale[tw] OR Perth Hamstring Assessment Tool[tw] OR "Copenhagen Hip and Groin Outcome Score"[tw] OR "Hip and Groin Outcome Score"[tw] OR NAHS[tiab] OR lower extremity functional scale[tw] OR LEFS[tiab] OR short form health survey[tw] OR short-form health survey[tw] OR SF36[tw] OR SF-36[tw] OR "SF 36"[tw] OR "short form 36"[tw] OR "shortform 36"[tw] OR shortform36[tw] OR "36 item short form"[tw] OR "36-item short form"[tw] OR SF12[tw] OR SF-12[tw] OR "SF 12"[tw] OR "short form 12"[tw] OR "shortform 12"[tw] OR shortform12[tw] OR "12 item short form"[tw] OR "12-item short form"[tw] OR tegner activity level scale[tw] OR hip sports activity scale[tw] OR HSAS[tiab] | 329938 |
| 9 | 5 AND 6 AND 7 AND English[language] | 681 |
| 10 | 5 AND 6 AND 8 AND English[language] | 323 |

## APPENDIX A

### *Embase (June 7, 2020)*

| | Search Term | Result |
|---|---|---|
| 1 | 'Hamstring Tendon'/exp OR 'biceps femoris tendon'/exp OR "Biceps Femoris": ti,ab,de,tn OR hamstring:ti,ab,de,tn OR hamstrings:ti,ab,de,tn OR 'semimembranosus tendon'/exp OR Semimembranosus:ti,ab,de,tn OR Semitendinosus:ti,ab,de,tn OR thigh:ti,ab,de,tn | 60500 |
| 2 | 'Myofascial pain'/de OR 'soft tissue injury'/de OR 'ossifying myositis'/exp OR 'leg injury'/de OR 'Pain'/de OR 'Chronic Pain'/exp OR 'Musculoskeletal Pain'/de OR Pain:ti,ab OR Painful:ti,ab,de,tn OR Ache:ti,ab,de,tn OR Injury:ti,ab,de,tn OR Injuries:ti,ab,de,tn | 2610373 |
| 3 | 1 AND 2 | 19523 |
| 4 | "Hamstring strain":ti,ab,de,tn OR "Hamstring strains":ti,ab,de,tn OR "Hamstring tear":ti,ab,de,tn OR "Torn Hamstring":ti,ab,de,tn OR "Hamstring injury":ti,ab,de,tn OR "Hamstring injuries":ti,ab,de,tn OR "Hamstring pain":ti,ab,de,tn OR "Hamstring ache":ti,ab,de,tn OR "Hamstring Myositis Ossificans":ti,ab,de,tn | 850 |
| 5 | 3 OR 4 | 19539 |
| 6 | 'sensitivity'/exp OR sensitivity:ti,ab,de OR 'specificity'/exp OR specificity:ti,ab,de OR 'evaluation indexes'/exp OR 'evaluation indexes':ti,ab,de OR 'evaluation report'/exp OR 'evaluation report':ti,ab,de OR 'evaluation reports':ti,ab,de OR 'evaluation research'/exp OR 'evaluation research':ti,ab,de OR 'use effectiveness'/exp OR 'use effectiveness':ti,ab,de OR 'pre post tests'/exp OR 'pre post tests':ti,ab,de OR 'prepost test':ti,ab,de OR 'qualitative evaluation'/exp OR 'qualitative evaluation':ti,ab,de OR 'qualitative evaluations':ti,ab,de OR 'quantitative evaluation'/exp OR 'quantitative evaluation':ti,ab,de OR 'quantitative evaluations':ti,ab,de OR 'theoretical effectiveness'/exp OR 'theoretical effectiveness':ti,ab,de OR 'critique'/exp OR critique:ti,ab,de OR critiques:ti,ab,de OR 'evaluation methodology'/exp OR 'evaluation methodology':ti,ab,de OR 'evaluation methodologies':ti,ab,de OR 'reproducibility'/exp OR reproducibility:ti,ab,de OR 'validity'/exp OR validity:ti,ab,de OR 'reliability'/exp OR reliability:ti,ab,de OR 'data accuracy'/exp OR 'data accuracy':ti,ab,de OR 'data accuracies':ti,ab,de OR 'data quality'/exp OR 'data quality':ti,ab,de OR 'data qualities':ti,ab,de OR 'precision'/exp OR precision:ti,ab,de OR 'responsiveness'/exp OR responsiveness:ti,ab,de OR 'consistency'/exp OR consistency:ti,ab,de OR consistencies:ti,ab,de OR consistent:ti,ab,de OR 'log-likelihood ratio' OR 'likelihood-ratio':ti,ab,de OR 'likelihood ratio'/exp OR 'likelihood ratio':ti,ab,de OR 'research design'/exp OR 'research design':ti,ab,de OR 'research designs':ti,ab,de OR 'research strategy':ti,ab,de OR 'research strategies':ti,ab,de OR 'research techniques':ti,ab,de OR 'research technique':ti,ab,de OR 'research methodology'/exp OR 'research methodology':ti,ab,de OR 'research methodologies':ti,ab,de OR 'experimental design'/exp OR 'experimental design':ti,ab,de OR 'experimental designs':ti,ab,de | 8608226 |
| 7 | 'Gait'/exp OR gait:ti,ab,de,tn OR "strength test":ti,ab,de,tn OR isokinetic:ti,ab,de,tn OR "range of motion":ti,ab,de,tn OR flexibility:ti,ab,de,tn OR "full movement":ti,ab,de,tn OR "lower extremity alignment":ti,ab,de,tn OR posture:ti,ab,de,tn OR "movement pattern":ti,ab,de,tn OR "movement patterns":ti,ab,de,tn OR "straight leg raise":ti,ab,de,tn OR "McConnell test":ti,ab,de,tn OR "dynamic horizontal side support":ti,ab,de,tn OR "dynamic valgus":ti,ab,de,tn OR "single leg bride":ti,ab,de,tn OR "Active hamstring test":ti,ab,de,tn OR "Hamstring 90/90 Test":ti,ab,de,tn OR "endurance test":ti,ab,de,tn OR "single leg squat":ti,ab,de,tn OR "single-leg stance":ti,ab,de,tn OR "single leg balance":ti,ab,de,tn OR "step down":ti,ab,de,tn OR "Agility testing":ti,ab,de,tn OR sprinting:ti,ab,de,tn OR jumping:ti,ab,de,tn OR "Timed hop for distance":ti,ab,de,tn OR "Star Excursion balance test":ti,ab,de,tn OR "step-down test":ti,ab,de,tn OR cross-over:ti,ab,de,tn OR "Copenhagen five second squeeze test":ti,ab,de,tn OR "Double straight leg lower test":ti,ab,de,tn OR 'Rehabilitation'/de OR rehabilitation:ti,ab,de,tn OR "physical function":ti,ab,de,tn OR "physical functions":ti,ab,de,tn OR "physical functioning":ti,ab,de,tn OR "performance status":ti,ab,de,tn OR 'Return to Sport'/exp OR back-to-sport:ti,ab,de,tn OR return-to-sport:ti,ab,de,tn OR "back to sport":ti,ab,de,tn OR "return to sport":ti,ab,de,tn OR back-to-sports:ti,ab,de,tn OR return-to-sports:ti,ab,de,tn OR "back to sports":ti,ab,de,tn OR "return to sports":ti,ab,de,tn OR "sporting activity resumption":ti,ab,de,tn OR "recreational activities resumption":ti,ab,de,tn OR "return to recreation":ti,ab,de,tn OR "return to recreational":ti,ab,de,tn OR "return to play":ti,ab,de,tn | 675912 |
| 8 | 'Pain'/exp/mj OR "pain rating":ti,ab,de,tn OR "pain scale":ti,ab,de,tn OR "visual analogue scale":ti,ab,de,tn OR "visual analog scale":ti,ab,de,tn OR "numerical rating scale":ti,ab,de,tn OR "number rating scale":ti,ab,de,tn OR "Perth Hamstring Assessment Tool":ti,ab,de,tn OR "Copenhagen Hip and Groin Outcome Score":ti,ab,de,tn OR "Hip and Groin Outcome Score":ti,ab,de,tn OR NAHS:ti,ab OR "lower extremity functional scale":ti,ab,de,tn OR LEFS:ti,ab OR "short form health survey":ti,ab,de,tn OR "short-form health survey":ti,ab,de,tn OR SF36:ti,ab,de,tn OR SF-36:ti,ab,de,tn OR "SF 36":ti,ab,de,tn OR "short form 36":ti,ab,de,tn OR "shortform 36":ti,ab,de,tn OR shortform36:ti,ab,de,tn OR "36 item short form":ti,ab,de,tn OR "36-item short form":ti,ab,de,tn OR SF12:ti,ab,de,tn OR SF-12:ti,ab,de,tn OR "SF 12":ti,ab,de,tn OR "short form 12":ti,ab,de,tn OR "shortform 12":ti,ab,de,tn OR shortform12:ti,ab,de,tn OR "12 item short form":ti,ab,de,tn OR "12-item short form":ti,ab,de,tn OR "tegner activity level scale":ti,ab,de,tn OR "hip sports activity scale":ti,ab,de,tn OR HSAS:ti,ab | 558290 |
| 9 | 5 AND 6 AND 7 AND [english]/lim AND [embase]/lim NOT 'conference abstract'/it | 887 |
| 10 | 5 AND 6 AND 8 AND [english]/lim AND [embase]/lim NOT 'conference abstract'/it | 619 |

## APPENDIX A

### *CINAHL (June 7, 2020)*

| | Search Term | Result |
|---|---|---|
| 1 | "Biceps Femoris" OR hamstring OR hamstrings OR Semimembranosus OR Semitendinosus OR thigh | 14767 |
| 2 | (MH "Myofascial pain syndromes") OR (MH "soft tissue injuries") OR (MH "Sprains and Strains") OR (MH "Myositis Ossificans") OR (MH "Leg Injuries") OR (MH "Pain") OR (MH "Chronic Pain") OR Pain OR Painful OR Ache OR Injury OR Injuries | 628076 |
| 3 | 1 AND 2 | 6892 |
| 4 | "Hamstring strain" OR "Hamstring tear" OR "Hamstring injury" OR "Hamstring injuries" OR "Hamstring pain" OR "Hamstring ache" OR "Hamstring Myositis Ossificans" | 633 |
| 5 | 3 OR 4 | 6896 |
| 6 | ((MH "Sensitivity and Specificity+") OR sensitivity OR specificity OR "evaluation indexes" OR "evaluation report" OR "evaluation reports" OR "evaluation research" OR use-effectiveness OR "use effectiveness" OR preposttests OR "pre post test" OR preposttest OR "pre post test" OR "qualitative evaluation" OR "qualitative evaluations" OR "quantitative evaluation" OR "quantitative evaluations" OR "theoretical effectiveness" OR critique OR critiques OR "evaluation methodology" OR "evaluation methodologies" OR reproducibility OR validity OR validation OR reliability OR "data accuracy" OR "data accuracies" OR "data quality" OR "data qualities" OR precision OR responsiveness OR consistency OR consistencies OR consistent OR "log-likelihood ratio" OR likelihood-ratio OR "likelihood ratio" OR TI "LR test" OR AB "LR test" OR (MH "Study Design+") OR "research design" OR "research designs" OR "research strategy" OR "research strategies" OR "research techniques" OR "research technique" OR "research methodology" OR "research methodologies" OR "experimental design" OR "experimental designs") | 1943500 |
| 7 | (MH "Gait+") OR (MH "Gait Analysis+") OR gait OR "strength test" OR isokinetic OR "range of motion" OR flexibility OR "full movement" OR "lower extremity alignment" OR posture OR "movement pattern" OR "movement patterns" OR "straight leg raise" OR "McConnell test" OR "dynamic horizontal side support" OR "dynamic valgus" OR "single leg bride" OR "Active hamstring test" OR "Hamstring 90/90 Test" OR "endurance test" OR "single leg squat" OR "single-leg stance" OR "single leg balance" OR "step down" OR "Agility testing" OR sprinting OR jumping OR "Timed hop for distance" OR "Star Excursion balance test" OR "step-down test" OR cross-over OR "Copenhagen five second squeeze test" OR "Double straight leg lower test" OR (MH "Rehabilitation+") OR rehabilitation OR "physical function" OR "physical functions" OR "physical functioning" OR "performance status" OR (MH "Sports Re-Entry+") OR back-to-sport OR return-to-sport OR "back to sport" OR "return to sport" OR back-to-sports OR return-to-sports OR "back to sports" OR "return to sports" OR "sporting activity resumption" OR "recreational activities resumption" OR "return to recreation" OR "return to recreational" OR "return to play" | 512742 |
| 8 | (MM "Pain") OR "pain rating" OR "pain scale" OR "visual analogue scale" OR "visual analog scale" OR "numerical rating scale" OR "number rating scale" OR "Perth Hamstring Assessment Tool" OR "Copenhagen Hip and Groin Outcome Score" OR "Hip and Groin Outcome Score" OR TI NAHS OR AB NAHS OR "lower extremity functional scale" OR TI LEFS OR AB LEFS OR "short form health survey" OR "short-form health survey" OR SF36 OR SF-36 OR "SF 36" OR "short form 36" OR "shortform 36" OR shortform36 OR "36 item short form" OR "36-item short form" OR SF12 OR SF-12 OR "SF 12" OR "short form 12" OR "shortform 12" OR shortform12 OR "12 item short form" OR "12-item short form" OR "tegner activity level scale" OR "hip sports activity scale" OR TI HSAS OR AB HSAS | 96485 |
| 9 | 5 AND 6 AND 7 AND Language: English | 1709 |
| 10 | 5 AND 6 AND 8 AND Language: English | 317 |

## APPENDIX A

### *Cochrane Library (June 7, 2020)*

| | Search Term | Result |
|---|---|---|
| 1 | "Hamstring Tendons" OR "Biceps Femoris" OR hamstring OR hamstrings OR Semimembranosus OR Semitendinosus OR thigh | 6171 |
| 2 | "Myofascial pain syndromes" OR "soft tissue injuries" OR strains OR "myositis ossificans" OR "leg injuries" OR "Acute Pain" OR "Chronic Pain" OR "Musculoskeletal Pain" OR Pain OR Painful OR Ache OR Injury OR Injuries | 232755 |
| 3 | 1 AND 2 | 2858 |
| 4 | "Hamstring strain" OR "Hamstring tear" OR "Hamstring injury" OR "Hamstring injuries" OR "Hamstring pain" OR "Hamstring ache" OR "Hamstring Myositis Ossificans" | 128 |
| 5 | 3 OR 4 | 2861 |
| 6 | (sensitivity OR specificity OR "evaluation indexes" OR "evaluation report" OR "evaluation reports" OR "evaluation research" OR use-effectiveness OR "use effectiveness" OR preposttests OR "pre post test" OR preposttest OR "pre post test" OR "qualitative evaluation" OR "qualitative evaluations" OR "quantitative evaluation" OR "quantitative evaluations" OR "theoretical effectiveness" OR critique OR critiques OR "evaluation methodology" OR "evaluation methodologies" OR reproducibility OR validity OR validation OR reliability OR "data accuracy" OR "data accuracies" OR "data quality" OR "data qualities" OR precision OR responsiveness OR consistency OR consistencies OR consistent OR "log-likelihood ratio" OR likelihood-ratio OR "likelihood ratio" OR "LR test" OR "research design" OR "research designs" OR "research strategy" OR "research strategies" OR "research techniques" OR "research technique" OR "research methodology" OR "research methodologies" OR "experimental design" OR "experimental designs") | 159592 |
| 7 | Gait OR "strength test" OR isokinetic OR "range of motion" OR flexibility OR "full movement" OR "lower extremity alignment" OR posture OR "movement pattern" OR "movement patterns" OR "straight leg raise" OR "McConnell test" OR "dynamic horizontal side support" OR "dynamic valgus" OR "single leg bride" OR "Active hamstring test" OR "Hamstring 90/90 Test" OR "endurance test" OR "single leg squat" OR "single-leg stance" OR "single leg balance" OR "step down" OR "Agility testing" OR sprinting OR jumping OR "Timed hop for distance" OR "Star Excursion balance test" OR "step-down test" OR cross-over OR "Copenhagen five second squeeze test" OR "Double straight leg lower test" OR rehabilitation OR "physical function" OR "physical functions" OR "physical functioning" OR "performance status" OR back-to-sport OR return-to-sport OR "back to sport" OR "return to sport" OR back-to-sports OR return-to-sports OR "back to sports" OR "return to sports" OR "sporting activity resumption" OR "recreational activities resumption" OR "return to recreation" OR "return to recreational" OR "return to play" | 167411 |
| 8 | "pain rating" OR "pain scale" OR "visual analogue scale" OR "visual analog scale" OR "numerical rating scale" OR "number rating scale" OR "Perth Hamstring Assessment Tool" OR "Copenhagen Hip and Groin Outcome Score" OR "Hip and Groin Outcome Score" OR NAHS OR "lower extremity functional scale" OR LEFS OR "short form health survey" OR "short-form health survey" OR SF36 OR SF-36 OR "SF 36" OR "short form 36" OR "shortform 36" OR shortform36 OR "36 item short form" OR "36-item short form" OR SF12 OR SF-12 OR "SF 12" OR "short form 12" OR "shortform 12" OR shortform12 OR "12 item short form" OR "12-item short form" OR "tegner activity level scale" OR "hip sports activity scale" OR HSAS | 65171 |
| 9 | 5 AND 6 AND 7 | 333 |
| 10 | 5 AND 6 AND 8 | 174 |

### Reinjury Risk

April 6, 2021: total results before duplicate removal, n = 1485; unique results after duplicate removal, n = 969. Updated on June 28, 2021: total results before duplicate removal, n = 1526; new unique results after duplicate removal, n = 33

### *PubMed*

| | Search Term | Result |
|---|---|---|
| 1 | "Hamstring Tendons"[Mesh] OR Biceps Femoris[tw] OR hamstring[tw] OR hamstrings[tw] OR Semimembranosus[tw] OR Semitendinosus[tw] OR thigh[tw] | 48808 |
| 2 | Myofascial pain syndromes[mh:noexp] OR soft tissue injuries[mh:noexp] OR strains[mh] OR myositis ossificans[mh] OR leg injuries[mh:noexp] OR Pain[mesh:noexp] OR Acute Pain[mesh] OR Chronic Pain[mesh] OR Musculoskeletal Pain[mesh:noexp] OR Pain[tiab] OR Painful[tw] OR Ache[tw] OR Injury[tw] OR Injuries[tw] | 1918350 |
| 3 | 1 AND 2 | 15217 |
| 4 | Hamstring strain[mesh] OR Hamstring strain[tw] OR Hamstring tear[tw] OR Torn Hamstring[tw] OR Hamstring injury[tw] OR Hamstring injuries[tw] OR Hamstring pain[tw] OR Hamstring ache[tw] OR Hamstring Myositis Ossificans[tw] | 939 |
| 5 | 3 OR 4 | 15230 |
| 6 | ("Recurrence"[Mesh] OR recur*[tw] OR reoccur*[tw] OR re-occur*[tw] OR re-injur*[tw] OR reinjur*[tw] OR "secondary injury"[tw] OR "secondary injuries"[tw] OR "secondary prevention"[tw] OR "preventing secondary"[tw] OR recidiv*[tw] OR relaps*[tw]) AND (Risk Assessment[Mesh] OR "Risk Adjustment"[Mesh] OR "Health Risk Behaviors"[Mesh] OR "Odds Ratio"[Mesh]OR risk[tw] OR risks[tw] OR prospective[tw] OR longitudinal[tw] OR long-term[tw] OR longterm[tw] OR predict*[tw] OR prognostic[tw] OR prognosis[tw] OR epidemiolog*[tw] OR "multivariate analysis"[tw] OR prevent*[tw] OR "odds ratio"[tw]) | 515934 |
| 7 | 5 AND 6 AND English[language] NOT ("comment"[Publication Type] OR "editorial"[Publication Type] OR "letter"[Publication Type] OR "news"[Publication Type] OR "retracted publication"[Publication Type] OR "retraction of publication"[Publication Type] OR "Case Reports"[Publication Type]) | 513 |

## APPENDIX A

### Embase

| | Search Term | Result |
|---|---|---|
| 1 | 'Hamstring Tendon'/exp OR 'biceps femoris tendon'/exp OR "Biceps Femoris":ti,ab,de,tn OR hamstring:ti,ab,de,tn OR hamstrings:ti,ab,de,tn OR 'semimembranosus tendon'/exp OR Semimembranosus:ti,ab,de,tn OR Semitendinosus:ti,ab,de,tn OR thigh:ti,ab,de,tn | 65504 |
| 2 | 'Myofascial pain'/de OR 'soft tissue injury'/de OR 'ossifying myositis'/exp OR 'leg injury'/de OR 'Pain'/de OR 'Chronic Pain'/exp OR 'Musculoskeletal Pain'/de OR Pain:ti,ab OR Painful:ti,ab,de,tn OR Ache:ti,ab,de,tn OR Injury:ti,ab,de,tn OR Injuries:ti,ab,de,tn | 2801563 |
| 3 | 1 AND 2 | 21512 |
| 4 | "Hamstring strain":ti,ab,de,tn OR "Hamstring strains":ti,ab,de,tn OR "Hamstring tear":ti,ab,de,tn OR "Torn Hamstring":ti,ab,de,tn OR "Hamstring injury":ti,ab,de,tn OR "Hamstring injuries":ti,ab,de,tn OR "Hamstring pain":ti,ab,de,tn OR "Hamstring ache":ti,ab,de,tn OR "Hamstring Myositis Ossificans":ti,ab,de,tn | 963 |
| 5 | 3 OR 4 | 21530 |
| 6 | ('recurrence risk'/exp OR recur*:ti,ab,de,tn OR reoccur*:ti,ab,de,tn OR re-occur*:ti,ab,de,tn OR re-injur*:ti,ab,de,tn OR reinjur*:ti,ab,de,tn OR "secondary injury":ti,ab,de,tn OR "secondary injuries":ti,ab,de,tn OR "secondary prevention":ti,ab,de,tn OR "preventing secondary":ti,ab,de,tn OR recidiv*:ti,ab,de,tn OR relaps*:ti,ab,de,tn) AND ('recurrence risk'/exp OR 'risk assessment'/exp OR 'risk behavior'/exp OR 'odds ratio'/exp OR risk:ti,ab,de,tn OR risks:ti,ab,de,tn OR prospective:ti,ab,de,tn OR longitudinal:ti,ab,de,tn OR long-term:ti,ab,de,tn OR longterm:ti,ab,de,tn OR predict*:ti,ab,de,tn OR prognostic:ti,ab,de,tn OR prognosis:ti,ab,de,tn OR epidemiolog*:ti,ab,de,tn OR "multivariate analysis":ti,ab,de,tn OR prevent*:ti,ab,de,tn OR "odds ratio":ti,ab,de,tn) | 796351 |
| 7 | 5 AND 6 AND [english]/lim AND [embase]/lim NOT ('conference abstract'/it OR 'editorial'/it OR 'letter'/it OR 'note'/it) | 420 |

### CINAHL

| | Search Term | Result |
|---|---|---|
| 1 | "Biceps Femoris" OR hamstring OR hamstrings OR Semimembranosus OR Semitendinosus OR thigh | 14880 |
| 2 | (MH "Myofascial pain syndromes") OR (MH "soft tissue injuries") OR (MH "Sprains and Strains") OR (MH "Myositis Ossificans") OR (MH "Leg Injuries") OR (MH "Pain") OR (MH "Chronic Pain") OR Pain OR Painful OR Ache OR Injury OR Injuries | 632767 |
| 3 | 1 AND 2 | 6936 |
| 4 | "Hamstring strain" OR "Hamstring tear" OR "Hamstring injury" OR "Hamstring injuries" OR "Hamstring pain" OR "Hamstring ache" OR "Hamstring Myositis Ossificans" | 634 |
| 5 | 3 OR 4 | 6941 |
| 6 | ((MH "Recurrence+") OR recur* OR reoccur* OR re-occur* OR re-injur* OR reinjur* OR "secondary injury" OR "secondary injuries" OR "secondary prevention" OR "preventing secondary" OR recidiv* OR relaps*) AND ((MH "Risk Assessment+") OR (MH "Risk Taking Behavior+") OR (MH "Odds Ratio+") OR risk OR risks OR prospective OR longitudinal OR long-term OR longterm OR predict* OR prognostic OR prognosis OR epidemiolog* OR "multivariate analysis" OR prevent* OR "odds ratio") | 131078 |
| 7 | 5 AND 6 AND Language: English and Source Type: Academic Journals | 402 |

### Cochrane Library

| | Search Term | Result |
|---|---|---|
| 1 | "Hamstring Tendons" OR "Biceps Femoris" OR hamstring OR hamstrings OR Semimembranosus OR Semitendinosus OR thigh | 6171 |
| 2 | "Myofascial pain syndromes" OR "soft tissue injuries" OR strains OR "myositis ossificans" OR "leg injuries" OR "Acute Pain" OR "Chronic Pain" OR "Musculoskeletal Pain" OR Pain OR Painful OR Ache OR Injury OR Injuries | 232755 |
| 3 | 1 AND 2 | 2858 |
| 4 | "Hamstring strain" OR "Hamstring tear" OR "Hamstring injury" OR "Hamstring injuries" OR "Hamstring pain" OR "Hamstring ache" OR "Hamstring Myositis Ossificans" | 128 |
| 5 | 3 OR 4 | 2861 |
| 6 | (recur* OR reoccur* OR re-occur* OR re-injur* OR reinjur* OR "secondary injury" OR "secondary injuries" OR "secondary prevention" OR "preventing secondary" OR recidiv* OR relaps*) AND (risk OR risks OR prospective OR longitudinal OR long-term OR longterm OR predict* OR prognostic OR prognosis OR epidemiolog* OR "multivariate analysis" OR prevent* OR "odds ratio") | 74768 |
| 7 | 5 AND 6 | 191 |

## APPENDIX A

### Return to Play

April 6, 2021: total results before duplicate removal, n = 1690; unique results after duplicate removal, n = 1103. Updated June 28, 2021: total results before duplicate removal, n = 1765; new unique results after duplicate removal, n = 53

#### *PubMed*

| | Search Term | Result |
|---|---|---|
| 1 | "Hamstring Tendons"[Mesh] OR Biceps Femoris[tw] OR hamstring[tw] OR hamstrings[tw] OR Semimembranosus[tw] OR Semitendinosus[tw] OR thigh[tw] | 48808 |
| 2 | Myofascial pain syndromes[mh:noexp] OR soft tissue injuries[mh:noexp] OR strains[mh] OR myositis ossificans[mh] OR leg injuries[mh:noexp] OR Pain[mesh:noexp] OR Acute Pain[mesh] OR Chronic Pain[mesh] OR Musculoskeletal Pain[mesh:noexp] OR Pain[tiab] OR Painful[tw] OR Ache[tw] OR Injury[tw] OR Injuries[tw] | 1918350 |
| 3 | 1 AND 2 | 15217 |
| 4 | Hamstring strain[mesh] OR Hamstring strain[tw] OR Hamstring tear[tw] OR Torn Hamstring[tw] OR Hamstring injury[tw] OR Hamstring injuries[tw] OR Hamstring pain[tw] OR Hamstring ache[tw] OR Hamstring Myositis Ossificans[tw] | 939 |
| 5 | 3 OR 4 | 15230 |
| 6 | "Return to Sport"[Mesh] OR "Athletic Performance"[Mesh] OR "back-to-sport"[tw] OR "return-to-sport"[tw] OR "back to sport"[tw] OR "return to sport"[tw] OR "back-to-sports"[tw] OR "return-to-sports"[tw] OR "back to sports"[tw] OR "return to sports"[tw] OR "return to recreation"[tw] OR "return to recreational"[tw] OR "return to play"[tw] OR "return to activity"[tw] OR "return to competition"[tw] OR "competition return"[tw] OR "resume competition"[tw] OR "resume play"[tw] OR "resume sport"[tw] OR "resume sports"[tw] OR "resume activity"[tw] OR "resume activities"[tw] OR "return to performance"[tw] OR "sport resumption"[tw] OR "sports resumption"[tw] OR "sporting activity resumption"[tw] OR "play resumption"[tw] OR "competition resumption"[tw] OR "activity resumption"[tw] OR "activities resumption"[tw] OR "unrestricted sport"[tw] OR "unrestricted sports"[tw] OR "unrestricted activity"[tw] OR "unrestricted play"[tw] OR "full recovery"[tw] OR "level of play"[tw] OR "athletic performance"[tw] OR "sports performance"[tw] OR "sports re-entry"[tw] | 75457 |
| 7 | 5 AND 6 AND English[language] NOT ("comment"[Publication Type] OR "editorial"[Publication Type] OR "letter"[Publication Type] OR "news"[Publication Type] OR "retracted publication"[Publication Type] OR "retraction of publication"[Publication Type] OR "Case Reports"[Publication Type]) | 673 |

#### *Embase*

| | Search Term | Result |
|---|---|---|
| 1 | 'Hamstring Tendon'/exp OR 'biceps femoris tendon'/exp OR "Biceps Femoris":ti,ab,de,tn OR hamstring:ti,ab,de,tn OR hamstrings:ti,ab,de,tn OR 'semimembranosus tendon'/exp OR Semimembranosus:ti,ab,de,tn OR Semitendinosus:ti,ab,de,tn OR thigh:ti,ab,de,tn | 65504 |
| 2 | 'Myofascial pain'/de OR 'soft tissue injury'/de OR 'ossifying myositis'/exp OR 'leg injury'/de OR 'Pain'/de OR 'Chronic Pain'/exp OR 'Musculoskeletal Pain'/de OR Pain:ti,ab OR Painful:ti,ab,de,tn OR Ache:ti,ab,de,tn OR Injury:ti,ab,de,tn OR Injuries:ti,ab,de,tn | 2801563 |
| 3 | 1 AND 2 | 21512 |
| 4 | "Hamstring strain":ti,ab,de,tn OR "Hamstring strains":ti,ab,de,tn OR "Hamstring tear":ti,ab,de,tn OR "Torn Hamstring":ti,ab,de,tn OR "Hamstring injury":ti,ab,de,tn OR "Hamstring injuries":ti,ab,de,tn OR "Hamstring pain":ti,ab,de,tn OR "Hamstring ache":ti,ab,de,tn OR "Hamstring Myositis Ossificans":ti,ab,de,tn | 963 |
| 5 | 3 OR 4 | 21530 |
| 6 | 'return to sport'/exp OR 'athletic performance'/exp OR back-to-sport:ti,ab,de,tn OR return-to-sport:ti,ab,de,tn OR "back to sport":ti,ab,de,tn OR "return to sport":ti,ab,de,tn OR back-to-sports:ti,ab,de,tn OR return-to-sports:ti,ab,de,tn OR "back to sports":ti,ab,de,tn OR "return to sports":ti,ab,de,tn OR "return to recreation":ti,ab,de,tn OR "return to recreational":ti,ab,de,tn OR "return to play":ti,ab,de,tn OR "return to activity":ti,ab,de,tn OR "return to competition":ti,ab,de,tn OR "competition return":ti,ab,de,tn OR "resume competition":ti,ab,de,tn OR "resume play":ti,ab,de,tn OR "resume sport":ti,ab,de,tn OR "resume sports":ti,ab,de,tn OR "resume activity":ti,ab,de,tn OR "resume activities":ti,ab,de,tn OR "return to performance":ti,ab,de,tn OR "sport resumption":ti,ab,de,tn OR "sports resumption":ti,ab,de,tn OR "sporting activity resumption":ti,ab,de,tn OR "play resumption":ti,ab,de,tn OR "competition resumption":ti,ab,de,tn OR "activity resumption":ti,ab,de,tn OR "activities resumption":ti,ab,de,tn OR "unrestricted sport":ti,ab,de,tn OR "unrestricted sports":ti,ab,de,tn OR "unrestricted activity":ti,ab,de,tn OR "unrestricted play":ti,ab,de,tn OR "full recovery":ti,ab,de,tn OR "level of play":ti,ab,de,tn OR "athletic performance":ti,ab,de,tn OR "sports performance":ti,ab,de,tn OR 'sports re-entry':ti,ab,de,tn | 36409 |
| 7 | 5 AND 6 AND [english]/lim AND [embase]/lim NOT ('conference abstract'/it OR 'editorial'/it OR 'letter'/it OR 'note'/it) | 382 |

## APPENDIX A

### CINAHL

| | Search Term | Result |
|---|---|---|
| 1 | "Biceps Femoris" OR hamstring OR hamstrings OR Semimembranosus OR Semitendinosus OR thigh | 14880 |
| 2 | (MH "Myofascial pain syndromes") OR (MH "soft tissue injuries") OR (MH "Sprains and Strains") OR (MH "Myositis Ossificans") OR (MH "Leg Injuries") OR (MH "Pain") OR (MH "Chronic Pain") OR Pain OR Painful OR Ache OR Injury OR Injuries | 632767 |
| 3 | 1 AND 2 | 6936 |
| 4 | "Hamstring strain" OR "Hamstring tear" OR "Hamstring injury" OR "Hamstring injuries" OR "Hamstring pain" OR "Hamstring ache" OR "Hamstring Myositis Ossificans" | 634 |
| 5 | 3 OR 4 | 6941 |
| 6 | (MH "Sports Re-Entry") OR (MH "Athletic Performance") OR back-to-sport OR return-to-sport OR "back to sport" OR "return to sport" OR back-to-sports OR return-to-sports OR "back to sports" OR "return to sports" OR "return to recreation" OR "return to recreational" OR "return to play" OR "return to activity" OR "return to competition" OR "competition return" OR "resume competition" OR "resume play" OR "resume sport" OR "resume sports" OR "resume activity" OR "resume activities" OR "return to performance" OR "sport resumption" OR "sports resumption" OR "sporting activity resumption" OR "play resumption" OR "competition resumption" OR "activity resumption" OR "activities resumption" OR "unrestricted sport" OR "unrestricted sports" OR "unrestricted activity" OR "unrestricted play" OR "full recovery" OR "level of play" OR "athletic performance" OR "sports performance" OR "sports re-entry" | 20789 |
| 7 | 5 AND 6 AND Language: English and Source Type: Academic Journals | 562 |

### Cochrane Library

| | Search Term | Result |
|---|---|---|
| 1 | "Hamstring Tendons" OR "Biceps Femoris" OR hamstring OR hamstrings OR Semimembranosus OR Semitendinosus OR thigh | 6171 |
| 2 | "Myofascial pain syndromes" OR "soft tissue injuries" OR strains OR "myositis ossificans" OR "leg injuries" OR "Acute Pain" OR "Chronic Pain" OR "Musculoskeletal Pain" OR Pain OR Painful OR Ache OR Injury OR Injuries | 232755 |
| 3 | 1 AND 2 | 2858 |
| 4 | "Hamstring strain" OR "Hamstring tear" OR "Hamstring injury" OR "Hamstring injuries" OR "Hamstring pain" OR "Hamstring ache" OR "Hamstring Myositis Ossificans" | 128 |
| 5 | 3 OR 4 | 2861 |
| 6 | back-to-sport OR return-to-sport OR "back to sport" OR "return to sport" OR back-to-sports OR return-to-sports OR "back to sports" OR "return to sports" OR "return to recreation" OR "return to recreational" OR "return to play" OR "return to activity" OR "return to competition" OR "competition return" OR "resume competition" OR "resume play" OR "resume sport" OR "resume sports" OR "resume activity" OR "resume activities" OR "return to performance" OR "sport resumption" OR "sports resumption" OR "sporting activity resumption" OR "play resumption" OR "competition resumption" OR "activity resumption" OR "activities resumption" OR "unrestricted sport" OR "unrestricted sports" OR "unrestricted activity" OR "unrestricted play" OR "full recovery" OR "level of play" OR "athletic performance" OR "sports performance" OR "sports re-entry" | 4041 |
| 7 | 5 AND 6 | 148 |

## APPENDIX A

### Intervention

September 6, 2019: all search results, n = 11 432; original citations, n = 9624. Updated on June 30, 2021: all search results, n = 6017; new original citations, n = 1825

#### *2019 Search*

#### PubMed

| | Search Term | Result |
|---|---|---|
| 1 | (((thigh [mh] OR quadriceps muscle [mh] OR lower extremity [mh:noexp] OR hamstring tendons [mh] OR hamstring muscles [mh] OR gracilis muscle [mh]) OR ("Adductor" [tiab] OR "Biceps Femoris" [tiab] OR "Gracilis" [tiab] OR "hamstring" [tiab] OR "Iliotibial Band" [tiab] OR "Ischial" [tiab] OR "Quadriceps" [tiab] OR "Quadriceps Femoris" [tiab] OR "Rectus Femoris" [tiab] OR "Semimembranosus" [tiab] OR "Semitendinosis" [tiab] OR "Tensor fascia lata" [tiab] OR "thigh" [tiab] OR "Vastus" [tiab])) AND ((myofascial pain syndromes [mh:noexp] OR soft tissue injuries [mh:noexp] OR tendon injuries [mh:noexp] OR tendinopathy [mh:noexp] OR sprains and strains [mh] OR myositis ossificans [mh] OR leg injuries [mh:noexp]) OR ("Avulsion" [tiab] OR "Ischiofemoral impingement" [tiab] OR "Muscle Strain" [tiab] OR "Muscle Tear" [tiab] OR "Myositis Ossificans" [tiab] OR soft tissue injuries [tiab] OR "injury" [tiab] OR "sprains and strains" [tiab] OR sprain* [tiab] OR "strains" [tiab])) AND ((Acupuncture Therapy [mh:noexp] OR Chiropractic [mh] OR Combined Modality Therapy [mh] OR Cryotherapy [mh] OR Diathermy [mh] OR Iontophoresis [mh] OR Muscle Contraction [mh] OR Orthotic Devices [mh] OR Patient Education as Topic [mh:noexp] OR Physical Therapy Modalities [mh] OR Rehabilitation [mh:noexp] OR Self Care [mh] OR Telerehabilitation [mh] OR Ultrasonography [mh]) OR ("Astym Treatment" [tiab] OR "Augmented Soft-Tissue" [tiab] OR "Mobilization" [tiab] OR "Mobilisation" [tiab] OR Brace* [tiab] OR Chiropract* [tiab] OR "Compression" [tiab] OR "Contract-relax stretching" [tiab] OR "Cross-Friction Massage" [tiab] OR Dry needl* [tiab] OR "Dynamic stretching" [tiab] OR "Exercise" [tiab] OR "Graston" [tiab] OR "Joint Mobilization" [tiab] OR " Kinesio tape" [tiab] OR "Manipulation" [tiab] OR Manual Therapy* [tiab] OR "Massage" [tiab] OR cryotherap* [Tiab] OR thermotherap* [Tiab] OR "Moist Heat" [tiab] OR "Ice" [tiab] OR "diathermy" [tiab] OR ultrasound* [Tiab] OR electrical* [Tiab] OR muscle stimul* [Tiab] OR neuromuscular stimulat* [Tiab] OR "electric muscle stimulation" [tiab] OR "functional electrical stimulation" [tiab] OR "neuromuscular electrical stimulation" [tiab] OR "transcutaneous electrical nerve stimulation" [tiab] OR "laser" [tiab] OR "iontophoresis" [tiab] OR "cryo-cuff" [tiab] OR "therapeutic modalities" [tiab] OR "physical agents" [tiab] OR "physical modalities" [tiab] OR "physical interventions" [tiab] OR Physical therap* [tiab] OR Physiotherap* [tiab] OR "passive modalities" [tiab] OR muscleso* [Tiab] OR "Nerve Mobilization" [tiab] OR "osteopathic manipulative treatment" [tiab] OR "orthotherapy" [Tiab] OR orthoti* [Tiab] OR "proprioceptive neuromuscular facilitation" [tiab] OR "stretching" [tiab] OR "Resistance Training" [tiab] OR "Soft-Tissue Therapy" [tiab] OR "Spray and stretch" [tiab] OR strength* [Tiab] OR stretch* [Tiab] OR "tape" [tiab] OR "taping" [tiab] OR trigger point* [Tiab] OR "Yoga" [tiab] OR "Platelet rich plasma injection" [tiab] OR "Shock wave therapy" [tiab] OR "Antiinflammatory medicine" [tiab] OR "Injection" [tiab] OR "Cortisone" [tiab] OR "repair" [tiab]) NOT ("animals"[MeSH Terms] NOT "humans"[MeSH Terms])) | 4095 |

#### Ovid: Journals@Ovid

| | Search Term | Result |
|---|---|---|
| 1 | ((exp thigh / OR muscle, skeletal / OR exp quadriceps muscle / OR lower extremity / OR exp hamstring tendons / OR exp hamstring muscles / OR exp gracilis muscle /) OR (Adductor.ti,ab. OR Biceps Femoris.ti,ab. OR Gracilis.ti,ab. OR hamstring.ti,ab. OR Iliotibial Band.ti,ab. OR Ischial.ti,ab. OR Quadriceps.ti,ab. OR Quadriceps Femoris.ti,ab. OR Rectus Femoris.ti,ab. OR Semimembranosus.ti,ab. OR Semitendinosis.ti,ab. OR Tensor fascia lata. ti,ab. OR thigh.ti,ab. OR Vastus.ti,ab.)) AND ((myofascial pain syndromes / OR soft tissue injuries / OR tendon injuries / OR tendinopathy / OR sprains AND exp strains / OR exp myositis ossificans / OR myofascial pain syndromes / OR leg injuries /) OR (Avulsion.ti,ab. OR Ischiofemoral impingement. ti,ab. OR Muscle Strain.ti,ab. OR Muscle Tear.ti,ab. OR Myositis Ossificans.ti,ab. OR soft tissue injuries.ti,ab. OR injury.ti,ab. OR sprains and strains.ti,ab. OR sprain*.ti,ab. OR strains.ti,ab.)) AND ((Acupuncture Therapy / OR exp Chiropractic / OR exp Combined Modality Therapy / OR exp Cryotherapy / OR exp Diathermy / OR exp Iontophoresis / OR exp Muscle Contraction / OR exp Orthotic Devices / OR Patient Education as Topic / OR exp Physical Therapy Modalities / OR Rehabilitation / OR exp Self Care / OR exp Telerehabilitation / OR exp Ultrasonography /) OR (Astym Treatment.ti,ab. OR Augmented Soft-Tissue.ti,ab. OR Mobilization.ti,ab. OR Mobilisation.ti,ab. OR Brace*.ti,ab. OR Chiropract*.ti,ab. OR Compression.ti,ab. OR Contract-relax stretching. ti,ab. OR Cross-Friction Massage.ti,ab. OR Dry needl*.ti,ab. OR Dynamic stretching.ti,ab. OR Exercise.ti,ab. OR Graston.ti,ab. OR Joint Mobilization.ti,ab. OR Kinesio tape.ti,ab. OR Manipulation.ti,ab. OR Manual Therapy*.ti,ab. OR Massage.ti,ab. OR cryotherap*.ti,ab. OR thermotherap*.ti,ab. OR Moist Heat. ti,ab. OR Ice.ti,ab. OR diathermy.ti,ab. OR ultrasound*.ti,ab. OR electrical*.ti,ab. OR muscle stimul*.ti,ab. OR neuromuscular stimulat*.ti,ab. OR EMS. ti,ab. OR FES.ti,ab. OR NMES.ti,ab. OR TENS.ti,ab. OR laser.ti,ab. OR iontophoresis.ti,ab. OR cryo-cuff.ti,ab. OR therapeutic modalities.ti,ab. OR physical agents.ti,ab. OR physical modalities.ti,ab. OR physical interventions.ti,ab. OR Physical therap*.ti,ab. OR Physiotherap*.ti,ab. OR passive modalities.ti,ab. OR muscleso*.ti,ab. OR Nerve Mobilization.ti,ab. OR OMT.ti,ab. OR orthotherapy.ti,ab. OR orthoti*.ti,ab. OR PNF.ti,ab. OR proprioceptive neuromuscular facilitation.ti,ab. OR stretching.ti,ab. OR Resistance Training.ti,ab. OR Soft-Tissue Therapy.ti,ab. OR Spray and stretch.ti,ab. OR strength*.ti,ab. OR stretch*.ti,ab. OR tape.ti,ab. OR taping.ti,ab. OR trigger point*.ti,ab. OR Yoga.ti,ab. OR Platelet rich plasma injection.ti,ab. OR RPP.ti,ab. OR Shock wave therapy.ti,ab. OR Antiinflammatory medicine.ti,ab. OR Injection.ti,ab. OR Cortisone.ti,ab. OR repair.ti,ab.)) | 19 |

## APPENDIX A

### CINAHL

| | Search Term | Result |
|---|---|---|
| 1 | (((MH "thigh +") OR (MH "quadriceps muscle +") OR (MH "lower extremity ") OR (MH "hamstring tendons +") OR (MH "hamstring muscles +") OR (MH "gracilis muscle +")) OR (TI Adductor OR AB Adductor OR TI "Biceps Femoris" OR AB "Biceps Femoris" OR TI Gracilis OR AB Gracilis OR TI hamstring OR AB hamstring OR TI "Iliotibial Band" OR AB "Iliotibial Band" OR TI Ischial OR AB Ischial OR TI Quadriceps OR AB Quadriceps OR TI "Quadriceps Femoris" OR AB "Quadriceps Femoris" OR TI "Rectus Femoris" OR AB "Rectus Femoris" OR TI Semimembranosus OR AB Semimembranosus OR TI Semitendinosis OR AB Semitendinosis OR TI "Tensor fascia lata" OR AB "Tensor fascia lata" OR TI thigh OR AB thigh OR TI Vastus OR AB Vastus)) AND (((MH "myofascial pain syndromes ") OR (MH "soft tissue injuries ") OR (MH "tendon injuries ") OR (MH "tendinopathy ") OR sprains AND (MH "strains +") OR (MH "myositis ossificans +") OR (MH "myofascial pain syndromes ") OR (MH "leg injuries ")) OR (TI Avulsion OR AB Avulsion OR TI "Ischiofemoral impingement" OR AB "Ischiofemoral impingement" OR TI "Muscle Strain" OR AB "Muscle Strain" OR TI "Muscle Tear" OR AB "Muscle Tear" OR TI "Myositis Ossificans" OR AB "Myositis Ossificans" OR TI "soft tissue injuries" OR AB "soft tissue injuries" OR TI injury OR AB injury OR TI "sprains and strains" OR AB "sprains and strains" OR TI sprain* OR AB sprain* OR TI strains OR AB strains)) AND (((MH "Acupuncture Therapy ") OR (MH "Chiropractic +") OR (MH "Combined Modality Therapy +") OR (MH "Cryotherapy +") OR (MH "Diathermy +") OR (MH "Iontophoresis +") OR (MH "Muscle Contraction +") OR (MH "Orthotic Devices +") OR (MH "Patient Education as Topic ") OR (MH "Physical Therapy Modalities +") OR (MH "Rehabilitation ") OR (MH "Self Care +") OR (MH "Telerehabilitation +") OR (MH "Ultrasonography +")) OR (TI "Astym Treatment" OR AB "Astym Treatment" OR TI "Augmented Soft-Tissue" OR AB "Augmented Soft-Tissue" OR TI Mobilization OR AB Mobilization OR TI Mobilisation OR AB Mobilisation OR TI Brace* OR AB Brace* OR TI Chiropract* OR AB Chiropract* OR TI Compression OR AB Compression OR TI "Contract-relax stretching" OR AB "Contract-relax stretching" OR TI "Cross-Friction Massage" OR AB "Cross-Friction Massage" OR TI "Dry needl*" OR AB "Dry needl*" OR TI "Dynamic stretching" OR AB "Dynamic stretching" OR TI Exercise OR AB Exercise OR TI Graston OR AB Graston OR TI "Joint Mobilization" OR AB "Joint Mobilization" OR TI " Kinesio tape" OR AB " Kinesio tape" OR TI Manipulation OR AB Manipulation OR TI "Manual Therapy*" OR AB "Manual Therapy*" OR TI Massage OR AB Massage OR TI cryotherap* OR AB cryotherap* OR TI thermotherap* OR AB thermotherap* OR TI "Moist Heat" OR AB "Moist Heat" OR TI Ice OR AB Ice OR TI diathermy OR AB diathermy OR TI ultrasound* OR AB ultrasound* OR TI electrical* OR AB electrical* OR TI "muscle stimul*" OR AB "muscle stimul*" OR TI "neuromuscular stimulat*" OR AB "neuromuscular stimulat*" OR TI "electric muscle stimulation" OR AB "electric muscle stimulation" OR TI "functional electrical stimulation" OR AB "functional electrical stimulation" OR TI "neuromuscular electrical stimulation" OR AB "neuromuscular stimulation" OR TI "transcutaneous electrical nerve stimulation" OR AB "transcutaneous electrical nerve stimulation" OR TI laser OR AB laser OR TI iontophoresis OR AB iontophoresis OR TI cryo-cuff OR AB cryo-cuff OR TI "therapeutic modalities" OR AB "therapeutic modalities" OR TI "physical agents" OR AB "physical agents" OR TI "physical modalities" OR AB "physical modalities" OR TI "physical interventions" OR AB "physical interventions" OR TI "Physical therap*" OR AB "Physical therap*" OR TI Physiotherap* OR AB Physiotherap* OR TI "passive modalities" OR AB "passive modalities" OR TI muscleso* OR AB muscleso* OR TI "Nerve Mobilization" OR AB "Nerve Mobilization" OR TI "osteopathic manipulative treatment" OR AB "osteopathic manipulative treatment" OR TI orthotherapy OR AB orthotherapy OR TI orthoti* OR AB orthoti* OR TI "proprioceptive neuromuscular facilitation" OR AB "proprioceptive neuromuscular facilitation" OR TI stretching OR AB stretching OR TI "Resistance Training" OR AB "Resistance Training" OR TI "Soft-Tissue Therapy" OR AB "Soft-Tissue Therapy" OR TI "Spray and stretch" OR AB "Spray and stretch" OR TI strength* OR AB strength* OR TI stretch* OR AB stretch* OR TI tape OR AB tape OR TI taping OR AB taping OR TI "trigger point*" OR AB "trigger point*" OR TI Yoga OR AB Yoga OR TI "Platelet rich plasma injection" OR AB "Platelet rich plasma injection" OR TI "Shock wave therapy" OR AB "Shock wave therapy" OR TI "Antiinflammatory medicine" OR AB "Antiinflammatory medicine" OR TI Injection OR AB Injection OR TI Cortisone OR AB Cortisone OR TI repair OR AB repair)) | 385 |

### Cochrane Library

| | Search Term | Result |
|---|---|---|
| 1 | (([mh thigh] OR [mh ^"muscle, skeletal"] OR [mh "quadriceps muscle"] OR [mh ^"lower extremity"] OR [mh "hamstring tendons"] OR [mh "hamstring muscles"] OR [mh "gracilis muscle"] OR Adductor:ti,ab OR "Biceps Femoris":ti,ab OR Gracilis:ti,ab OR hamstring:ti,ab OR "Iliotibial Band":ti,ab OR Ischial:ti,ab OR Quadriceps:ti,ab OR "Quadriceps Femoris":ti,ab OR "Rectus Femoris":ti,ab OR Semimembranosus:ti,ab OR Semitendinosis:ti,ab OR "Tensor fascia lata":ti,ab OR thigh:ti,ab OR Vastus:ti,ab)) AND (([mh ^"myofascial pain syndromes"] OR [mh ^"soft tissue injuries"] OR [mh ^"tendon injuries"] OR [mh ^tendinopathy] OR sprains AND [mh strains] OR [mh "myositis ossificans"] OR [mh ^"myofascial pain syndromes"] OR [mh ^"leg injuries"]) OR (Avulsion:ti,ab OR "Ischiofemoral impingement":ti,ab OR "Muscle Strain":ti,ab OR "Muscle Tear":ti,ab OR "Myositis Ossificans":ti,ab OR "soft tissue injuries":ti,ab OR injury:ti,ab OR "sprains and strains":ti,ab OR sprain*:ti,ab OR strains:ti,ab)) AND (([mh ^"Acupuncture Therapy"] OR [mh Chiropractic] OR [mh "Combined Modality Therapy"] OR [mh Cryotherapy] OR [mh Diathermy] OR [mh Iontophoresis] OR [mh "Muscle Contraction"] OR [mh "Orthotic Devices"] OR [mh ^"Patient Education as Topic"] OR [mh "Physical Therapy Modalities"] OR [mh ^Rehabilitation] OR [mh "Self Care"] OR [mh Telerehabilitation] OR [mh Ultrasonography]) OR ("Astym Treatment":ti,ab OR "Augmented Soft-Tissue":ti,ab OR Mobilization:ti,ab OR Mobilisation:ti,ab OR Brace*:ti,ab OR Chiropract*:ti,ab OR Compression:ti,ab OR "Contract-relax stretching":ti,ab OR "Cross-Friction Massage":ti,ab OR "Dry needl*":ti,ab OR "Dynamic stretching":ti,ab OR Exercise:ti,ab OR Graston:ti,ab OR "Joint Mobilization":ti,ab OR " Kinesio tape":ti,ab OR Manipulation:ti,ab OR "Manual Therapy*":ti,ab OR Massage:ti,ab OR cryotherap*:ti,ab OR thermotherap*:ti,ab OR "Moist Heat":ti,ab OR Ice:ti,ab OR diathermy:ti,ab OR ultrasound*:ti,ab OR electrical*:ti,ab OR "muscle stimul*":ti,ab OR "neuromuscular stimulat*":ti,ab OR "electric muscle stimulation":ti,ab OR "functional electric stimulation":ti,ab OR "neuromuscular electric stimulation":ti,ab OR "transcutaneous electrical nerve stimulation":ti,ab OR laser:ti,ab OR iontophoresis:ti,ab OR cryo-cuff:ti,ab OR "therapeutic modalities":ti,ab OR "physical agents":ti,ab OR "physical modalities":ti,ab OR "physical interventions":ti,ab OR "Physical therap*":ti,ab OR Physiotherap*:ti,ab OR "passive modalities":ti,ab OR muscleso*:ti,ab OR "Nerve Mobilization":ti,ab OR "osteopathic manipulative treatment":ti,ab OR orthotherapy:ti,ab OR orthoti*:ti,ab OR "proprioceptive neuromuscular facilitation":ti,ab OR stretching:ti,ab OR "Resistance Training":ti,ab OR "Soft-Tissue Therapy":ti,ab OR "Spray and stretch":ti,ab OR strength*:ti,ab OR stretch*:ti,ab OR tape:ti,ab OR taping:ti,ab OR "trigger point*":ti,ab OR Yoga:ti,ab OR "Platelet rich plasma injection":ti,ab OR "Shock wave therapy":ti,ab OR "Antiinflammatory medicine":ti,ab OR Injection:ti,ab OR Cortisone:ti,ab OR repair:ti,ab)) | 658 |

## APPENDIX A

### SPORTDiscus

| | Search Term | Result |
|---|---|---|
| 1 | (((MH "thigh +") OR (MH "muscle, skeletal ") OR (MH "quadriceps muscle +") OR (MH "lower extremity ") OR (MH "hamstring tendons +") OR (MH "hamstring muscles +") OR (MH "gracilis muscle +")) OR (TI Adductor OR AB Adductor OR TI "Biceps Femoris" OR AB "Biceps Femoris" OR TI Gracilis OR AB Gracilis OR TI hamstring OR AB hamstring OR TI "Iliotibial Band" OR AB "Iliotibial Band" OR TI Ischial OR AB Ischial OR TI Quadriceps OR AB Quadriceps OR TI "Quadriceps Femoris" OR AB "Quadriceps Femoris" OR TI "Rectus Femoris" OR AB "Rectus Femoris" OR TI Semimembranosus OR AB Semimembranosus OR TI Semitendinosis OR AB Semitendinosis OR TI "Tensor fascia lata" OR AB "Tensor fascia lata" OR TI thigh OR AB thigh OR TI Vastus OR AB Vastus)) AND (((MH "myofascial pain syndromes ") OR (MH "soft tissue injuries ") OR (MH "tendon injuries ") OR (MH "tendinopathy ") OR sprains AND (MH "strains +") OR (MH "myositis ossificans +") OR (MH "myofascial pain syndromes ") OR (MH "leg injuries ")) OR (TI Avulsion OR AB Avulsion OR TI "Ischiofemoral impingement" OR AB "Ischiofemoral impingement" OR TI "Muscle Strain" OR AB "Muscle Strain" OR TI "Muscle Tear" OR AB "Muscle Tear" OR TI "Myositis Ossificans" OR AB "Myositis Ossificans" OR TI "soft tissue injuries" OR AB "soft tissue injuries" OR TI injury OR AB injury OR TI "sprains and strains" OR AB "sprains and strains" OR TI sprain* OR AB sprain* OR TI strains OR AB strains)) AND (((MH "Acupuncture Therapy ") OR (MH "Chiropractic +") OR (MH "Combined Modality Therapy +") OR (MH "Cryotherapy +") OR (MH "Diathermy +") OR (MH "Iontophoresis +") OR (MH "Muscle Contraction +") OR (MH "Orthotic Devices +") OR (MH "Patient Education as Topic ") OR (MH "Physical Therapy Modalities +") OR (MH "Rehabilitation ") OR (MH "Self Care +") OR (MH "Telerehabilitation +") OR (MH "Ultrasonography +")) OR (TI "Astym Treatment" OR AB "Astym Treatment" OR TI "Augmented Soft-Tissue" OR AB "Augmented Soft-Tissue" OR TI Mobilization OR AB Mobilization OR TI Mobilisation OR AB Mobilisation OR TI Brace* OR AB Brace* OR TI Chiropract* OR AB Chiropract* OR TI Compression OR AB Compression OR TI "Contract-relax stretching" OR AB "Contract-relax stretching" OR TI "Cross-Friction Massage" OR AB "Cross-Friction Massage" OR TI "Dry needl*" OR AB "Dry needl*" OR TI "Dynamic stretching" OR AB "Dynamic stretching" OR TI Exercise OR AB Exercise OR TI Graston OR AB Graston OR TI "Joint Mobilization" OR AB "Joint Mobilization" OR TI " Kinesio tape" OR AB " Kinesio tape" OR TI Manipulation OR AB Manipulation OR TI "Manual Therapy*" OR AB "Manual Therapy*" OR TI Massage OR AB Massage OR TI cryotherap* OR AB cryotherap* OR TI thermotherap* OR AB thermotherap* OR TI "Moist Heat" OR AB "Moist Heat" OR TI Ice OR AB Ice OR TI diathermy OR AB diathermy OR TI ultrasound* OR AB ultrasound* OR TI electrical* OR AB electrical* OR TI "muscle stimul*" OR AB "muscle stimul*" OR TI "neuromuscular stimulat*" OR AB "neuromuscular stimulat*" OR TI "electric muscle stimulation" OR AB "electric muscle stimulation" OR TI "functional electrical stimulation" OR AB "functional electrical stimulation" OR TI "neuromuscular electrical stimulation" OR AB "neuromuscular electrical stimulation" OR TI "transcutaneous electrical nerve stimulation" OR AB "transcutaneous electrical nerve stimulation" OR TI laser OR AB laser OR TI iontophoresis OR AB iontophoresis OR TI cryo-cuff OR AB cryo-cuff OR TI "therapeutic modalities" OR AB "therapeutic modalities" OR TI "physical agents" OR AB "physical agents" OR TI "physical modalities" OR AB "physical modalities" OR TI "physical interventions" OR AB "physical interventions" OR TI "Physical therap*" OR AB "Physical therap*" OR TI Physiotherap* OR AB Physiotherap* OR TI "passive modalities" OR AB "passive modalities" OR TI muscleso* OR AB muscleso* OR TI "Nerve Mobilization" OR AB "Nerve Mobilization" OR TI "osteopathic manipulative treatment" OR AB "osteopathic manipulative treatment" OR TI orthotherapy OR AB orthotherapy OR TI orthoti* OR AB orthoti* OR TI "proprioceptive neuromuscular facilitation" OR AB "proprioceptive neuromuscular facilitation" OR TI stretching OR AB stretching OR TI "Resistance Training" OR AB "Resistance Training" OR TI "Soft-Tissue Therapy" OR AB "Soft-Tissue Therapy" OR TI "Spray and stretch" OR AB "Spray and stretch" OR TI strength* OR AB strength* OR TI stretch* OR AB stretch* OR TI tape OR AB tape OR TI taping OR AB taping OR TI "trigger point*" OR AB "trigger point*" OR TI Yoga OR AB Yoga OR TI "Platelet rich plasma injection" OR AB "Platelet rich plasma injection" OR TI "Shock wave therapy" OR AB "Shock wave therapy" OR TI "Antiinflammatory medicine" OR AB "Antiinflammatory medicine" OR TI Injection OR AB Injection OR TI Cortisone OR AB Cortisone OR TI repair OR AB repair)) | 741 |

### *2021 Search Update*

### PubMed

| | Search Term | Result |
|---|---|---|
| 1 | ("Hamstring Tendons"[Mesh] OR "Biceps Femoris"[tw] OR hamstring[tw] OR hamstrings[tw] OR Semimembranosus[tw] OR Semitendinosus[tw] OR thigh[tw]) | 48828 |
| 2 | ("Myofascial pain syndromes" [mh:noexp] OR "soft tissue injuries" [mh:noexp] OR strains[mh] OR "myositis ossificans"[mh] OR "leg injuries"[mh:noexp] OR Pain[mesh:noexp] OR "Acute Pain" [mesh] OR "Chronic Pain" [mesh] OR "Musculoskeletal Pain"[mesh:noexp] OR Pain[tiab] OR Painful[tw] OR Ache[tw] OR Injury[tw] OR Injuries[tw]) | 1918733 |
| 3 | 1 AND 2 | 15225 |
| 4 | ("Hamstring strain"[mesh] OR Hamstring strain[tw] OR Hamstring tear[tw] OR Torn Hamstring[tw] OR Hamstring injury[tw] OR Hamstring injuries[tw] OR Hamstring pain[tw] OR Hamstring ache[tw] OR Hamstring Myositis Ossificans[tw]) | 846 |
| 5 | 3 OR 4 | 15244 |

*Table continues on page CPG37*

## APPENDIX A

| | Search Term | Result |
|---|---|---|
| 6 | ("Combined Modality Therapy"[Mesh:NoExp] OR Cryotherapy[mh] OR Diathermy[mh] OR Iontophoresis[mh] OR "Orthotic Devices"[mh] OR "Physical Therapy Modalities"[mh] OR Rehabilitation[mh:noexp]) OR ("Astym Treatment"[tiab] OR "Augmented Soft-Tissue"[tiab] OR "Mobilization"[tiab] OR "Mobilisation"[tiab] OR Brace[tiab] OR Braces[tiab] OR "Compression"[tiab] OR "Contract-relax stretching"[tiab] OR "Cross-Friction Massage"[tiab] OR "Dry needle"[tiab] OR "Dry needles"[tiab] OR "Dry needling"[tiab] OR "Dynamic stretching"[tiab] OR "Exercise"[tiab] OR "Graston"[tiab] OR "Joint Mobilization"[tiab] OR "Manipulation"[tiab] OR "Manual Therapy*"[tiab] OR "Massage"[tiab] OR cryotherapy[tiab] OR cryotherapies[tiab] OR thermotherapeutic[tiab] OR thermotherapy[tiab] OR thermotherapies[tiab] OR "Moist Heat"[tiab] OR "Ice"[tiab] OR "diathermy"[tiab] OR "muscle stimulation"[tiab] OR "neuromuscular stimulation"[tiab] OR "electric muscle stimulation"[tiab] OR "neuromuscular electrical stimulation"[tiab] OR "transcutaneous electrical nerve stimulation"[tiab] OR "laser therapy"[tiab] OR "laser therapies"[tiab] OR "iontophoresis"[tiab] OR "cryo-cuff"[tiab] OR "therapeutic modalities"[tiab] OR "physical agents"[tiab] OR "physical modalities"[tiab] OR "physical interventions"[tiab] OR "Physical therapeutic*"[tiab] OR "Physical therapy"[tiab] OR "Physical therapies"[tiab] OR Physiotherapy[tiab] OR Physiotherapies[tiab] OR Physiotherapeutic[tiab] OR "passive modalities"[tiab] OR "Nerve Mobilization"[tiab] OR "osteopathic manipulative treatment"[tiab] OR "orthotherapy"[tiab] OR orthotic*[tiab] OR "proprioceptive neuromuscular facilitation"[tiab] OR "stretching"[tiab] OR "Resistance Training"[tiab] OR "Strength Training"[tiab] OR "Soft-Tissue Therapy"[tiab] OR "Spray and stretch"[tiab] OR "strengthen"[tiab] OR "strengthens"[tiab] OR "strengthening"[tiab] OR stretch[tiab] OR stretches[tiab] OR stretching[tiab] OR "kinesiology tape"[tiab] OR "kinesiology taping"[tiab] OR "kinesio tape"[tiab] OR "kinesio taping"[tiab] OR "therapeutic tape"[tiab] OR "therapeutic taping"[tiab] OR "trigger point*"[tiab] OR "Yoga"[tiab]) | 1142488 |
| 7 | 5 AND 6 AND English[language] NOT ("animals"[MeSH Terms] NOT "humans"[MeSH Terms]) | 2801 |

### CINAHL

| | Search Term | Result |
|---|---|---|
| 1 | ("Biceps Femoris" OR hamstring OR hamstrings OR Semimembranosus OR Semitendinosus OR thigh) | 14889 |
| 2 | (MH "Myofascial pain syndromes") OR (MH "soft tissue injuries") OR (MH "Sprains and Strains") OR (MH "Myositis Ossificans") OR (MH "Leg Injuries") OR (MH "Pain") OR (MH "Chronic Pain") OR Pain OR Painful OR Ache OR Injury OR Injuries | 632844 |
| 3 | 1 AND 2 | 6942 |
| 4 | "Hamstring strain" OR "Hamstring tear" OR "Hamstring injury" OR "Hamstring injuries" OR "Hamstring pain" OR "Hamstring ache" OR "Hamstring Myositis Ossificans" | 634 |
| 5 | 3 OR 4 | 6947 |
| 6 | (MH "Combined Modality Therapy +") OR (MH "Cryotherapy +") OR (MH "Diathermy +") OR (MH "Iontophoresis +") OR (MH "Muscle Contraction +") OR (MH "Orthotic Devices +") OR (MH "Physical Therapy Modalities +") OR (MH "Rehabilitation ") OR ((TI "Astym Treatment" OR AB "Astym Treatment") OR (TI "Augmented Soft-Tissue" OR AB "Augmented Soft-Tissue") OR (TI Mobilization OR AB Mobilization) OR (TI Mobilisation OR AB Mobilisation) OR (TI Brace OR AB Brace) OR (TI Braces OR AB Braces) OR (TI Compression OR AB Compression) OR (TI "Contract-relax stretching" OR AB "Contract-relax stretching") OR (TI "Cross-Friction Massage" OR AB "Cross-Friction Massage") OR (TI "Dry needle" OR AB "Dry needle") OR (TI "Dry needles" OR AB "Dry needles") OR (TI "Dry needling" OR AB "Dry needling") OR (TI "Dynamic stretching" OR AB "Dynamic stretching") OR (TI Exercise OR AB Exercise) OR (TI Graston OR AB Graston) OR (TI "Joint Mobilization" OR AB "Joint Mobilization") OR (TI Manipulation OR AB Manipulation) OR (TI "Manual Therapy*" OR AB "Manual Therapy*") OR (TI Massage OR AB Massage) OR (TI cryotherapy OR AB cryotherapy) OR (TI cryotherapies OR AB cryotherapies) OR (TI thermotherapeutic OR AB thermotherapeutic) OR (TI thermotherapy OR AB thermotherapy) OR (TI thermotherapies OR AB thermotherapies) OR (TI "Moist Heat" OR AB "Moist Heat") OR (TI Ice OR AB Ice) OR (TI diathermy OR AB diathermy) OR (TI "muscle stimulation" OR AB "muscle stimulation") OR (TI "neuromuscular stimulation" OR AB "neuromuscular stimulation") OR (TI "electric muscle stimulation" OR AB "electric muscle stimulation") OR (TI "neuromuscular electrical stimulation" OR AB "neuromuscular electrical stimulation") OR (TI "transcutaneous electrical nerve stimulation" OR AB "transcutaneous electrical nerve stimulation") OR (TI "laser therapy" OR AB "laser therapy") OR (TI "laser therapies" OR AB "laser therapies") OR (TI iontophoresis OR AB iontophoresis) OR (TI cryo-cuff OR AB cryo-cuff) OR (TI "therapeutic modalities" OR AB "therapeutic modalities") OR (TI "physical agents" OR AB "physical agents") OR (TI "physical modalities" OR AB "physical modalities") OR (TI "physical interventions" OR AB "physical interventions") OR (TI "Physical therapeutic*" OR AB "Physical therapeutic*") OR (TI "Physical therapy" OR AB "Physical therapy") OR (TI "Physical therapies" OR AB "Physical therapies") OR (TI Physiotherapy OR AB Physiotherapy) OR (TI Physiotherapies OR AB Physiotherapies) OR (TI Physiotherapeutic OR AB Physiotherapeutic) OR (TI "passive modalities" OR AB "passive modalities") OR (TI "Nerve Mobilization" OR AB "Nerve Mobilization") OR (TI "osteopathic manipulative treatment" OR AB "osteopathic manipulative treatment") OR (TI orthotherapy OR AB orthotherapy) OR (TI orthotic* OR AB orthotic*) OR (TI "proprioceptive neuromuscular facilitation" OR AB "proprioceptive neuromuscular facilitation") OR (TI stretching OR AB stretching) OR (TI "Resistance Training" OR AB "Resistance Training") OR (TI "Strength Training" OR AB "Strength Training") OR (TI "Soft-Tissue Therapy" OR AB "Soft-Tissue Therapy") OR (TI "Spray and stretch" OR AB "Spray and stretch") OR (TI strengthen OR AB strengthen) OR (TI strengthens OR AB strengthens) OR (TI strengthening OR AB strengthening) OR (TI stretch OR AB stretch) OR (TI stretches OR AB stretches) OR (TI stretching OR AB stretching) OR (TI "kinesiology tape" OR AB "kinesiology tape") OR (TI "kinesiology taping" OR AB "kinesiology taping") OR (TI "kinesio tape" OR AB "kinesio tape") OR (TI "kinesio taping" OR AB "kinesio taping") OR (TI "therapeutic tape" OR AB "therapeutic tape") OR (TI "therapeutic taping" OR AB "therapeutic taping") OR (TI "trigger point*" OR AB "trigger point*") OR (TI Yoga OR AB Yoga)) | 282834 |
| 7 | 5 AND 6 AND Language: English | 1676 |

## APPENDIX A

### Cochrane Library

| | Search Term | Result |
|---|---|---|
| 1 | "Hamstring Tendons" OR "Biceps Femoris" OR hamstring OR hamstrings OR Semimembranosus OR Semitendinosus OR thigh | 7072 |
| 2 | "Myofascial pain syndromes" OR "soft tissue injuries" OR strains OR "myositis ossificans" OR "leg injuries" OR "Acute Pain" OR "Chronic Pain" OR "Musculoskeletal Pain" OR Pain OR Painful OR Ache OR Injury OR Injuries | 257943 |
| 3 | 1 AND 2 | 3275 |
| 4 | "Hamstring strain" OR "Hamstring tear" OR "Hamstring injury" OR "Hamstring injuries" OR "Hamstring pain" OR "Hamstring ache" OR "Hamstring Myositis Ossificans" | 151 |
| 5 | 3 OR 4 | 3278 |
| 6 | ([mh ^"Combined Modality Therapy"] OR [mh Cryotherapy] OR [mh Diathermy] OR [mh Iontophoresis] OR [mh "Orthotic Devices"] OR [mh "Physical Therapy Modalities"] OR [mh ^Rehabilitation]) OR ("Astym Treatment":ti,ab OR "Augmented Soft-Tissue":ti,ab OR Mobilization:ti,ab OR Mobilisation:ti,ab OR Brace:ti,ab OR Braces:ti,ab OR Compression:ti,ab OR "Contract-relax stretching":ti,ab OR "Cross-Friction Massage":ti,ab OR "Dry needle":ti,ab OR "Dry needles":ti,ab OR "Dry needling":ti,ab OR "Dynamic stretching":ti,ab OR Exercise:ti,ab OR Graston:ti,ab OR "Joint Mobilization":ti,ab OR Manipulation:ti,ab OR "Manual Therapy":ti,ab OR Massage:ti,ab OR cryotherapy:ti,ab OR cryotherapies:ti,ab OR thermotherapeutic:ti,ab OR thermotherapy:ti,ab OR thermotherapies:ti,ab OR "Moist Heat":ti,ab OR Ice:ti,ab OR diathermy:ti,ab OR "muscle stimulation":ti,ab OR "neuromuscular stimulation":ti,ab OR "electric muscle stimulation":ti,ab OR "neuromuscular electrical stimulation":ti,ab OR "transcutaneous electrical nerve stimulation":ti,ab OR "laser therapy":ti,ab OR "laser therapies":ti,ab OR iontophoresis:ti,ab OR cryo-cuff:ti,ab OR "therapeutic modalities":ti,ab OR "physical agents":ti,ab OR "physical modalities":ti,ab OR "physical interventions":ti,ab OR "Physical therapeutic":ti,ab OR "Physical therapy":ti,ab OR "Physical therapies":ti,ab OR Physiotherapy:ti,ab OR Physiotherapies:ti,ab OR Physiotherapeutic:ti,ab OR "passive modalities":ti,ab OR "Nerve Mobilization":ti,ab OR "osteopathic manipulative treatment":ti,ab OR orthotherapy:ti,ab OR orthotic*:ti,ab OR "proprioceptive neuromuscular facilitation":ti,ab OR stretching:ti,ab OR "Resistance Training":ti,ab OR "Strength Training":ti,ab OR "Soft-Tissue Therapy":ti,ab OR "Spray and stretch":ti,ab OR strengthen:ti,ab OR strengthens:ti,ab OR strengthening:ti,ab OR stretch:ti,ab OR stretches:ti,ab OR stretching:ti,ab OR "kinesiology tape":ti,ab OR "kinesiology taping":ti,ab OR "kinesio tape":ti,ab OR "kinesio taping":ti,ab OR "therapeutic tape":ti,ab OR "therapeutic taping":ti,ab OR "trigger point":ti,ab OR Yoga:ti,ab) | 170452 |
| 7 | 5 AND 6 | 1540 |

## APPENDIX B

## ARTICLE INCLUSION AND EXCLUSION CRITERIA

### Return to Play

| Inclusion | Exclusion |
|---|---|
| • Strain injury of 1 or more of the hamstring muscles<br>• 10 or more participants<br>• Primarily adult and adolescent (12 years old or older) participants<br>• Studies reporting on persons younger than 12 years old if the proportion in the sample is small (less than 5%) or if separate data are available for adults<br>• Includes the outcome of return to play, defined by any of the following terms: return/resume: play, sport, recreation, activity, competition<br>• Studies that follow participants from onset of injury to return to play | • Studies not published in English<br>• Fewer than 10 participants<br>• Primarily infant and child (younger than 12 years old) participants<br>• Surgical management of hamstring strain injury<br>• Any condition other than hamstring muscle strain injury, such as<br>- Adductor or quadriceps strain<br>- Contusions<br>- Tendinosis and tendinopathy, including of the hamstring muscles<br>- Fractures (including stress fracture and avulsion)<br>- Postoperative thigh pain from hip/knee surgery<br>- Compartment syndrome<br>- Nonmusculoskeletal thigh pain<br>- Primary peripheral nerve entrapment<br>- Peripheral vascular disease<br>- Tumors |

### Reinjury Risk

| Inclusion | Exclusion |
|---|---|
| • Strain injury of 1 or more of the hamstring muscles<br>• 10 or more participants<br>• Primarily adult and adolescent (12 years old or older) participants<br>• Studies reporting on persons younger than 12 years old if the proportion in the sample is small (less than 5%) or if separate data are available for adults<br>• Longitudinal studies that follow participants from onset of injury to reinjury | • Studies not published in English<br>• Fewer than 10 participants<br>• Primarily infant and child (younger than 12 years old) participants<br>• Surgical management of hamstring strain injury<br>• Any condition other than hamstring muscle strain injury, such as<br>- Adductor or quadriceps strain<br>- Contusions<br>- Tendinosis and tendinopathy, including of the hamstring muscles<br>- Fractures (including stress fracture and avulsion)<br>- Postoperative thigh pain from hip/knee surgery<br>- Compartment syndrome<br>- Nonmusculoskeletal thigh pain<br>- Primary peripheral nerve entrapment<br>- Peripheral vascular disease<br>- Tumors |

### Evaluation

| Inclusion | Exclusion |
|---|---|
| • Individuals with a hamstring strain injury of 1 or more of the hamstring muscles<br>• Studies that assess hamstring strain, including diagnosis (likelihood ratios, sensitivity and specificity, positive and negative predictive values, all pertinent evaluations, and patient-reported outcome measures in those with a hamstring strain)<br>• Outcome must include injury risk or occurrence<br>• 10 or more participants<br>• Primarily adult and adolescent (12 years old or older) participants<br>• Studies reporting on persons younger than 12 years old if the proportion in the sample is small (less than 5%) or if separate data are available for adults<br>• Diagnostic imaging (ultrasound, MRI, etc) for hamstring muscle strains<br>• Interventions within the scope of physical therapy practice | • Outcome that does not include injury risk or occurrence<br>• Fewer than 10 participants<br>• Primarily infant and child (younger than 12 years old) participants<br>• Diagnostic imaging (ultrasound, MRI, etc) for hamstring muscle tendon injuries<br>• Studies that include surgical management of hamstring strain injury<br>• Adductor or quadriceps strain, contusions<br>• Tendinosis and tendinopathy, including of the hamstring muscles<br>• Fractures (including stress fractures)<br>• Postoperative thigh pain from hip/knee surgery<br>• Compartment syndrome, nonmusculoskeletal thigh pain<br>• Primary peripheral nerve entrapment, peripheral vascular disease, tumors |

*Abbreviation: MRI, magnetic resonance imaging.*

## APPENDIX B

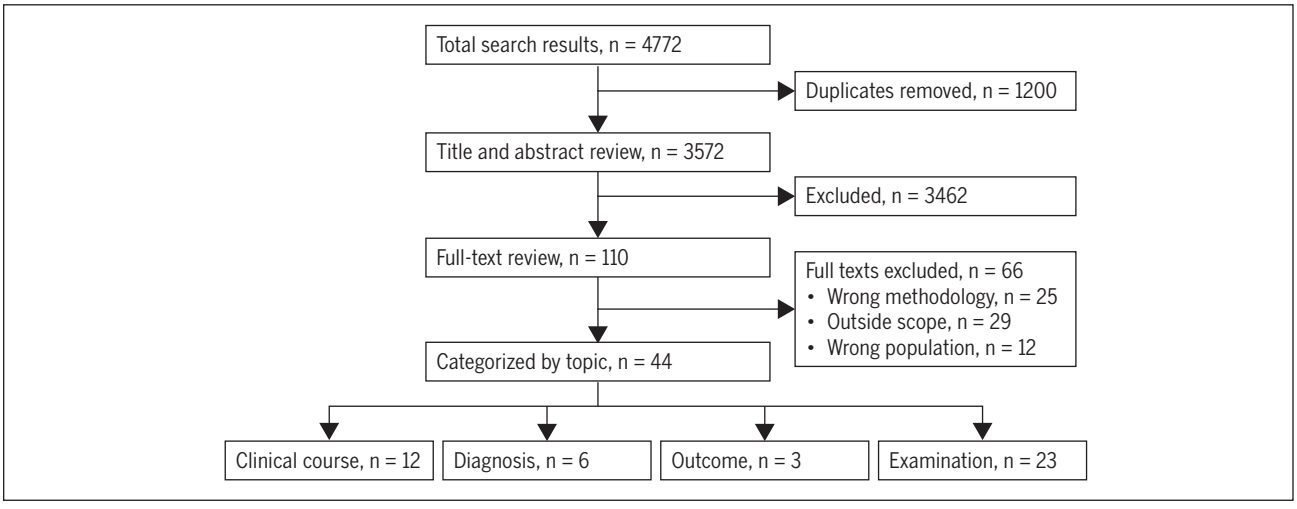
### Intervention

| Inclusion | Exclusion |
|---|---|
| Prevention<br>• Healthy individuals; a history of hamstring strain injury is acceptable<br>• Interventions within the scope of physical therapy practice<br>• Outcome must include injury risk or occurrence (longitudinal prospective)<br>• 10 or more participants<br>• Primarily adult and adolescent (12 years old or older) participants<br>• Studies reporting on persons younger than 12 years old if the proportion in the sample is small (less than 5%) or if separate data are available for adults<br>Rehabilitation<br>• Strain injury of 1 or more of the hamstring muscles<br>• Interventions within the scope of physical therapy practice<br>• 10 or more participants<br>• Primarily adult and adolescent (12 years old or older) participants<br>• Studies reporting on persons younger than 12 years old if the proportion in the sample is small (less than 5%) or if separate data are available for adults | Prevention<br>• Interventions not specifically targeting hamstring strain injury prevention<br>• Interventions outside the scope of physical therapy practice<br>• Outcome that does not include injury risk or occurrence<br>• Fewer than 10 participants<br>• Primarily infant and child (younger than 12 years old) participants<br>Interventions<br>• Interventions outside the scope of physical therapy practice<br>• Fewer than 10 participants<br>• Primarily infant and child (younger than 12 years old) participants<br>• Surgical management of hamstring strain injury<br>• Any condition other than hamstring muscle strain injury, such as<br>- Adductor or quadriceps strain<br>- Contusions<br>- Tendinosis and tendinopathy, including of the hamstring muscles<br>- Fractures (including stress fractures)<br>- Postoperative thigh pain from hip/knee surgery<br>- Compartment syndrome<br>- Nonmusculoskeletal thigh pain<br>- Primary peripheral nerve entrapment<br>- Peripheral vascular disease<br>- Tumors |

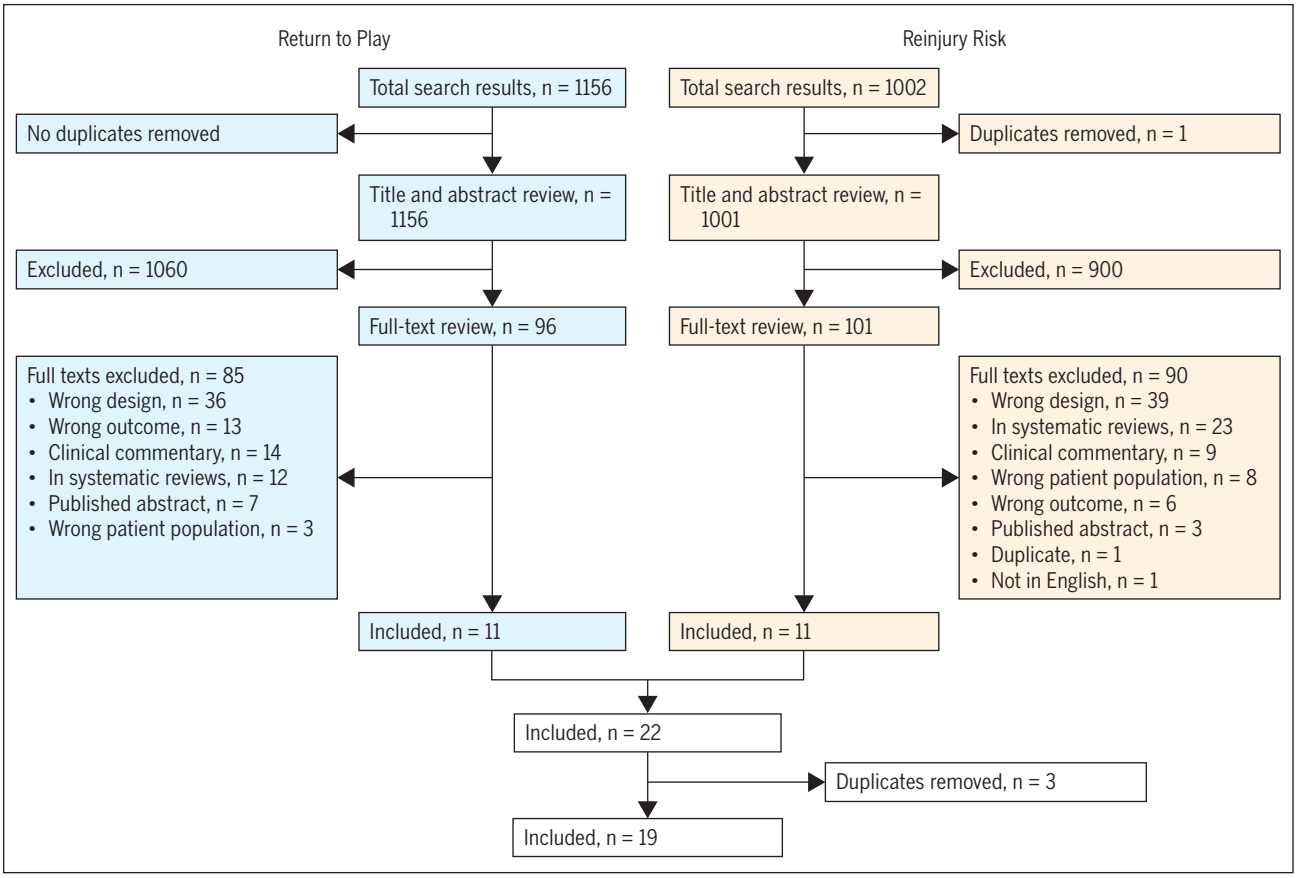
## APPENDIX C

# FLOW CHARTS OF ARTICLES

## Evaluation

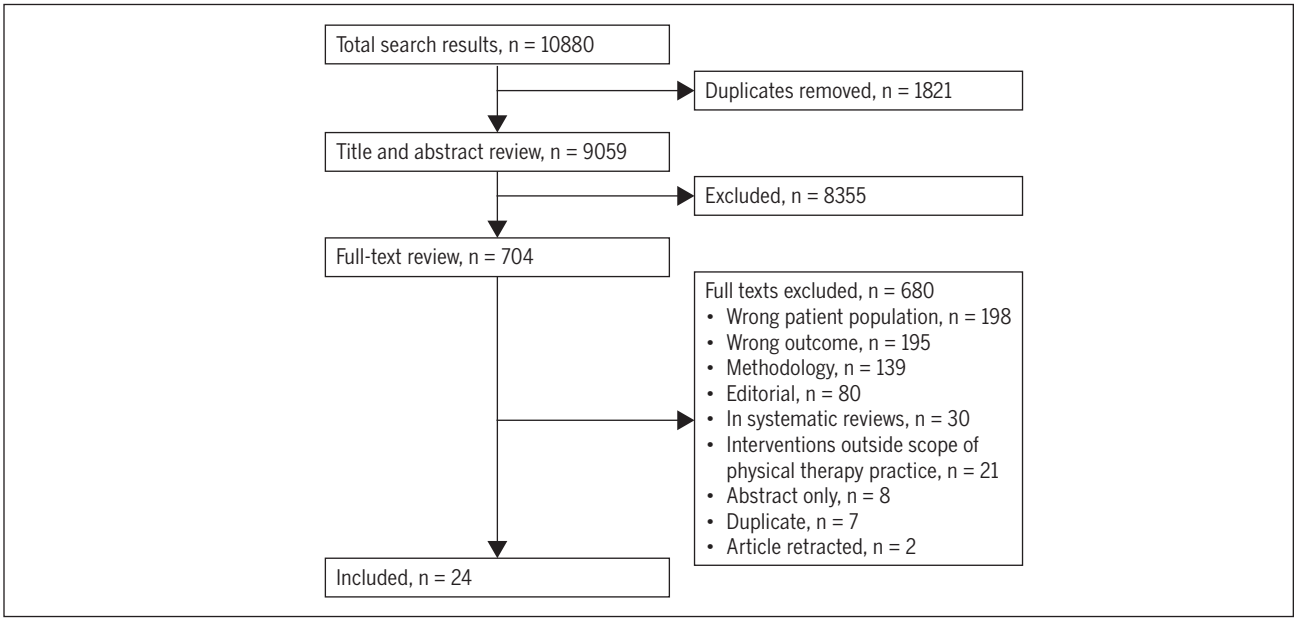



## Return to Play and Reinjury Risk



## APPENDIX C

### Injury Prevention and Intervention



## APPENDIX D

### LEVEL-OF-EVIDENCE TABLE[a]

| Level | Intervention/Prevention | Pathoanatomic/Risk/Clinical Course/Prognosis/Differential Diagnosis | Diagnosis/Diagnostic Accuracy | Prevalence of Condition/ Disorder | Exam/Outcomes |
|---|---|---|---|---|---|
| I | Systematic review of high-quality RCTs<br>High-quality RCT[b] | Systematic review of prospective cohort studies<br>High-quality prospective cohort study[c] | Systematic review of high-quality diagnostic studies<br>High-quality diagnostic study[d] with validation | Systematic review, high-quality cross-sectional studies<br>High-quality cross-sectional study[e] | Systematic review of prospective cohort studies<br>High-quality prospective cohort study |
| II | Systematic review of high-quality cohort studies<br>High-quality cohort study[c]<br>Outcomes study or ecological study<br>Lower-quality RCT[f] | Systematic review of retrospective cohort study<br>Lower-quality prospective cohort study<br>High-quality retrospective cohort study<br>Consecutive cohort<br>Outcomes study or ecological study | Systematic review of exploratory diagnostic studies or consecutive cohort studies<br>High-quality exploratory diagnostic studies<br>Consecutive retrospective cohort | Systematic review of studies that allows relevant estimate<br>Lower-quality cross-sectional study | Systematic review of lower-quality prospective cohort studies<br>Lower-quality prospective cohort study |
| III | Systematic reviews of case-control studies<br>High-quality case-control study<br>Lower-quality cohort study | Lower-quality retrospective cohort study<br>High-quality cross-sectional study<br>Case-control study | Lower-quality exploratory diagnostic studies<br>Nonconsecutive retrospective cohort | Local nonrandom study | High-quality cross-sectional study |
| IV | Case series | Case series | Case-control study | | Lower-quality cross-sectional study |
| V | Expert opinion | Expert opinion | Expert opinion | Expert opinion | Expert opinion |

*Abbreviation: RCT, randomized clinical trial.*

[a]*Adapted from Phillips B, Ball C, Sackett D, et al. Oxford Centre for Evidence-Based Medicine: levels of evidence (March 2009). Available at: https://www.cebm.ox.ac.uk/resources/levels-of-evidence/oxford-centre-for-evidence-based-medicine-levels-of-evidence-march-2009. Accessed January 26, 2021. See also* **APPENDIX E**.

[b]*High quality includes RCTs with greater than 80% follow-up, blinding, and appropriate randomization procedures.*

[c]*High-quality cohort study includes greater than 80% follow-up.*

[d]*High-quality diagnostic study includes consistently applied reference standard and blinding.*

[e]*High-quality prevalence study is a cross-sectional study that uses a local and current random sample or censuses.*

[f]*Weaker diagnostic criteria and reference standards, improper randomization, no blinding, and less than 80% follow-up may add bias and threats to validity.*

## APPENDIX E

### PROCEDURES FOR ASSIGNING LEVELS OF EVIDENCE

- Level of evidence is assigned based on the study design, using the levels-of-evidence table (**APPENDIX D**), assuming high quality (eg, for intervention, randomized clinical trial starts at level I)
- Study quality is assessed using the critical appraisal tool, and the study is assigned 1 of 4 overall quality ratings, based on the critical appraisal results
- Level of evidence assignment is adjusted based on the overall quality rating
  - High quality (high confidence in the estimate/results): the study remains at its assigned level of evidence (eg, if the randomized clinical trial is rated high quality, then its final assignment is level I). High quality should include
    - Randomized clinical trial with greater than 80% follow-up, blinding, and appropriate randomization procedures
    - Cohort study includes greater than 80% follow-up
    - Diagnostic study includes a consistently applied reference standard and blinding
    - Prevalence study is a cross-sectional study that uses a local and current random sample or censuses
  - Acceptable quality (the study does not meet requirements for high quality and weaknesses limit the confidence in the accuracy of the estimate): downgrade 1 level
    - Based on critical appraisal results
  - Low quality: the study has significant limitations that substantially limit confidence in the estimate: downgrade 2 levels
    - Based on critical appraisal results
  - Unacceptable quality: serious limitations—exclude from consideration in the guideline
    - Based on critical appraisal results