Chapter 18
Hamstring Injury

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Introduction

Hamstring strains and tears are among the most common injuries seen in sports. Involvement of the distal hamstring is a rare yet important consideration in the evaluation of a pediatric patient with posterior knee pain. Understanding the contributions of the hamstring to knee function lays a foundation for how injuries to these muscles cause dysfunction and pain at the knee. This chapter's aim is to provide an overview of the hamstring complex, pathology associated with its distal components, and spectrum of treatments available to improve function and pain outcomes.

Anatomy and Function

The hamstrings are a group of three biarticular muscles, crossing both the hip and knee joints posteriorly. During the gait cycle, the hamstring muscles antagonize the quadriceps and are responsible for both hip extension and knee flexion with concentric contraction. At higher speeds, this group of muscles plays a role in deceleration of both hip flexion and knee extension with eccentric contraction. Additionally, the hamstrings serve to stabilize both the hip and knee joints throughout the gait cycle. The distal hamstring tendons act in conjunction with the anterior cruciate ligament (ACL) to prevent anterior tibial translation; therefore, hamstring strengthening has

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N. Coleman (ed.), *Common Pediatric Knee Injuries*,
https://doi.org/10.1007/978-3-030-55870-3_18

become an important component of ACL prevention programs [1]. Each of these muscles has a large distal tendon that originates deep within the muscle belly and runs close to the entire length of the muscles [2]. The central tendon is attached to the muscle fibers in a symmetric pennate arrangement, like a feather. These long tendons allow for a “spring” effect of contraction and lengthening that accentuates performance but also leads to injury susceptibility [3]. From medial to lateral, this muscle group includes the semimembranosus, the semitendinosus, and the biceps femoris (Fig. 18.1).

The semimembranosus originates from the superolateral portion of the ischial tuberosity of the pelvis. The proximal tendon of the semimembranosus is the longest proximally of the three hamstring muscles and courses both medial and anterior to the other muscles of the posterior thigh [4]. The muscle belly of the semimembranosus is the largest of the three, generating the greatest force but also the slowest velocity [5]. The distal tendon of the semimembranosus inserts on the posterior aspect of the medial tibial condyle. The distal tendon of the semimembranosus crosses that of the medial gastrocnemius at the posteromedial knee. This intersection has been identified as the most common location for the “stalk” of a

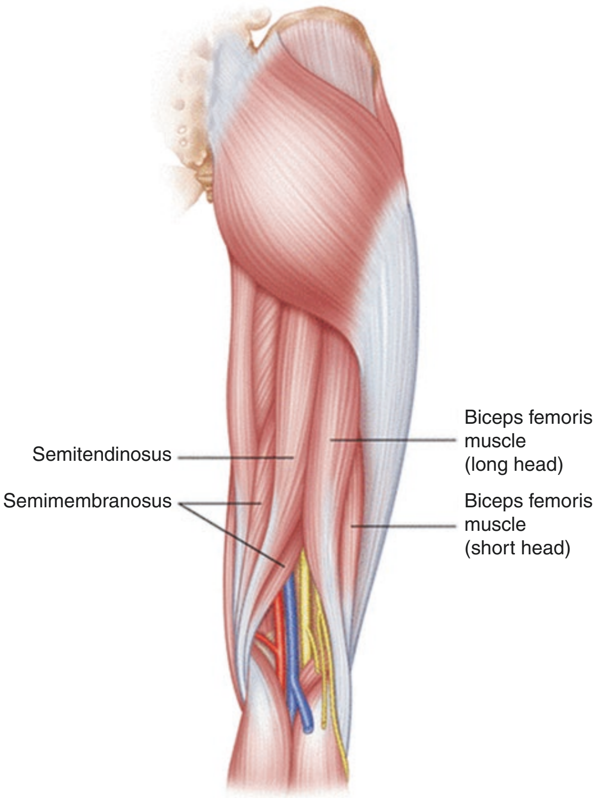

Fig. 18.1 Hamstring anatomy

popliteal cyst. There is a chapter on popliteal cyst, which can provide more information on that condition.

The semitendinosus and long head of the biceps femoris originates from the inferomedial portion of the ischial tuberosity dividing from a conjoint tendon to become two separate muscles. The semitendinosus is named for its long distal tendinous component formed at the midpoint of the posterior thigh, and the longest distal tendon of the three hamstrings [1]. The distal tendon courses medially over the medial femoral condyle, to the anterior medial tibia condyle, where it joins the tendons of the gracilis and sartorius to form the pes anserine. There is a chapter on pes anserine pain, which can provide more information on that condition.

From the conjoint tendon the long head of the biceps femoris courses laterally down the thigh deep to the Iliotibial band. The short head of the biceps originates from the lateral supracondylar ridge of the femur, thus acting only at the knee joint and not at the hip. The origin of the short head of the biceps is commonly used as the level to differentiate a proximal from distal hamstring injury [6]. The distal tendons of the long and short heads of the biceps femoris form a complex network of attachments to the fibular head, the iliotibial band, the lateral collateral ligament, the posterior lateral tibial condyle, and the posterolateral joint capsule at the level of the posterior horn of the lateral meniscus [7]. This complex is key to providing rotatory stability to the posterolateral corner of the knee. There is a chapter on posterolateral corner injury, which can provide more information on that condition.

The semimembranosus, semitendinosus, and long head of the biceps femoris are innervated by the tibial component of the sciatic nerve, primarily the L5 nerve root but with additional input from S1 and S2. The medial hamstring reflex can be used to evaluate the L5 nerve root. The short head of the biceps femoris is innervated by the common fibular branch of the sciatic nerve and can be tested in electromyography as the last muscle innervated before the common fibular nerve crosses the fibular head, a common site of entrapment or injury.

Pathology and Dysfunction

The powerful and complex hamstring muscle group is highly vulnerable to injury. Hamstring injuries account for up to 29% of all injuries in athletes [8]. In the pediatric, skeletally immature athlete, the weakest link in the kinetic chain is the ischial apophysis, which begins to ossify between the ages of 15 and 17. This apophysis does not fuse to the ischium until the ages of 19 to 25 [9]. Injuries to the hamstrings themselves are more common proximally than distally. The most common location of muscle injury is the proximal myotendinous junction [6, 10, 11]. These proximal injuries are out of the scope of this book on knee injuries, and the remainder of this chapter will focus on middle-to-distal hamstring injuries.

Hamstring injuries are typically the result of an eccentric muscle contraction or elongation against contraction and not caused by contact. Hamstring injuries range from a mild strain to a complete rupture. In the mildest injuries, only the myofibrils are damaged, releasing creatine kinase and resulting in pain. More severe injuries involve disruption of the extracellular matrix, fascia, and myotendinous architecture with the release of muscle enzymes, collagen and proteoglycan degradation, and local inflammation. When this damage involves the blood vessels supplying the muscle, this leads not only to increased bleeding and bruising but can result in a local ischemic environment, leading to additional muscle damage and impaired healing.

Various factors have been identified for their contribution to hamstring injuries, including but not limited to the following: high training volume, poor hamstring and quadriceps flexibility, poor muscle strength, improper or no warm-up, muscle fatigue and overexertion, and various anatomic imbalance of muscle strength and posture [3]. Many of these factors are especially applicable to the pediatric and adolescent athlete. For example, during periods of rapid growth, hamstring flexibility and muscle balance is lacking, potentially leading to increased risk of injury.

Specific Pointers

Epidemiology

A systematic review and meta-analysis of risk factors for hamstring injury in sport by Frecklton and Pizzari identified age as a significant risk factor for hamstring injury, with athletes over the age of 23 at an increased risk (OR:2.46, 95% CI 0.98 to 6.14, $p = 0.06$) [12]. Gabbe et al. attributed the increased risk with age to significant differences in hip flexor flexibility, hip internal rotation, and ankle dorsiflexion range of motion, total body weight, and body mass index, when comparing athletes older or younger than 20 years of age [13]. The majority of studies on hamstring injuries in athletes report highest incidence between 18 and 30 years of age. Valle et al. reported on 50 hamstring injuries among a large cohort of 1157 young athletes with an average age of 13.56 years and with the youngest hamstring injury occurring in a 9-year-old. They reported an age-related increased rate of injury with a peak incidence at age 17 [14]. Most commonly, hamstring injuries are seen in sports that involve explosive running, rapid acceleration and deceleration, kicking, and hurdling, including soccer, football, track and field, and dance.

Mechanism of Injury

The mechanism of hamstring injuries most commonly is an acute tensile overload. This can happen anywhere along the length of the hamstring from the proximal insertion on the ischial tuberosity, the proximal muscle tendon, the intramuscular area, the distal muscle tendon junction, or the distal insertions on the tibia and fibula [3]. Regardless of the location, acute hamstring injuries occur, most commonly, while sprinting full speed or attempting to overstride, immediately before or after foot contact. Distal hamstring injuries are often seen with hyperextension of the knee [15].

Hamstring injuries, less commonly, occur with chronic low-grade tensile overload forces, leading to microtear and tendinosis, or in the skeletally immature athlete apophysis at the bony origin.

Diagnosis: History and Exam Findings, Testing

History

With an acute hamstring injury, most athletes report a sudden sharp pain to the posterior thigh or knee. Injuries can occur with hip flexion and knee extension or hip extension with knee extension. The history may or may not include the report of a single identifiable stride as the cause of injury or an audible or palpable "pop." In a case series of professional soccer players with acute hamstring injuries, the timing of the injury was not discernible on video analysis [16]. Athletes who have sustained distal hamstring injuries often report a knee hyperextension moment and a sense of knee instability [15].

Physical Exam

After hamstring injury, most athletes present with a "stiff-legged" gait pattern in an attempt to avoid simultaneous hip flexion and knee extension [17]. While examining the patient in the prone position, there may or may not be swelling or ecchymosis to the posterior thigh or knee (Fig. 18.2). Ecchymosis can be an indication of a more severe injury, indicating significant macrotearing of the hamstring.

Despite the location of pain or bruising, the exam should include the entire hamstring from ischial tuberosity down to the distal insertions on the tibia and fibula. Palpatory exam may reveal a focal defect, secondary to muscle retraction, or, more consistently, focal tenderness over the muscle, tendon, or bony insertion.

In the prone position, hamstring strength should also be assessed with the knee flexed to 90 degrees against the examiner's forced extension to 30 degrees and compared to the contralateral side. This position reproduces an eccentric load to the hamstring and may help to identify the location of injury more precisely. Higher-grade injuries may demonstrate decreased knee flexion strength; however, diminished strength may also be a result of fear avoidance or guarding in more mild injuries.

Fig. 18.2 Posterior thigh ecchymosis

Range of motion should be assessed in the supine position, assessing the popliteal angle with the hip and knee both flexed to 90 degrees and slowly extending the knee. This should be compared to the contralateral side.

Inspection, palpation, strength, and range of motion are often sufficient to identify a hamstring injury, but the Puranen-Orava test and bent-knee stretch test are specialized tests with moderate-to-high validity and reliability in identifying both proximal hamstring tendinopathy and strain; they may also be positive with a distal hamstring injury [18]. The bent-knee stretch test is performed in the supine position with the knee and hip placed into full flexion. The knee is then extended with reproduction of pain indicating a positive finding. The Puranen-Orava test is performed in a standing position with the knee fully extended and foot on a low-lying table. The spine is then flexed forward with a positive exam reproducing pain.

If a distal hamstring pathology is suspected, the physical exam should also include an evaluation of the other structures of the posterolateral corner. This should include a varus stress test of the lateral collateral ligament (LCL), a posterolateral drawer test (posterior drawer test with foot externally rotated to 15 degrees), and a dial test. Please refer to the chapter on posterolateral corner injury for more information.

Testing

The physical exam is the most beneficial diagnostic tool for most hamstring injuries; however, in skeletally immature athletes, and in those in which an insertional injury is suspected, radiographs should be obtained to evaluate for a bony avulsion. This includes an AP view of the pelvis to evaluate the ischial tuberosity or an AP and lateral view of the knee to evaluate for distal avulsion fractures.

To grade the extent of injury better, soft tissue imaging modalities can be very helpful, as well. Point-of-care musculoskeletal ultrasound (US) can be used to evaluate the hamstring from origin to insertion for convenient, timely, and reliable information in the clinic or training room. Detected abnormalities can range from a bony avulsion with displacement of the hyperechoic bony cortex, a tendon or muscle tear or rupture with hypoechoic signal within a muscle or tendon, or a more subtle partial tear or strain with loss of the normal muscle or tendon architecture and surrounding edema or hematoma. US can also be used to monitor interval healing of a hamstring injury. An added benefit of US is directly correlating a region of pain on palpation with pathologic changes. US has been shown to be as sensitive as magnetic resonance imaging (MRI) in imaging acute hamstring injuries, though it is important to mention that the diagnostic utility of US is highly operator dependent [19].

A noncontrast MRI of the thigh has been shown to be more reliable than US for deeper hamstring injuries and, therefore, frequently viewed as the modality of choice due, in part, to the reliability and availability across institutions [19]. A T2 hyperintense signal on MRI represents muscle or tendon edema or hemorrhage in the setting of acute injury. Sagittal and coronal sequences on MRI can also best longitudinally approximate the amount of muscle or tendon retraction in complete avulsions or ruptures. When there is a concern for a severe distal hamstring injury and knee instability, a noncontrast MRI of the knee is best to evaluate and differentiate the extent of a distal hamstring injury in the setting of concomitant posterior lateral corner injuries, as outlined above.

Management

Goals in managing hamstring injuries are focused on returning an athlete to his/her prior level of function while minimizing risk for reinjury.

Initial management strategies depend on the severity of the injury. In the most severe situation of a complete distal hamstring avulsion injury, surgical referral should be urgent [20], though the more common scenario of hamstring strains will follow a three-phase progressive rehabilitation protocol.

Phase 1 in rehabilitation, the acute phase, focuses on the reduction in pain and edema and on the prevention of excessive scar formation. The RICE (rest, ice, compression, elevation) protocol can be used during this phase of healing. Nonsteroidal anti-inflammatories (NSAIDs) or acetaminophen can be used for pain reduction during this phase. There lacks consensus around the use of NSAIDs during this early phase in recovery, as some data have shown NSAIDs impair muscle function and recovery, when used in this phase [21]. Immobilization can be considered but should be limited to less than 4 days to prevent excessive scar formation [22]. Short-term immobilization can also prevent excessive scar formation and contracture [23]. Range of motion during this phase is important but should be within a protected range of motion. A shortened stride with ambulation is recommended. The use of crutches is considered, when the injury is higher grade and the patient's functionally is limited. Avoidance of resistance training during this phase is also strongly recommended, and progressive agility and trunk stabilization exercises should be performed at only low-to-moderate intensity. Progression to phase II can occur when there is a normal, nonantalgic gait; the ability to jog pain free at low speed; and the ability to perform an isometric hamstring contraction in prone knee flexion at 90 degrees with at least 50–70% the total resistance force of the uninjured contralateral hamstring [24].

Phase II, the subacute phase, will focus on pain-free range of motion, correction of muscle imbalances, neuromuscular control, and low resistance eccentric loading of the hamstring. Emphasis is placed on a progressive increase in intensity and speed of exercises for neuromuscular control, agility, and trunk stability, based on tolerance. Strength should be maximized in mid ranges of motion. End range of motion loading should be limited during this phase in recovery. Pain medications during this phase can lead to overwork and further injury of the healing hamstring; therefore, they are generally not recommended during this phase of rehabilitation. Ice is the pain relief option of choice in this phase of recovery. Completion of this phase occurs with two specific parameters. The first is a pain-free isometric contraction with full resistance in a prone position and the knee flexed to 90 degrees. The second is the ability to jog both forward and backward at 50% maximum speed. This phase is the preparation phase for exercises specific for return to sport or activity [24].

Phase III will focus on higher level neuromuscular control and eccentric loading exercises. Multidirectional movement activities and an increase to full strength utilization at end ranges of motion should be emphasized during this phase. Return to activity criteria include lack of palpatory tenderness over the injury, full concentric and eccentric strength without pain, and absence of kinesiophobia [24].

Injectable Therapeutic Options

There is very limited data on the use of corticosteroids for the treatment of hamstring strains. Levine et al. looked retrospectively at a group of 58 professional football players, who received corticosteroid injection within 72 hours of hamstring strain onset. Their primary conclusion was that steroids did not cause any detrimental side effects and that there may be an accelerated recovery time for return to play [25]. Corticosteroids have been shown to be both myotoxic and tenotoxic [26], and data are lacking on a proven benefit.

Platelet-rich plasma, most commonly known as “PRP,” is a regenerative medicine treatment that involves injecting a concentrated solution of platelets into a damaged area within the body to enhance the body’s own ability to heal. It is considered to both accelerate healing early during injury recovery and to promote healing when rehabilitation efforts have not resolved pain and functional limitations. PRP has been shown to increase the expression of myogenic molecules within the body, thereby modulating anabolic and myogenic responses to injury [27]. Studies have both supported and refuted the efficacy of PRP injection for accelerated return to play after hamstring injury and prevention of injury recurrence. Rossi et al. used return to play and recurrence rate as outcome measures in a study comparing PRP injections (34 patients) to control (38 patients) with hamstring injuries [28]. Rehabilitation course post-injection was standardized [28]. Mean time to play was 4.9 days faster in the PRP versus control group ($p = 0.001$) [28]. In this study, the rate of recurrence did not show a statistical difference between the groups [28].

Sheth et al. published a systematic review looking at the benefit of PRP on a standard return-to-play rehabilitation program for a variety of muscle injuries. This study looked at 268 athletes across five studies with follow-up at 12 months [29]. When incorporating all muscle groups, there was a six-day decrease in return to sport noted in those who received a PRP injection; however, with a subgroup analysis focusing just on hamstrings, there was not a noted difference between control and PRP groups [29].

Another paper by Reurink et al. did not find a difference between hamstring reinjury rates in athletes who received PRP injections in acute hamstring strains versus those who did not [27].

Additional high-level randomized controlled trials that standardize for the intrinsic makeup of PRP being used are needed to confirm whether there is truly a benefit in using platelet-rich plasma injections for hamstring injuries.

Injury Prevention

Hamstring strains occur during excessive eccentric loading of the muscle tendon unit; therefore, eccentric strengthening has been proven to be the mainstay of hamstring injury prevention. Specifically, the Nordic hamstring lowering exercise has been shown to be effective in limiting recurrence of injury [22]. (Fig. 18.3) This exercise is performed with the athlete in an upright kneeling position. The feet and calves are stabilized by an assistant, and the patient maintains the hips and knees in parallel. The patient then lowers his body (from knees to chest) to the floor in a controlled fashion. Research has shown that use of the Nordic hamstring exercise reduces the rate of hamstring strains by more than 60% and reduces the rate of

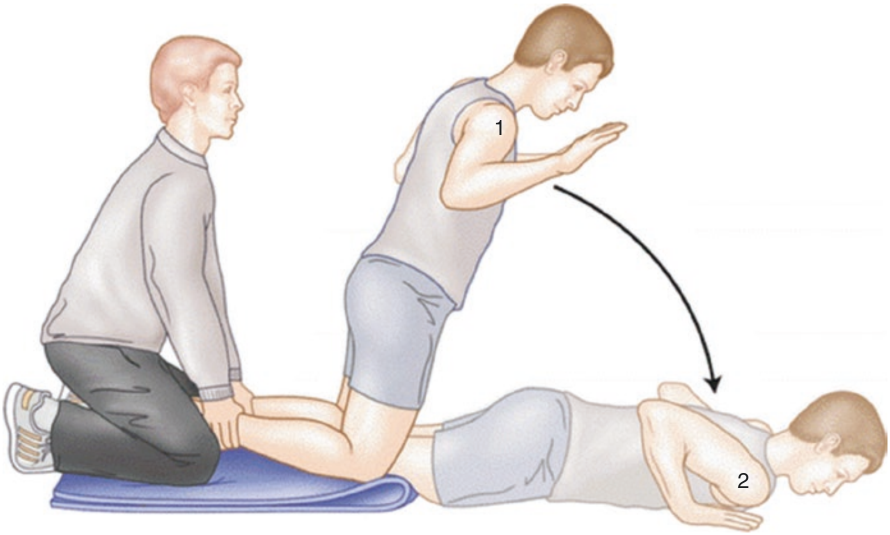

Fig. 18.3 Nordic hamstring exercise

recurrence by 85% [22]. The addition of neuromuscular control exercises of the lumbopelvic and lower extremity region have also been shown to help prevent injury [23]. Lastly, varying trunk positions for activity or sport-specific drills has been shown to reduce the hamstring injury occurrence rate [24]. Another key prevention strategy, especially in the pediatric athlete, is maintenance of good hamstring flexibility.

Demonstration Cases

Common Presentation

A 17-year-old female soccer player chases a ball to prevent it from going out of bounds. The sudden increase in speed causes a severe sharp pain with an associated snapping sensation in the posterior thigh. The player is able to limp off the field with support. There is no immediate bruising or ecchymosis. Tenderness is appreciated along the distal third of the posterolateral thigh. No palpable focal defects are appreciated. Knee range of motion incites pain over the region. Lachman maneuver, anterior drawer test, McMurray's, and dial test of the knee are all negative. There is reproducible pain with knee flexion strength testing. A point-of-care US performed in the locker room 3 hours post-injury shows small areas of hypoechogenicity involving 25% of the distal myotendinous junction of the hamstring.

A moderate distal hamstring strain of the biceps femoris is diagnosed. The player should be taken through a structured and graduated rehabilitation program as noted above, followed by a return-to-play protocol.

Uncommon Presentation

A 14-year-old male football player begins to develop posterolateral knee pain insidiously through the preseason football practices of his freshman year. He does not recall a specific event but rather a discomfort-like feeling that slowly becomes more noticeable. His only prior medical history is a history of Osgood-Schlatter disease 2 years ago. He feels the pain predominantly, when his foot is planted with the knee in full extension or hyperextension. The pain noticeably limits his ability to move at full speed.

He comes into the clinic for evaluation. On exam, he exhibits no focal defects in muscle structure, no visible knee effusions anterior or posterior, and no skin discoloration. He is tender over the posterolateral knee. He has full knee range of motion and strength testing. Popliteal angle is only 45 degrees bilaterally. He has a negative anterior drawer, Lachman, McMurray's, Thessaly's, and dial test. He does have a positive bent-knee stretch test and Puranen-Orava test. Simulated sprinting in the clinic reproduces pain. X-rays do not reveal any bony abnormalities or avulsion. No further imaging is indicated.

His diagnosis is consistent with a mild strain of the distal hamstrings, as a result of poor flexibility. Rehabilitation for this type of injury would focus on a progressive rehabilitation program of the hamstring (as noted above) and on hip flexor stretching, followed by return-to-play protocol.

Pearls and Pitfalls

- Acute isolated distal hamstring injuries are rare, and special consideration should be given to a full knee evaluation to rule out concomitant posterolateral corner injury.
- Hamstring injury recurrence rates are high and most often seen in the first 3 weeks of return to sport.
- The Nordic hamstring strengthening exercise has been proven to be beneficial in injury prevention.

Chapter Summary

Distal hamstring injuries are rare but an important injury consideration in the differential diagnosis of posterior thigh and knee pain in the adolescent patient. It is important to understand that the hamstring is a biarticular tendon-muscle complex that crosses both the hip and knee. This makes it susceptible to both stretch and eccentric load type injuries. Rehabilitation from distal hamstring injuries can be achieved with a graduated protocol and progressive return to play. Platelet-rich plasma injections have not been rigorously studied to prove efficacy in strain-like injuries, though safety of use has been identified in the available literature [27–29]. Prevention is aimed at maintaining flexibility and working on progressive eccentric loading exercises, with the Nordic hamstring lowering exercise proving to be superior in prevention management [23].

Chart/Table for Review

Condition	Hamstring Injuries
Description	Acute or chronic strain of biarticular muscle crossing the hip and knee at the posterior thigh
Epidemiology	Age-related increased rate with a peak incidence at age 17 Explosive sports involving rapid acceleration and deceleration, kicking, and hurdling
Mechanism (common)	Hyperextension of the knee Excessive eccentric load with hip flexed and knee extended
History and exam findings	Audible pop with inability to continue play Ecchymosis and/or palpable defect Pain with passive stretch of knee extended with hip flexed
Management	Graduated rehab protocol Focus on hamstring stretching and eccentric loading Progressive return to sport

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