US Assessment of Sports-related Hip Injuries[1]

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Abbreviations: AIIS = anterior inferior iliac spine, GTPS = greater trochanteric pain syndrome, ITB = iliotibial band, RICE = rest, ice, compression, and elevation

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SA-CME LEARNING OBJECTIVES

After completing this journal-based SA-CME activity, participants will be able to:

- Identify the normal soft-tissue anatomy of the hip at US.
- Describe the surface anatomy landmarks used to perform an efficient US examination of the anterior, lateral, and posterior hip compartments.
- Discuss common sports-related injuries of the anterior, lateral, and posterior hip compartments.

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Traumatic and overuse hip injuries occur frequently in amateur and professional athletes. After clinical assessment, imaging plays an important role in diagnosis and in defining care management of these injuries. Ultrasonography (US) is being increasingly used in assessment of hip injuries because of the wide availability of US machines, the lower cost, and the unique real-time imaging capability, which allows both static and dynamic evaluation as well as guidance of point-of-care interventions such as fluid aspiration and steroid injection. Accurate diagnosis of hip injuries is often challenging, given the complex soft-tissue anatomy of the hip and the wide spectrum of injuries that can occur. To conduct a skillful US evaluation of hip injuries, physicians must have pertinent knowledge of the normal anatomy and should make judicious use of surface anatomy landmarks while using a compartmentalized diagnostic approach. In this article, common sports-related injuries of the anterior, lateral, and posterior hip compartments are discussed. This review includes assessment of joint effusion, acetabular labral tear, acute and chronic tendon injuries including tendinopathy, partial and full-thickness tears, snapping hip syndromes, relevant US-guided procedures, and some other conditions such as Morel-Lavallée lesion and perineal nodular induration. Principles of care management and current knowledge on imaging findings that may affect return to activity are also presented. Using an oriented US examination technique and having knowledge of the normal hip anatomy will help physicians characterize US findings of common sports-related hip injuries and make accurate diagnoses.

Online supplemental material is available for this article.

Introduction

Ultrasonographic (US) evaluation of the hip is a powerful tool in the hands of a skilled operator. It allows a cost-effective targeted assessment based on patient symptoms, especially when combined with a concurrent physical examination. Moreover, US has also been found to be useful in guiding diagnostic and therapeutic interventions. When compared with other imaging modalities, the benefits include lack of ionizing radiation, portability, speedy assessment, ability to compare findings with those of the contralateral side in a timely manner, and potential cost savings (1). Above all, the unique advantage of US over other imaging modalities is its real-time imaging capability, which allows evaluation while patients move their extremities, contract their muscles, or change position or while the operator applies compression with the probe, to help distinguish fluid from more solid lesions or evaluate for pain and reproducibility of symptoms with sonopalpation.

TEACHING POINTS

- Acquiring cine loops while dynamically evaluating a joint allows more detailed and careful analysis of subtle, quickly occurring, or transient abnormalities, such as peroneal tendon subluxation, which may be apparent only during maneuvers or in certain positions.
- Hip joint effusion is an indirect sign of intra-articular disease and has a wide differential diagnosis that includes inflammatory, traumatic, and other pathologic conditions. In cases of a simple joint effusion, the fluid may appear anechoic or hypoechoic. A more complex joint effusion resulting from inflammatory debris, hemorrhage, cartilage fragments, or crystals may appear hypo- to hyperechoic; however, these signs are nonspecific.
- The presence of a paralabral cyst at MR imaging or US is often taken as a *sine qua non* of a labral tear, whether it is seen at imaging or not.
- A snapping iliopsoas phenomenon can occur in up to 40% of the asymptomatic population and does not necessarily require further investigation.
- The musculotendinous junction is the most vulnerable area of the hamstring muscle complex in adults and is easily predisposed to strain injuries. The long head of the biceps femoris is the most commonly implicated, followed by the semitendinosus and semimembranosus muscles in equal measure.

An efficient hip US examination requires a thorough understanding of its complex anatomy. A structured approach based on identification of important surface anatomy landmarks and compartmentalization of the internal anatomy into anterior, lateral, and posterior aspects can significantly simplify the task. For sports physicians, US is especially valuable in assessment, management, and prognostic evaluation of hip musculotendinous injuries, which represent 14% of all injuries in professional association football players and approximately 6% of all sports injuries affecting the hip in the adult (2). Conversely, US is limited in its ability to assess osteoarticular injuries about the hip and groin area, such as fractures, femoroacetabular impingement, labral tears, and articular cartilage injuries. These are generally more advantageously evaluated using radiography, computed tomography (CT), or magnetic resonance (MR) imaging, although in certain conditions US may allow acquisition of additional complementary findings (3,4).

An important concern for amateur or professional athletes with an injury is the delay in returning to their activity. Traditionally, return to activity guidelines are based on clinical concepts such as painless activity and restoration of strength and flexibility to those of the contralateral side or to preinjury levels. It has been suggested that imaging features may assist in prognostic assessment, thus potentially shaping the recovery track of injured athletes (5).

In this review, we present the most common sports-related hip injuries that can be assessed using US, describe surface anatomy landmarks and a compartmentalized approach to performing an efficient hip US examination, and discuss principles of care management, including current knowledge on imaging features that may affect return to activity guidelines.

General Considerations

US examination of the hip will generally be directed to the anterior, lateral, or posterior compartments on the basis of the patient's clinical presentation, and the position in which the patient will be examined is determined accordingly.

An array of transducers may be used for an adequate US assessment of the hip, depending on patient body habitus and the depth of the assessed structures. Broad-bandwidth high-frequency (5–12 MHz) linear probes may be employed to evaluate more superficial structures with adequate spatial resolution. Lower-frequency (3–6 MHz) curvilinear probes allow better visualization of deep structures or in larger patients. Color or power Doppler techniques may be employed to differentiate vascular structures from neighboring anatomy or to assess the vascularity of identified disease.

However, as the Doppler signal of deeper structures can be difficult to detect, findings should be interpreted with caution. All imaged structures should be visualized in the short and long axes, and comparison with the contralateral limb should be performed as necessary. Acquiring cine loops while dynamically evaluating a joint allows more detailed and careful analysis of subtle, quickly occurring, or transient abnormalities, such as peroneal tendon subluxation, which may be apparent only during maneuvers or in certain positions.

At US, normal muscle appears as parallel hypoechoic fascicles of muscle fibers that are surrounded by the echogenic linear septa of perimysium; the muscle fibers converge toward the hyperechoic musculotendinous junction in a pennate configuration (6). The muscle is globally surrounded by epimysium, which appears as a thick layer of hyperechoic fascia that demarcates the muscle boundaries. At US, normal tendon appears as parallel, echogenic, fibrillar structures on longitudinal images and as echogenic dots or lines on transverse images (7).

The appearance of acute or subacute muscle or musculotendinous junction strains at US ranges from subtle hypoechoic areas with minimal fiber disruption to partial or complete fiber discontinuity and muscle retraction, surrounded by fluid of various echogenicity (6). Tendon tears demonstrate either partial or complete fibrillar pattern discontinuity depending on the severity of the injury, with intervening anechoic fluid, which tends to become isoechoic in more chronic tears (7). Tendinopathic changes include tendon hypertrophy, decreased echogenicity associated with loss of fibrillary pattern, presence of calcifications, and signs of neovascularization at color or power Doppler US (7).

When performing a US examination, it is important to be aware of potential artifacts that may cause erroneous image interpretation. Anisotropy may cause a normal tendon or ligament to appear hypoechoic and tendinopathic; this may be mitigated by rocking the transducer back and forth or heel-toeing the transducer when over the structure of interest to maintain a perpendicular orientation relative to the anatomy of interest. Radiographs of the hip and pelvis are complementary to the US examination and should be systematically obtained to exclude traumatic and tumoral lesions as well as degenerative, inflammatory, or dysplastic articular disease.

Anterior Compartment

Femoroacetabular Joint

Diagnostic Landmark Approach.—The enarthrodial femoroacetabular joint is composed of the spherical femoral head and the acetabulum. Hyaline cartilage covers the femoral head (except at the fovea centralis) and aids force transmission in the joint. The fibrocartilaginous labrum that is attached to the acetabular rim enlarges the acetabular cavity and retains synovial fluid inside the joint cavity, thus enhancing joint lubrication, which helps protect the articular cartilage (3). The synovium-lined joint capsule attaches to the acetabular rim and encircles the hip joint and femoral neck. The iliopsoas tendon is closely associated with the anterior joint capsule, and its bursa may communicate directly with the hip joint.

Important neurovascular structures in the region include the femoral vessels and nerve. The femoral artery is separated from the superior pubic ramus by the psoas major muscle and its tendon. The femoral vein is located on the medial side of the artery, whereas the common femoral nerve travels lateral to the artery (8). The lateral femoral cutaneous nerve travels more laterally than the common femoral nerve and emerges at the confluence of the inguinal ligament and the anterior superior iliac spine.

US evaluation of the hip joint begins with the patient in the supine position with the hip in extension with slight abduction. A small cushion may be placed underneath the knee to achieve slight knee flexion, which relaxes the hip joint capsule and may provide more comfort to the patient. The probe is placed in a longitudinal oblique plane, aligned with the femoral head and neck (Fig 1).

The acetabular rim and the more distal femoral head and neck are hyperechoic with posterior acoustic shadowing. The normal joint capsule is located immediately superficial and parallel to the concave femoral neck. The iliofemoral ligament is closely joined to the anterior surface of the capsule (9). The joint may contain small amounts of physiologic synovial fluid, which usually appears as a hypoechoic area between the femoral cortex and capsule. The triangular labrum is visualized as a hyperechoic structure attached to the inferior acetabular rim, and only its anterosuperior portion can be adequately assessed at US (Fig 2). The probe is moved in a proximal-to-distal and medial-to-lateral fashion for a complete assessment of the hip joint.

Hip Joint Effusion.—At US, hip joint effusion is defined as a distance of 7 mm or greater between the femoral neck and the anterior joint capsule–iliofemoral ligament complex or as a difference of 1 mm between both hips (Fig 3) (10). Hip joint effusion is an indirect sign of intra-articular disease and has a wide differential diagnosis that includes inflammatory, traumatic, and other pathologic conditions.

In cases of a simple joint effusion, the fluid may appear anechoic or hypoechoic. A more complex joint effusion resulting from inflammatory debris, hemorrhage, cartilage fragments, or crystals may appear hypo- to hyperechoic; however, these signs are nonspecific. Moreover, it may be difficult to differentiate an echogenic synovial thickening from a complex joint effusion; alternatively, a hypoechoic synovial thickening may mimic a simple hip effusion. Color or power Doppler US may show synovial hyperemia suggestive of active synovitis; however, it has poor sensitivity owing to the synovial membrane's deep location in the hip joint (11).

US-guided hip joint aspiration and injection may be employed to manage a hip effusion in athletes. The femoral neurovascular bundle is localized, and the probe is moved laterally over the hip joint. A longitudinal oblique approach is used to guide a spinal-type needle into the femoroacetabular joint under continuous US visualization (Fig 3). A 20-gauge needle may be used for aspiration, whereas a 22-gauge needle may be used for injection. Fluid may be aspirated for analysis, and delivery of intra-articular medication, such as local analgesics or corticosteroids, may then be performed.

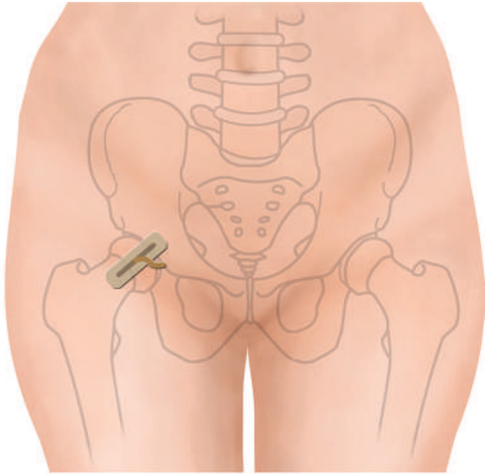
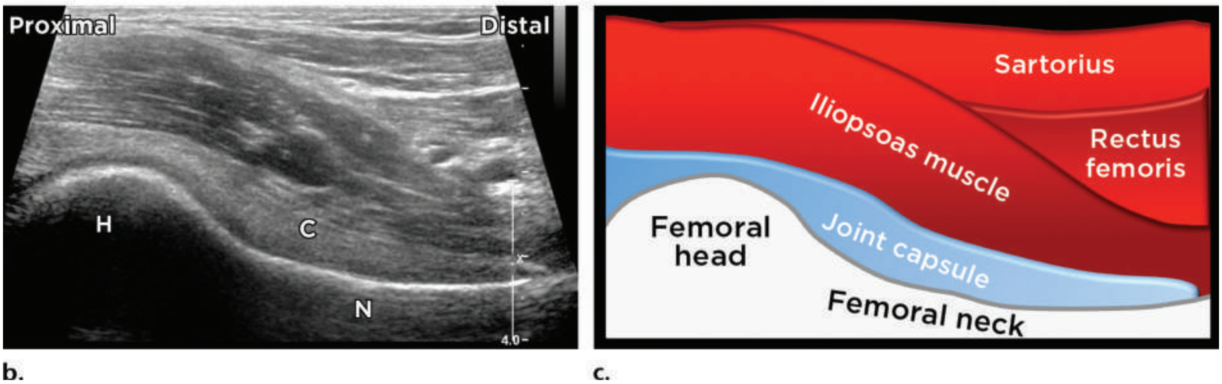


Figure 1. US assessment of the femoroacetabular joint at the level of the femoral head and neck. **(a)** The patient lies supine, and the probe is positioned in a longitudinal oblique plane over the femoral head and neck. **(b)** US image shows the normal appearance of the anterior aspect of the femoroacetabular joint. *C* = joint capsule, *H* = femoral head, *N* = femoral neck. **(c)** Corresponding diagram shows the normal articular and muscular anatomy.



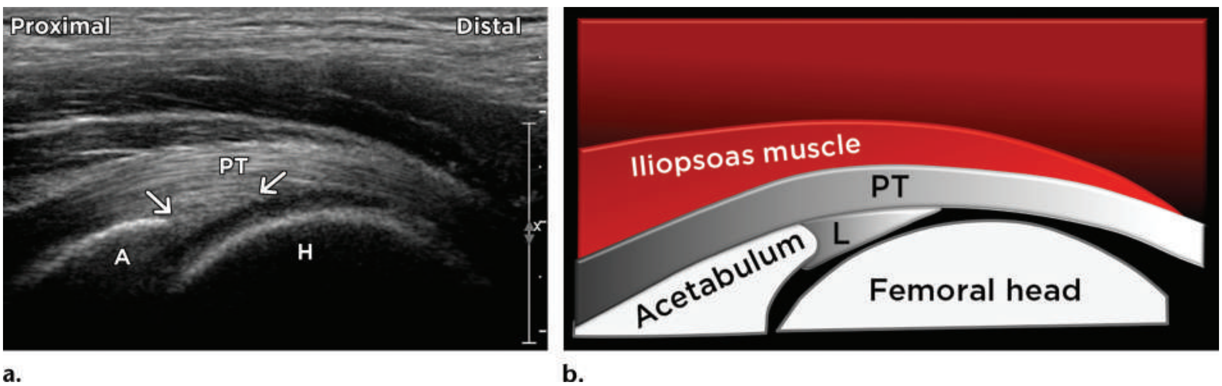
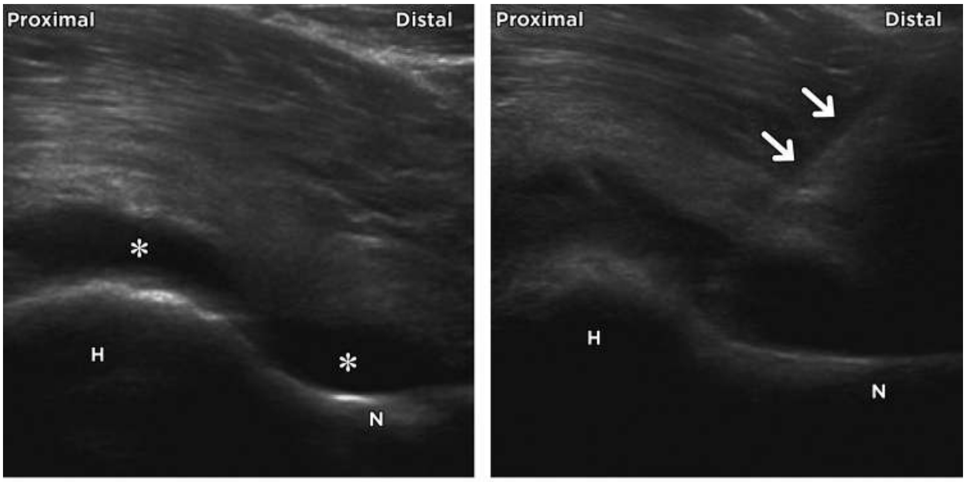


Figure 2. US assessment of the femoroacetabular joint at the level of the acetabular rim and femoral head. The probe is in a longitudinal oblique plane, slightly more cranial than in Figure 1. US image **(a)** and corresponding diagram **(b)** show the normal appearance of the anterior aspect of the acetabular rim (*A* in **a**), acetabular labrum (arrows in **a**, *L* in **b**), and femoral head (*H* in **a**). The psoas tendon *(PT)* with its fibrillary appearance is seen superficial to the labrum.

Osteoarthritis.—Degenerative articular changes may occur secondary to various traumatic and microtraumatic conditions and may be a source of pain and symptoms in athletes. At US, osteoarthritis of the hip may manifest as a joint effusion, thickening of the joint capsule, irregularities of the joint margins, osteophytes, or loss of normal femoral head sphericity (11).

Acetabular Labrum Tears.—Labral tears are common in a variety of athletic activities and are a result of abnormal repetitive contact between the femur and labrum. Risk factors include direct trauma, extreme motion, hip dysplasia, and femoroacetabular impingement. Labral tears usually manifest as insidious dull anterior hip or groin pain and mechanical symptoms such as clicking and giving way (12). The prevalence of asymptomatic labral tears is estimated to be 38% in young athletes (average of 15 years old) and 56% in adult collegiate and professional athletes (13). The majority of acetabular labral tears (84%)



a. b.

Figure 3. Hip joint effusion in a 36-year-old hockey player with anterior hip pain at rest and during skating. *H* = femoral head, *N* = femoral neck. **(a)** Longitudinal oblique US image of the anterior hip shows the joint capsule distended by hypoechoic effusion (*). **(b)** US image shows joint aspiration, which is performed by directing a needle (arrows) obliquely, from distal to proximal, toward the femoral head and neck junction under continuous US visualization.

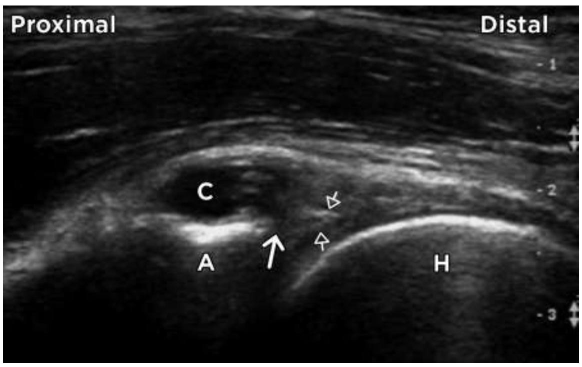


Figure 4. Acetabular labrum tear in a 21-year-old female ballet dancer with chronic activity-related right-sided groin pain. Longitudinal oblique US image shows an anechoic paralabral cyst *(C)* adjacent to the anterior acetabulum *(A)* associated with an anterosuperior labral tear. The anterior labrum (open arrows) appears small with mixed echogenicity and is detached from the acetabular rim (solid arrow). *H* = femoral head.

occur anterosuperiorly, and although this area is well visualized at US, the modality has lower sensitivity than MR arthrography (14,15).

At US, abnormal labral morphology, a hypoechoic labral cleft, and detachment of the labrum from the acetabular rim are signs of a labral tear. Paralabral cysts may appear as anechoic or hypoechoic lesions adjacent to the acetabular rim (Fig 4). The presence of a paralabral cyst at MR imaging or US is often taken as a *sine qua non* of a labral tear, whether it is seen at imaging or not (16). Some authors have suggested that the presence of a joint effusion—either spontaneous or after intra-articular injection—may improve detection of labral tears by outlining the labrum and potentially by filling a labral cleft or paralabral cyst with fluid (16).

Management and Return to Activity.—Intra-articular injections of analgesics such as lidocaine and bupivacaine can be useful diagnostic guides, as they may help distinguish between an intra-articular versus extra-articular pain generator (17). Labral tears are initially managed with a combination of rest, ice, nonsteroidal anti-inflammatory drugs (NSAIDs), activity modification, and rehabilitation. Therapeutic US-guided corticosteroid injections may help manage acute bouts of pain (12). Arthroscopic débridement of the labral tear is considered the standard-of-reference treatment and may be of equal diagnostic value in selected cases (12). We are unaware of any reported imaging features associated with return to activity after intra-articular hip pathologic conditions. Pain-free activities and restoration of preinjury performance levels are signs of safe return to activity.

Rectus Femoris Muscle

Diagnostic Landmark Approach.—The rectus femoris muscle represents the most superficial and anterior part of the quadriceps muscle group. Its main functions are to generate hip flexion torque, stabilize the pelvis on weight bearing, and aid knee extension (18). Cadaveric and MR imaging studies describe in detail its complex proximal anatomy (19,20).

The rectus femoris has two components: a direct (straight) head that originates at the anterior inferior iliac spine (AIIS) and an indirect (reflected) head that attaches along the superolateral aspect of the acetabulum. Both heads join just inferior to the AIIS, forming the conjoint tendon (Fig 5). The musculotendinous junction of the direct head lies at the level of the proximal third of the rectus femoris and is flat and thin; its tendinous fibers blend with the proximal fascia superficially. The indirect tendon component forms the posterior aspect of the conjoint tendon, has a horizontal ovoid or comma-like shape, and extends into the muscle substance distally, forming a long musculotendinous junction that reaches the inferior third of the muscle.

US evaluation of the rectus femoris begins with the patient in a supine position with the hip extended and the probe in a longitudinal plane over the AIIS. The direct head is visualized immediately near its insertion; the obliquely oriented indirect head appears hypoechoic because of anisotropy and thus may mimic tendon disease (Fig 6). The central tendon is identified more distally by its characteristic well-defined echogenic linear pattern.

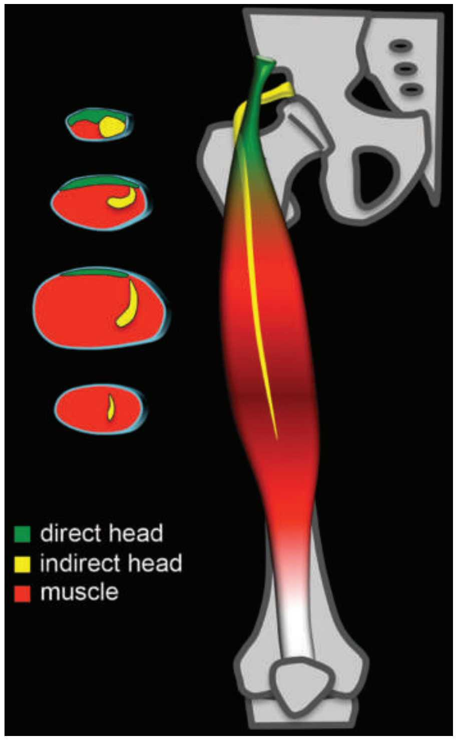
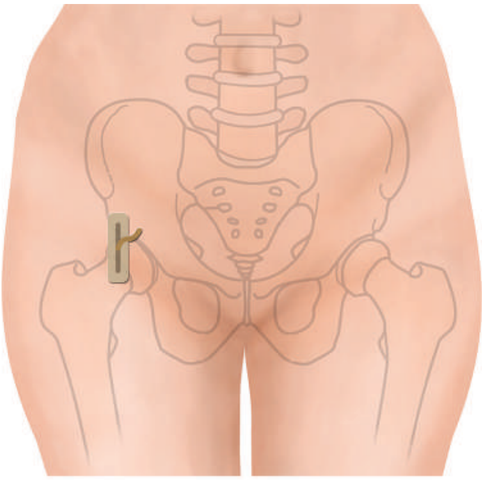


Figure 5. Normal anatomy of the rectus femoris muscle. The direct head (green) originates at the anterior inferior iliac spine (AIIS), while the indirect head (yellow) originates at the superolateral aspect of the acetabulum. Both heads join to form the conjoint tendon just distal to the AIIS, and each contributes to the muscle substance (red) more distally.

Common Pathologic Conditions.—The rectus femoris is the most commonly injured muscle of the hip flexors and ranks second behind the hamstrings in athletes (21). Sports injuries tend to occur in activities involving sprinting and kicking, especially when the hip is hyperextended and the knee is flexed, such as in rugby and football, with the dominant leg often preferentially involved (22). Rectus femoris injuries are related to the muscle's biarticular nature (crossing both the hip and knee joints), its high proportion of fast-twitch (type II) muscle fibers, and its powerful eccentric and concentric contractions. Prior rectus femoris injury or tendinopathy as well as recent hamstring injury predispose to a new injury. Other risk factors have been proposed and include preferential injuries in players of shorter stature, overtraining, improper warm-up, as well as cold humid activity conditions (23).

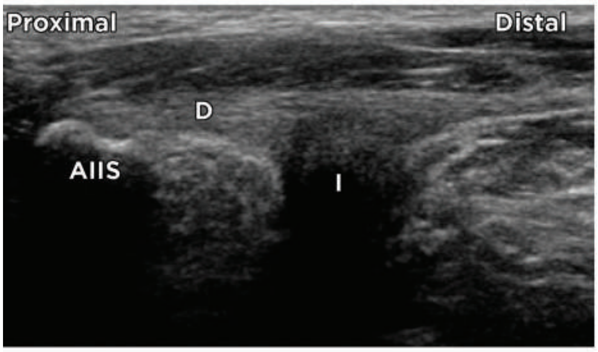
Rectus Femoris Strains.—Traumatic injuries can be classified according to the location of the abnormality. Proximal tendon injuries near the muscle origin are less common in adults (0.5% of all rectus femoris injuries) and can manifest as acute or chronic groin pain (24). In skeletally immature athletes, avulsion of the AIIS apophysis is a common acute traumatic manifestation (18). Musculotendinous strains of the indirect head (central aponeurotic strain) are the most common pattern of injury and typically have an insidious onset, with athletes often reporting mild discomfort and increased muscle tone along the anterior thigh. An acutely injured central tendon may appear at US as ill defined, thickened, and heterogeneous, and the edema around the tendon may confer a classic bull's-eye appearance on transverse US images (25).

High-grade strains may manifest as complete disruption of the musculotendinous junction, with varying degrees of tendon retraction, and may sometimes mimic a soft-tissue mass (Fig 7). In chronic cases, the indirect head usually displays characteristic tendinopathic changes, with a thickened hypoechoic appearance with loss of the fibrillar pattern combined with posterior acoustic shadowing due to scar tissue formation (Fig 8). Musculotendinous injuries of the direct head are uncommon (24). Myofascial injuries of the rectus femoris have been described as a distinct type of architectural distortion of muscle fibers and fascia in proximity to but not necessarily involving the musculotendinous junction (23). However, MR imaging may reveal these injuries more adequately compared with US.



a.

Figure 6. US assessment of the rectus femoris muscle at the level of the AIIS. **(a)** The patient is placed in a supine position with the hip in extension and the probe in a longitudinal plane over the AIIS. **(b)** US image shows the normal appearance of the rectus femoris origin, with the hyperechoic direct head *(D)* inserting on the AIIS. The indirect head *(I)* is obliquely oriented toward its origin along the lateral aspect of the acetabulum and appears hypoechoic because of anisotropy. **(c)** Corresponding diagram shows the normal anatomy of the rectus femoris *(RF)*.



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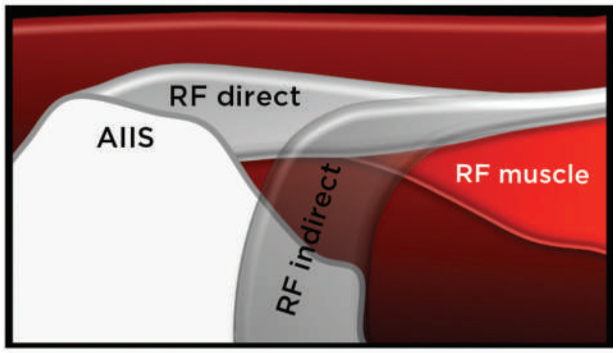

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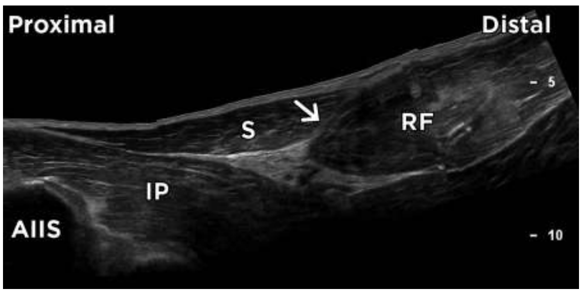


Figure 7. Rectus femoris tendon tear in a 21-year-old male soccer player with a painless mass in the anterior right thigh and a history of a remote episode of severe anterior hip pain while running. Longitudinal extended-field-of-view US image shows a complete chronic avulsion tear of the rectus femoris tendon, with a retracted muscle (arrow) seen more distally. *IP* = iliopsoas muscles, *RF* = rectus femoris muscle, *S* = sartorius muscle.

Rectus Femoris Calcific Tendinopathy.—Calcific tendinopathy of the rectus femoris tendon preferentially affects the proximal reflected head, is often idiopathic, but can be associated with repetitive trauma. In its acute phase, it is characterized by pain and tenderness in the groin area, as well as restricted range of motion and limping. Acute episodes are likely precipitated by the rupturing of deposits within the tendon into the hip joint (26). At US, calcific tendinopathy appears as an area of linear, rounded, or amorphous hyperechogenicity with posterior acoustic shadowing.

Management and Return to Activity.—Treatment of rectus femoris injuries begins with rest, ice, compression, and elevation (RICE), followed by a rehabilitation program including manual therapy modalities, stretching, and strengthening exercises (23). Other modalities such as extracorporeal shock wave therapy, US-guided fenestration, platelet-rich plasma injections, and autologous blood and stem cell injections are also employed routinely; however, their use is based on scarce evidence or inferred from experience with similar pathologic conditions at different anatomic sites (27). Surgical intervention is reserved for high-grade tears with significant muscle retraction, as well as cases refractory to 3–6 months of conservative treatment (23,27,28). Corticosteroid injections have been shown to benefit patients with rectus femoris calcific tendinopathy (26). US-guided percutaneous lavage or surgical excision is reserved for recalcitrant cases (26).

Return to activity after a rectus femoris injury is guided by achievement of preinjury levels of pain-free performance (23). Only limited evidence exists of US parameters associated with return to activity. In the case of central tendon

Figure 8. Chronic tendinosis of the rectus femoris in a 64-year-old female recreational long-distance runner with chronic anterior right hip pain while running. Longitudinal US image, slightly oblique and laterally oriented along the indirect head of the rectus femoris (arrow), shows thickening and hypoechogenicity of the tendon, characteristic of chronic tendinosis. The direct head is off plane and not shown on the image. *H* = femoral head.

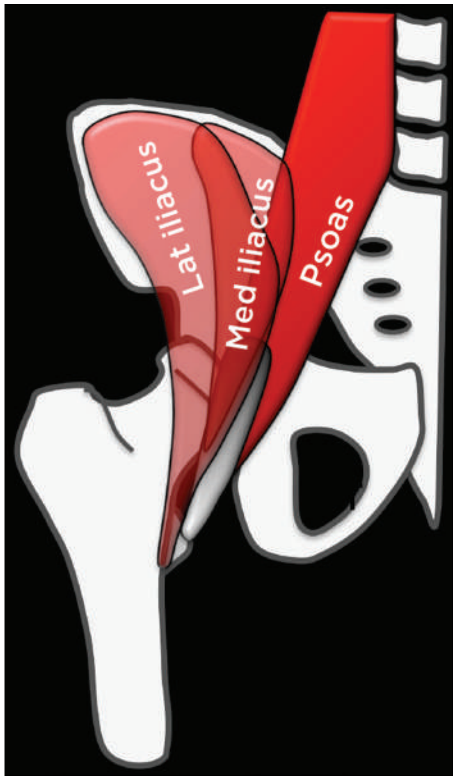


Figure 9. Normal anatomy of the iliopsoas musculotendinous unit. The medial *(Med)* fibers of the iliacus muscle join the psoas major tendon to form the iliopsoas tendon distal to the superior pubic ramus, while the lateral *(Lat)* fibers of the iliacus muscle insert directly onto the anterior aspect of the lesser trochanter.

injuries, the presence of proximal as opposed to distal injury, grade II injury (partial fibrillary discontinuity) as opposed to grade I injury (ill-defined hyper- or hypoechoic area without objective fibrillar discontinuity or thickening and/or hyperemia of the fascia), and greater injury length were associated with a longer duration before return to activity in high-level soccer players (29). MR imaging parameters associated with a longer absence from activity include acute bull's-eye appearance of a central tendon injury and the presence of perifascial fluid (30).

Iliopsoas Musculotendinous Unit

Diagnostic Landmark Approach.—The iliopsoas muscle bridges the lumbar spine and the lower extremity. Aside from providing pelvic stability and trunk balance in static and dynamic conditions, it is the main hip flexor and aids in external hip rotation and lateral lumbar flexion (31). Knowledge of the complex anatomy of the musculotendinous unit of the iliopsoas is paramount to understand the pathophysiology of the conditions affecting it. Traditionally thought to represent a single tendon originating from the merging of the iliacus and psoas muscles, the distal iliopsoas muscle has received closer attention in recent cadaveric and imaging studies, and a more complex anatomy encompassing five distinct muscle components at the groin level has been described (32) (Fig 9).

The medial fibers of the iliacus muscle form an accessory tendon that joins the psoas major tendon along with the inferior fibers of the iliacus originating from the arcuate line, thus forming the main tendon of the iliopsoas. The lateral fibers of the iliacus muscle as well as an ilioinfratrochanteric muscle adjacent to the anterolateral surface of the iliacus muscle both join the anterior aspect of the lesser trochanter and the infratrochanteric area without a tendinous insertion. The iliopsoas bursa, the largest bursa in the body, lies between the iliacus muscle, psoas tendon, and anterior hip capsule. It is indiscernible when not fluid filled and communicates with the hip joint in 15% of normal cases and 40% of pathologic cases (33).

Both static and dynamic US evaluation should be performed in cases of suspected iliopsoas musculotendinous unit disease. The patient lies in a supine position, and the probe is used to scan in

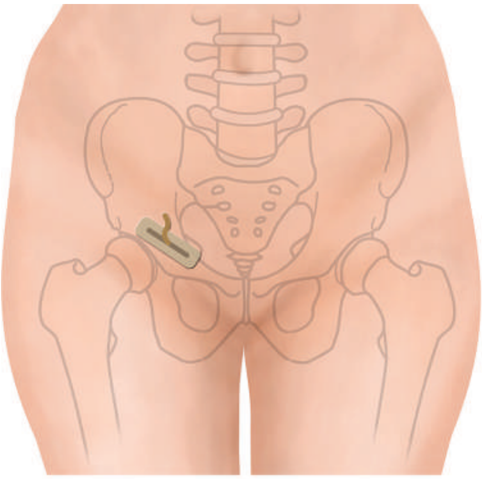
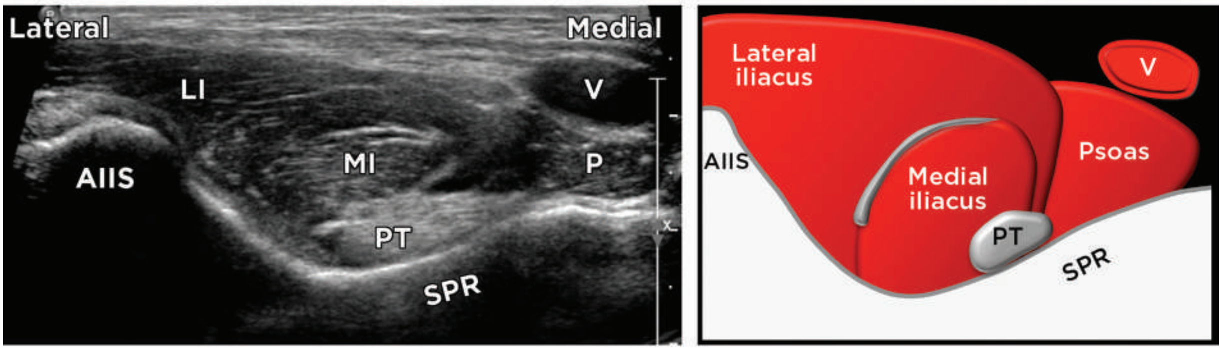


Figure 10. US assessment of the iliopsoas musculotendinous unit. **(a)** The patient lies supine, and the probe is placed between the AIIS and superior pubic ramus in a transverse oblique plane. **(b, c)** Transverse oblique US image **(b)** and corresponding diagram **(c)** show the iliopsoas muscle and tendon at the level of the superior pubic ramus *(SPR)*. *LI* = lateral iliacus muscle, *MI* = medial iliacus muscle, *P* = psoas muscle, *PT* = psoas tendon, *V* = femoral artery.

a.



b. c.

a transverse oblique plane between the AIIS and superior pubic ramus (Fig 10). The unit components are then identified down to the insertion on the lesser trochanter.

Because of the deep and somewhat posterior location of the musculotendinous unit at the lesser trochanter, some authors advocate imaging in the longitudinal plane with the hip in the flexion-abduction–external rotation (FABER) position (34). For the dynamic evaluation, movement of the psoas major tendon and iliacus muscle is observed in real time while patients perform flexion-abduction–external rotation followed by extension and adduction of the hip, or any other movement that is known to reproduce symptoms (Movie 1).

Lesser Trochanteric Apophysitis and Avulsion.—Lesser trochanteric apophysitis with concomitant avulsion of the lesser trochanter is a common injury among skeletally immature athletes, especially boys involved in athletics, football, and skating (36). It usually manifests as acute shooting hip pain and hip flexion weakness. US evaluation may demonstrate widening of the physis or displacement of the apophysis with associated hypoechoic edema or heterogeneous hemorrhagic fluid in the widened space, as well as hyperemia at color or power Doppler US (37). Other tendon insertion sites around the pelvis, such as the ischial tuberosity (proximal hamstrings), AIIS (rectus femoris), and anterior superior iliac spine (sartorius), are associated with similar risks of injuries in young athletes. Radiography is a useful adjunct to US in evaluation of these injuries.

Musculotendinous Injuries.—Iliopsoas musculotendinous injuries are rare in the general population (prevalence of 0.66%) but seem to be more common in active individuals and are associated with sports that involve kicking and jumping, such as football, basketball, and gymnastics (36,38). Partial tendon tears and strains are more common in younger individuals, whereas complete tears almost exclusively affect elderly women (38,39). Iliopsoas tendinopathy has been described after acute and overuse injuries, as well as in association with osteophyte or hip arthroplasty impingement and internal snapping hip syndrome. Partial and complete tears manifest with symptoms of acute groin pain and tenderness as well as hip flexion weakness, while overuse-associated tendinopathy has a more progressive onset with activity-related anterior hip pain that gradually occurs at rest (36).

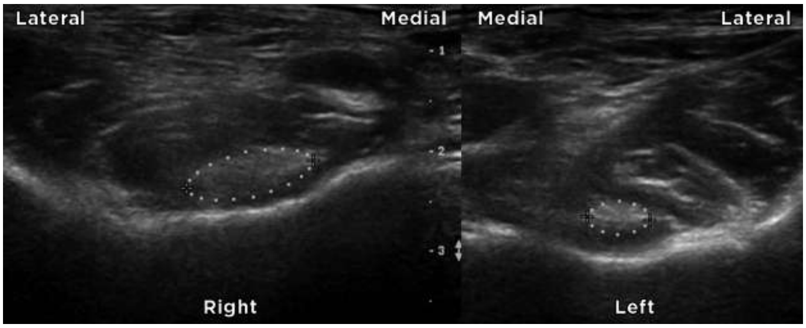


Figure 11. Right psoas tendinosis in a 49-year-old man with a right hip resurfacing arthroplasty who experienced right hip pain while running. Transverse oblique US image at the level of the superior pubic ramus, similar to that in Figure 10, shows an enlarged and hypoechoic right psoas tendon (dotted oval) consistent with tendinosis. The normal left psoas tendon is shown for comparison.

US evaluation of partial-thickness musculotendinous tears highlights focal discontinuity of the fibrillar pattern with associated focal fluid, whereas full-thickness tears manifest as complete discontinuity of the fibers, presence of a fluid-filled gap, and various degrees of muscle retraction (40). Hallmarks of iliopsoas tendinopathy are a hypoechoic heterogeneous appearance with loss of the fibrillar pattern accompanying hypertrophic changes of the iliopsoas tendon, along with signs of neoangiogenesis at color or power Doppler US (Fig 11) (40).

Internal Snapping Hip Syndrome.—This condition is characterized by painful, palpable, and sometimes audible snapping phenomena provoked by certain movements of the hip (35). It predominantly affects athletes performing repeated hip abduction movements, such as in ballet dancing, martial arts, and gymnastics (35). Considered a type of extra-articular snapping hip syndrome, it is most often linked to altered biomechanics of the musculotendinous unit of the iliopsoas muscle. The classic explanation posits impingement of the iliopsoas tendon on the iliopectineal eminence or lesser trochanter; however, this mechanism has not been demonstrated at imaging.

The most commonly observed mechanism entails snapping of the psoas major tendon over the superior pubic ramus, after release of the medial fibers of the iliacus from a transient position between the psoas tendon and superior pubic ramus on hip extension. During combined flexion-abduction–external rotation of the hip, the medial fibers of the iliacus muscle become trapped between the psoas tendon and superior pubic ramus. On hip extension, the medial fibers are suddenly liberated from underneath the psoas tendon, causing the psoas tendon to return abruptly against the ramus, thus producing the snap (41) (Movie 2). Other mechanisms of snapping have been directly visualized at imaging, including impingement of the psoas major tendon on a paralabral cyst or on the AIIS with the patient in a frog leg position, as well as impingement between the two heads of a bifid psoas major tendon, representing an anatomic variant.

A snapping iliopsoas phenomenon can occur in up to 40% of the asymptomatic population and does not necessarily require further investigation (32). However, repetitive occurrences may lead to inflammation of the neighboring structures, leading to pain and limitations. Dynamic US is the modality of choice for evaluation of this pathologic condition, as it allows real-time assessment of the relative movements of the structures. Static US evaluation should exclude other possible concomitant anomalies such as iliopsoas tendinopathy and bursitis, femoroacetabular synovitis, and paralabral cysts.

Iliopsoas Bursitis.—Iliopsoas bursitis usually occurs in conjunction with a primary intra-articular disease extending into the bursal space or secondary to impingement from adjacent pathologic processes such as iliopsoas musculotendinous injuries or internal snapping hip syndrome (42). Symptoms are usually nonspecific and are related to the concomitant neighboring pathologic processes and to the degree of bursal distention (43). At US, the inflamed bursa appears as a well-defined thin-walled fluid-filled lesion with homogeneous or heterogeneous contents.

Management and Return to Activity.—Conservative management of acute iliopsoas musculotendinous injuries includes the RICE protocol and progressive physical therapy. Surgical management of musculotendinous tears has not been described. Image-guided peritendinous or iliopsoas bursa corticosteroid injections may prove beneficial in improving symptoms associated with iliopsoas tendinopathy in both the short term and the long term and have the potential to delay tenotomy, which is considered a second-intention treatment (44). Under US guidance, a needle is inserted anterior to the AIIS with a lateral-to-medial approach, or alternatively with an anterior oblique approach, to reach a distended bursa. If the bursa is not distended, the anterior oblique approach is used to direct the needle to contact the superior pubic ramus, next to the psoas, and injection is performed.

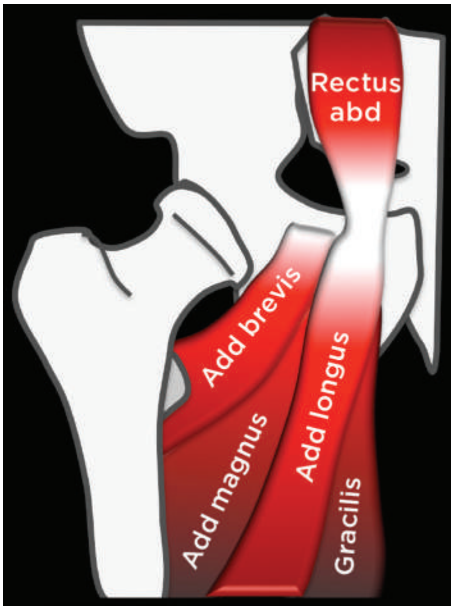


Figure 12. Normal anatomy of the proximal adductor muscles. The adductor *(Add)* longus muscle originates at the anterior pubic bone and forms a common aponeurosis with the rectus abdominis *(abd)* muscle. The adductor brevis and magnus muscles are located posteriorly and the gracilis muscle medially.

Management of internal snapping hip syndrome is generally conservative, with rest, anti-inflammatory medication, and rehabilitation generally being sufficient. US-guided corticosteroid injection of the iliopsoas bursa, even in the absence of associated bursitis, can provide long-term analgesic effects (45). Psoas tendon surgical release is reserved for refractory cases (46).

No imaging features predictive of return to activity after iliopsoas musculotendinous unit injuries have been described, with achievement of a pain-free state currently employed as a marker to safely resume activity.

Adductor Muscles

Diagnostic Landmark Approach.—The adductor muscle group is closely associated with the anatomy of the pubic symphysis and adjacent abdominal muscles (Fig 12). The pubic symphysis is a nonsynovial amphiarthrodial joint comprising the medial borders of the pubic bodies lined with a thin layer of hyaline cartilage, the adjoining interpubic fibrocartilaginous disk, and supporting ligamentous structures. The sheet-like rectus abdominis muscle originates laterally from the pubic crest and tubercle via a broad tendon and medially from the anterior superior aspect of the pubic body, where it fuses with its contralateral counterpart and joins the anterior pubic ligament, capsular tissues, and fibrocartilaginous disk via a superficial aponeurosis.

The triangular adductor longus muscle originates from a narrow tendinous attachment on the anterior pubic body, just inferior to the pubic crest, and is contiguous with the rectus abdominis aponeurosis. The adductor longus tendon inserts on the pubis via a poorly vascularized and highly innervated enthesis that is composed of fibrocartilaginous tissue (47). Posterior to the tendon, the adductor longus muscle has a broad direct muscular attachment to the pubis.

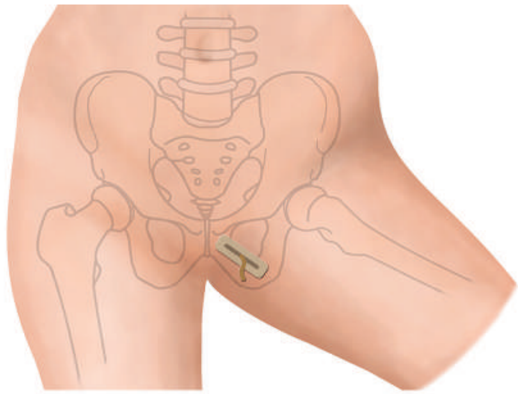
The adductor brevis muscle originates immediately posterior and lateral to the adductor longus and is also contiguous with the rectus abdominis aponeurosis. The adductor magnus fibers originate at the lower border of the inferior pubic ramus, ischial ramus, and ischial tuberosity, with respective distal insertions at the gluteal tuberosity, linea aspera, and adductor tubercle. The medially located gracilis muscle originates at the anterior aspect of the pubic body and the inferior pubic ramus. It has a thin muscle belly and is part of the pes anserine muscle group.

The inguinal canal and its constituents are intimately related to the adductor muscle complex, as the superficial inguinal ring is located only 2–5 mm lateral to the common rectus abdominis–adductor longus aponeurosis, and the inguinal ligament attaches to the same capsular tissues as the common aponeurosis (48,49). Functionally, the adductor muscles are involved in hip adduction, contribute to hip flexion and internal rotation, and act as dynamic stabilizers of the hip joint (48). The adductor longus and rectus abdominis muscles are relative antagonists and form a stabilizing unit of the pubic symphysis (48,50).

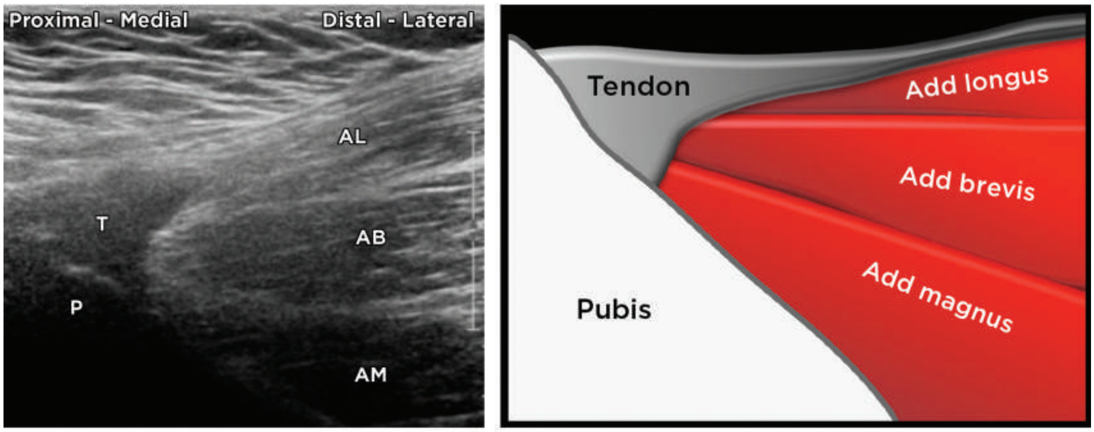
US evaluation of the adductor muscles is performed with the patient supine in a frog leg position (Fig 13). The pubic symphysis serves as an anatomic landmark, and the probe is positioned in a transverse oblique plane. The rectus abdominis tendon and aponeurosis may be seen blending with the adductor longus tendon. At US, the origin of the adductor longus, brevis, and magnus on the pubis is sometimes difficult to differentiate, and a conjoint tendon appearance may be visualized (Fig 13). The adductor longus is identified superficially, while the adductor brevis and adductor magnus are located immediately posteriorly, in that order (49).

Athletic Pubalgia.—This clinical entity comprises a continuum of processes with similar clinical manifestations and probably a common pathophysiologic insult. It is posited that an initial injury to the common aponeurosis of the rectus abdominis and adductor longus muscles during hip abduction and trunk extension combined with repetitive microtrauma of these

Figure 13. US assessment of the adductor tendons at the pubic symphysis. **(a)** The patient lies supine in a frog leg position, and the probe is placed in a longitudinal oblique plane over the pubic symphysis. **(b, c)** Longitudinal oblique US image **(b)** and corresponding diagram **(c)** show the conjoint tendon–like appearance *(T)* of the proximal adductor *(Add)* muscle insertions, with the individual muscle bellies discernible more distally. *AB* = adductor brevis muscle, *AL* = adductor longus muscle, *AM* = adductor magnus muscle, *P* = pubis.



a.



b. c.

structures explain groin pain in athletes (48). The initial injury may also affect either of the muscles' origins individually, and subsequent unbalanced contraction at the pubic symphysis causes increased stress on the opposite tendon and on the aponeurosis. This repetitive microtrauma may cause the injury to extend to the opposite tendon and to the aponeurosis, possibly leading to frank tendinous and aponeurotic disruption, sometimes even affecting the contralateral side, especially in women (48).

The initial injury to the aponeurosis may be associated with reactive osseous abnormalities at the symphysis pubis, such as bone marrow edema. In a subgroup of patients with initial aponeurotic abnormalities, an inflammatory reaction of the pubic bone, termed *osteitis pubis*, causes abnormal bone activity that may culminate with osseous resorption (48,50). However, as is generally the case with reactive osseous abnormalities, US is of limited use in evaluation of osteitis pubis.

Athletic pubalgia is more frequent in athletes performing repetitive turning and twisting movements such as in hockey, football, and tennis and predominantly affects male athletes under 40 years of age (48,50). Patients may experience insidious onset of unilateral groin pain at rest or during exercise; however, most also recall a remote episode of an acute tearing sensation in the same area. At physical examination, focal tenderness can be noted at the pubic attachments of the rectus abdominis and adductor longus, and pain can be noted during resisted hip adduction and sit-ups (48).

At US, athletic pubalgia related to shear injury, enthesopathy, tendinosis (Fig 14), or partial tear or frank disruption of the common aponeurosis or rectus abdominis or adductor longus tendons at their pubic attachments has the same appearance as any other similar lesions of tendons.

Musculotendinous Injuries.—Adductor tendinopathy and partial or complete tears are part of the athletic pubalgia spectrum when they affect the adductor longus, adductor brevis, and more rarely the gracilis muscle; however, they can occur separately without involving the common aponeurosis (51). Musculotendinous injuries are usually the result of an acute event in the case of partial or complete tears (Fig 15) and of chronic overuse in adductor tendinopathy. Acute tears of the adductor longus muscle are especially prevalent in football players, with more experienced players more often affected because of presumed underlying tendinopathy (49). Patients usually

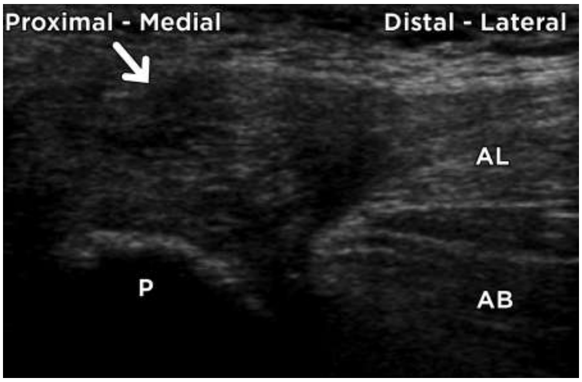


Figure 14. Athletic pubalgia in a 27-year-old male hockey player with activity-related right inguinal pain. Longitudinal oblique US image at the pubic bone *(P)* shows an enlarged and hypoechoic tendinopathic conjoint adductor tendon (arrow). *AB* = adductor brevis muscle, *AL* = adductor longus muscle.

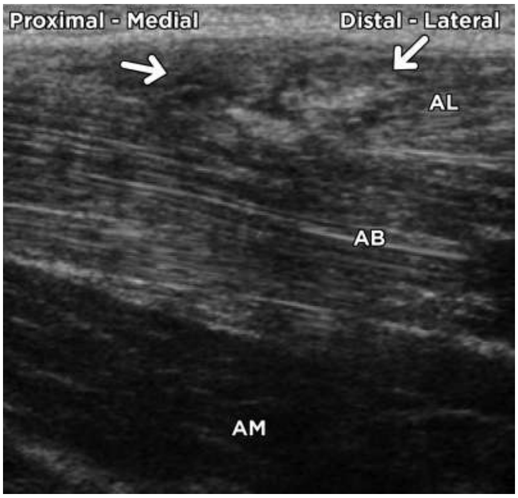


Figure 15. Partial adductor longus muscle tear in a 22-year-old male tennis player with an acute tearing sensation in the right inguinal area. Longitudinal oblique US image of the proximal adductor muscles shows focal heterogeneity, architectural distortion, and discontinuity of the muscle fibers (arrows) of the adductor longus muscle *(AL)*, consistent with a partial muscle tear. *AB* = adductor brevis muscle, *AM* = adductor magnus muscle.

present with pain in the upper medial thigh that is exacerbated with resisted hip adduction (48).

Perineal Nodular Induration.—This condition is known under many denominations, including biker's nodule, ischiatic hygroma, or third testicle (52,53). It represents a fibroblastic hypovascular pseudotumor that develops in the soft tissues of the paramedian region of the perineum, adjacent to the ischial tuberosity and scrotal sac, and is seen almost exclusively in male cyclists. It is associated with repetitive contact between the saddle and ischial tuberosities, leading to increased pressure, vibration, and constant rubbing of the superficial perineal fascia against the ischial tuberosity.

Histologically, it shows necrosis of the superficial perineal fascia causing myxoid degeneration of the tissue overlying the ischial tuberosity lacking vascularity, with occasional formation of a pseudocyst (52). Clinically, it may manifest as a unilateral or occasionally bilateral nodule, 20–30 mm in diameter, sometimes adherent to adjacent soft tissue. The nodule is painful when sitting on the saddle.

At US evaluation, the patient is placed supine with the hip abducted and externally rotated; the inferior pubic ramus serves as a landmark. The lesion is identified as a hypoechoic ill-defined fibrotic mass superficial to the adductor muscles (Fig 16).

Management and Return to Activity.—Initial treatment of athletic pubalgia involves rest from athletic activity, nonsteroidal anti-inflammatory drugs (NSAIDs), and progressive rehabilitation aimed at stabilizing the anterior pelvis and core musculature. Corticosteroid injections of the pubic symphysis and aponeurotic attachments can be used for pain management. A recent study reported a sustained improvement in symptoms after a minimum of 6 months in 58% of patients with sports-related symphysis pubis injuries. The subset of patients with rectus abdominis–adductor longus attachment injury were more likely to experience a complete recovery (54). Adductor tenotomy and release as well as rectus abdominis repair are reserved for cases refractory to conservative treatment.

The treatment of musculotendinous injuries of the adductor tendons is primarily conservative and initially involves the RICE protocol, strengthening exercises, and progressive return to physical activities. Reports of treatment with intratendinous injections of platelet-rich plasma and US-guided percutaneous tenotomy are anecdotal (48,50). In cases of recalcitrant groin symptoms or complete tears, surgical repair may be indicated (48,50,55). To our knowledge, no US feature of adductor compartment injuries in sportsmen has been associated with return to activity guidelines.

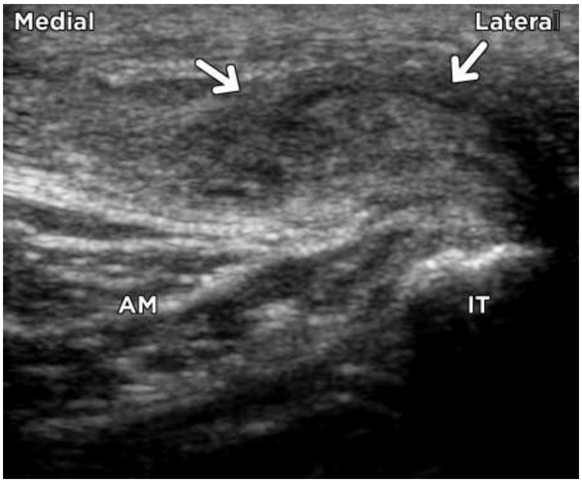


Figure 16. Perineal nodular induration in a 32-year-old female cyclist with a painful chronic left-sided perineal mass. For US evaluation of this condition, the patient lies supine with the hip in a flexed and abducted position. The probe is placed in a transverse oblique plane over the posterior perineal region. US image shows an ill-defined, subcutaneous, hypoechoic fibrotic mass (arrows) superficial to the ischial tuberosity *(IT)* and adductor magnus muscle *(AM)*.

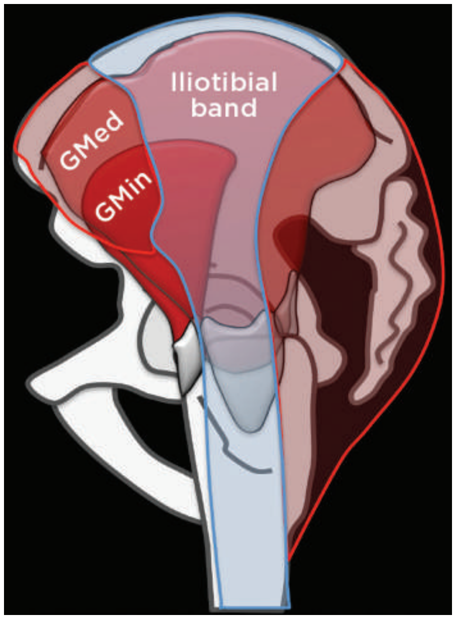


Figure 17. Normal anatomy of the lateral hip region. The gluteus medius muscle *(GMed)* inserts mainly at the superolateral facet of the greater trochanter, with a minor insertion at the lateral facet. The gluteus minimus muscle *(GMin)* inserts at the anterior facet of the greater trochanter. The iliotibial band (ITB) has an insertion at the iliac tubercle and passes along with the gluteus maximus (red outline) superficial to the greater trochanter.

The treatment approach for perineal nodular induration should be aimed at altering the causative factor, such as adjusting the saddle and choosing appropriate pants, as rest alone is insufficient (53). Corticosteroids and hyaluronidase injections have been advocated by some authors for small lesions, a prominent side effect of these being subcutaneous atrophy (56). Complete surgical excision is a treatment of second intention (56).

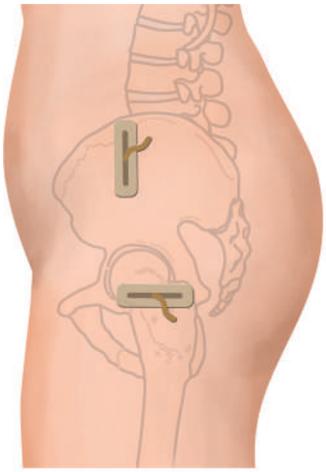
Lateral Compartment

Gluteal Muscles and Iliotibial Band

Diagnostic Landmark Approach.—The greater trochanter of the femur is an essential osseous landmark of the lateral hip region, with important muscular attachments, as well as bursal and aponeurotic structures in its vicinity (Fig 17). It consists of four facets: anterior, lateral, superolateral, and posterior (57). The gluteus medius muscle arises from a zone in the external iliac fossa located between the anterior and posterior gluteal lines, is covered by the gluteal aponeurosis, and has two insertions on the greater trochanter: the main more posteriorly located tendon inserts onto the superolateral facet, while its anterior portion inserts onto the lateral facet (57). The gluteus minimus originates more anteriorly from the external iliac fossa from a region between the anterior and inferior iliac lines and has an insertion onto the anterior facet of the greater trochanter (57).

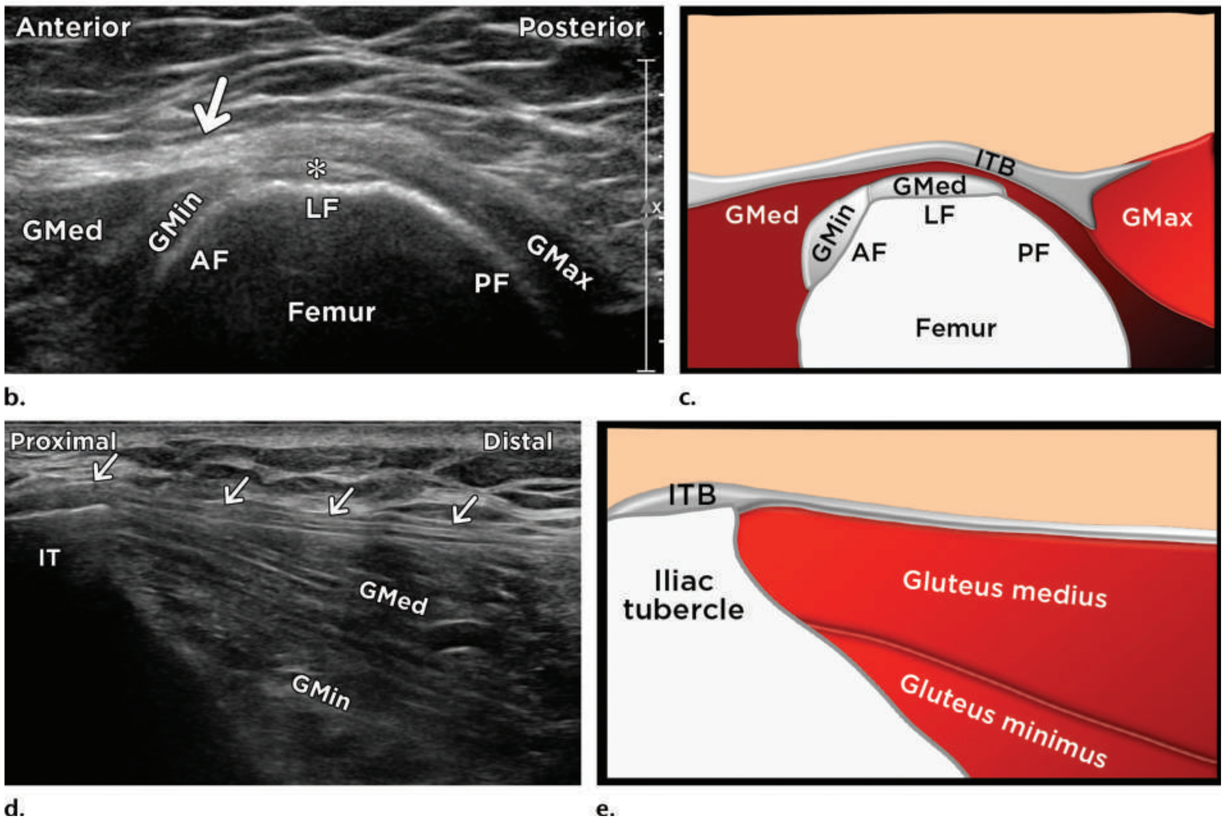
The gluteus maximus muscle does not have an attachment on the greater trochanter but courses superficially over the posterior facet and is separated from it by the trochanteric bursa. Its superior fibers insert into the posterior aspect of the iliotibial band (ITB), whereas the inferior fibers end on the gluteal tuberosity located at the linea aspera (58). Underneath the gluteus maximus muscle and ITB, the trochanteric bursa covers the posterior facet and the lateral insertion of the gluteus medius on the lateral facet (57). The sub–gluteus medius bursa is located between the lateral part of the gluteus medius tendon and the lateral facet, while the sub–gluteus minimus bursa overlies the anterior facet and is found deep to the gluteus minimus insertion (57).

The ITB is a thick longitudinal region of the lateral fascia lata that invests the musculature of the thigh and is most prominent proximally at



a.

Figure 18. US assessment of the lateral hip region. **(a)** The patient lies in the lateral decubitus position with the knees in slight flexion. For assessment of the peritrochanteric region, the probe is placed in a transverse plane over the junction between the anterior and lateral facets of the greater trochanter (transversely oriented probe). For assessment of the proximal ITB, the probe is placed in a longitudinal plane over the iliac tubercle (longitudinally oriented probe). **(b, c)** Transverse US image **(b)** and corresponding diagram **(c)** show the normal appearance of the peritrochanteric region. *AF* = anterior facet, *GMax* = gluteus maximus muscle, *GMed* = gluteus medius muscle, *GMin* = gluteus minimus tendon, *LF* = lateral facet, *PF* = posterior facet, arrow in **b** = ITB, ∗ in **b** = gluteus medius lateral tendon. **(d, e)** Longitudinal US image **(d)** and corresponding diagram **(e)** show the normal appearance of the ITB (arrows in **d**) at the iliac tubercle (*IT* in **d**).



the level of the iliac tubercle (58). Proximally, the ITB has superficial, intermediate, and deep origins on the ilium that are closely associated with the tensor fascia lata muscle and has posterior contributions from tendinous fibers of the gluteus maximus muscle as well as the gluteal aponeurosis (58,59). These different layers coalesce over the greater trochanter, have an insertion on the linea aspera of the femur, and also course further distally, inserting at the infracondylar (Gerdy) tubercle of the tibia, lateral femorotibial ligament, lateral femoral epicondyle, and patella (59).

The gluteal muscles are the main external rotators and abductors of the hip, assist hip extension, and are involved in stabilization of the hip joint during standing and locomotion (60). The ITB is also an important stabilizer of the lateral knee.

US evaluation of the peritrochanteric region begins with the patient in a lateral decubitus position with the hip slightly flexed, while the probe is placed in a transverse plane over the junction between the anterior and lateral facets of the greater trochanter (Fig 18). The gluteus minimus tendon can be seen inserting onto the anterior facet, and the anterior aspect of the gluteus medius can be seen inserting onto the lateral facet. The respective subgluteus bursae can be identified if fluid is present. The ITB and gluteus maximus can be seen coursing superficially.

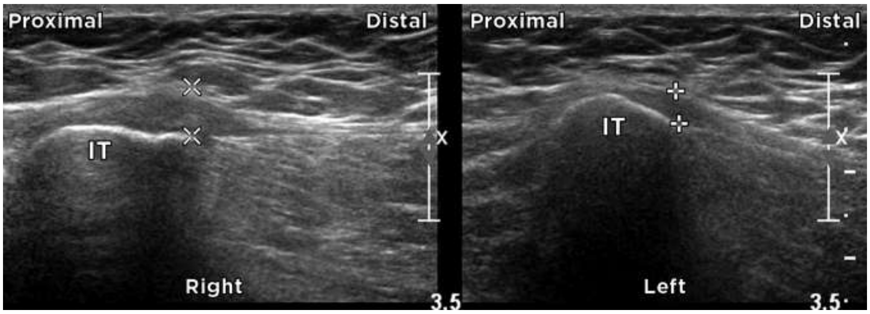


Figure 19. Proximal ITB syndrome in a 21-year-old female ballet dancer with chronic lateral right hip pain. Longitudinal US image at the level of the iliac tubercle *(IT)* shows a thickened hypoechoic right ITB (between cursors), consistent with proximal ITB syndrome. A normal proximal left ITB is shown for comparison.

For US assessment of the proximal ITB, the probe is placed in a longitudinal plane overlying the iliac tubercle (5 cm posterior to the anterior superior iliac spine) (Fig 18). The ITB can be seen inserting onto the iliac tubercle and coursing superficially, with the gluteus medius and minimus muscles visualized more deeply.

Greater Trochanteric Pain Syndrome.—This condition is described as chronic intermittent pain in the peritrochanteric region with tenderness on palpation and on hip abduction (61). It is most commonly associated with gluteus medius and minimus tendinous derangements and much more rarely involves the peritrochanteric bursae (61). GTPS is classically found in late-middle-aged women, with sports-related injuries more common in runners, especially in those adducting the hip past the midline (62).

Factors predisposing to abnormal hip biomechanics, such as lower back pain, asymmetric shoe wear, inadequate core stability, gluteal weakness, and functional limb-length discrepancies, predispose to acute trauma and/or repetitive stress, leading most commonly to gluteal tendinopathy and in around 8% of cases to concurrent bursitis (61). Therefore, trochanteric bursitis is seldom associated with gluteal tendinopathy. Calcific tendinopathy of the gluteal tendons associated with hydroxyapatite deposition disease is another cause of GTPS (22).

At US, gluteal tendinopathy can be identified as variable hypertrophy of the tendons and a diffuse hypoechoic appearance (60). Foci of dystrophic calcification can also be identified, while findings of neoangiogenesis at color or power Doppler US are less common (60). Tears manifest as partial- or full-thickness anechoic defects, with the deep and anterior fibers of the gluteus medius most commonly involved. Greater trochanteric bursitis can be appreciated as a hypoechoic fluid collection, sometimes accompanied by bursal wall thickening or synovial fold proliferation, located deep to the gluteus maximus muscle and ITB and superficial to the greater trochanter posterior facet and the lateral insertion of the gluteus medius tendon on the lateral facet of the greater trochanter (60).

Proximal ITB Syndrome.—This condition has been described in athletes presenting with isolated pain at the iliac tubercle and the inferior lip of the iliac crest (58,63). It is postulated that proximal ITB syndrome is an overuse-associated enthesopathy of the ITB fibers originating at the iliac tubercle. Findings of adjacent marrow edema at MR imaging further support this hypothesis (59). There is a female preponderance of this condition, tentatively explained by an increased hip width to femoral length that may cause greater strain on the hip abductors and ITB (63). At US, a thickened hypoechoic ITB can be observed at the iliac tubercle in comparison with that of the normal contralateral side (Fig 19).

External Snapping Hip Syndrome.—This condition represents abnormal transient "subluxation" of the junction between the ITB and the anterior margin of the gluteus maximus muscle, over the greater trochanter of the femur, accompanied by a painful clicking or popping sensation at the lateral hip (35). During normal movement, the ITB and the anterior margin of the gluteus maximus glide smoothly anteriorly over the lateral facet of the greater trochanter on hip flexion and posteriorly on extension. In external snapping hip syndrome, during the early phase of flexion, the ITB and the anterior aspect of the gluteus maximus are transiently caught over the posterolateral aspect of the greater trochanter; as the flexion angle increases, the two structures are then released and produce the audible snap. A similar mechanism may occur when the hip is moved from flexion to extension.

Hip flexion from an extended more adducted position, such as when the patient is positioned standing and leaning on the symptomatic side, may facilitate occurrence of the snap. Firmly positioning the stretched ITB over the greater trochanter promotes a more abrupt release on flexion. The pain associated with this condition is thought to arise from repetitive snapping that leads to tendinopathy and bursopathy (35,59). Painless snapping of the lateral hip may also occur and should not be cause for concern.

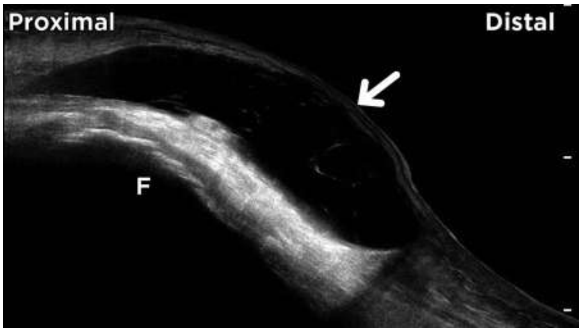


Figure 20. Morel-Lavallée lesion in a 27-year-old ski jumper with a fluctuating painless mass in the left greater trochanteric region 2 months after a fall. Extended-field-of-view longitudinal US image of the lateral hip shows a large, homogeneous, anechoic fluid collection (arrow) between subcutaneous tissues and superficial muscle fascia at the level of the proximal femur *(F)*, consistent with a Morel-Lavallée lesion.

This syndrome primarily affects young female athletes and ballet dancers and has been associated with chronic repetitive movements of the hip, especially extremes of motion, as well as biomechanical alterations resulting from variant anatomy, pathologic conditions such as femoral osteochondroma, and postoperative changes (35,59).

Although the diagnosis of external snapping hip is usually clinical, dynamic US is the modality of choice for demonstrating the pathologic translation of the structures leading to the snap (Movie 3). The patient is positioned in a lateral decubitus position, lying on the asymptomatic side. The probe is positioned similarly to that for static evaluation of the peritrochanteric region, and the relative movements of the structures are observed as the patient performs hip flexion and extension. Static evaluation of the peritrochanteric region should be performed before the dynamic assessment, as it may demonstrate a thickened and hypoechoic ITB and stigmata of greater trochanteric bursopathy (35).

Morel-Lavallée Lesion.—These lesions denote posttraumatic closed degloving soft-tissue injuries secondary to shear stress causing a separation between subcutaneous tissues and superficial muscle fascia and less commonly between the superficial and deep fascia layers (64,65). This creates potential virtual spaces, and injury to the perforating fascial vessels leads to accumulation of serosanguineous fluid and necrotic fat. With time, local inflammatory reaction promotes development of a fibrous pseudocapsule, rendering the collection prone to persistence and recurrence (65). Most commonly, Morel-Lavallée lesions are encountered in the peritrochanteric region and anterior proximal thigh, may be associated with pelvic fractures, and are most frequently described in sports requiring sliding actions, such as football and baseball (4).

Clinically, this lesion manifests as an enlarging, painful, and fluctuant mass with some degree of bruising and skin hypermobility, as well as decreased cutaneous sensation (66). Because they may develop slowly, Morel-Lavallée lesions may be missed initially and may become painless with time (65). Continuous accumulation of hemolymphatic material may mimic soft-tissue tumors.

At US, patients are placed in a lateral decubitus position, and the probe is positioned on the lateral hip. Acute lesions may appear as heterogeneous hyperechoic collections owing to debris such as necrotic fat lobules with irregular margins (65). With time, a smooth margin develops, and the collection becomes fusiform and is compressible; the fluid tends to become more homogeneous and anechoic and lacks internal Doppler flow (Fig 20) (65). However, no correlation between US findings and lesion age can be established, as rebleeding of a chronic lesion and persistence of peripheral fat remnants may confer a heterogeneous hyperechoic appearance (65).

Management and Return to Activity.—Initial treatment of GTPS includes rest, ice, and anti-inflammatory medication. US-guided bursal corticosteroid injections can provide marked short-term benefits; however, their effects tend to recede after several months (67,68). For performance of US-guided injection of the greater trochanteric bursa, the patient lies in a lateral decubitus position on the nonaffected side. Using a standard sterile technique and a transverse US approach, a 22-gauge needle is advanced superficially under continuous US visualization to the lateral insertion of the gluteus medius tendon on the lateral facet of the greater trochanter at the expected location of the bursa (Movie 4). US-guided gluteal tendon fenestration and injections of platelet-rich plasma have also been found to be beneficial in a small case series (69). Open or arthroscopic repair may be indicated for high-grade tears and usually yields satisfactory results (67).

Treatment of proximal ITB enthesopathy is symptomatic and consists of rest, ice, anti-inflammatory medication, and stretching (58). Similarly, management of external snapping hip syndrome is primarily conservative. US-guided peritrochanteric or bursal injections with corticosteroids and local anesthetics can be used to alleviate the symptoms and as a diagnostic measure (4). Patients who do not respond to a course of conservative management are surgical candidates. There are various possible techniques such as ITB lengthening and release as well as Z-plasty, leading to generally favorable outcomes (35,59).

After injuries to the abductor muscles of the hip as well as the ITB, athletes usually return to their activities when pain free. No imaging features at US have been associated with the duration of absence from physical activities.

Morel-Lavallée lesions can be managed according to their age (70). Acute lesions can be treated with compressive banding, aspiration, and use of sclerosing agents such as talc and doxycycline. Refractory cases are amenable to percutaneous drainage, and if this fails, open débridement is indicated. Some authors advocate early open débridement of larger lesions (66).

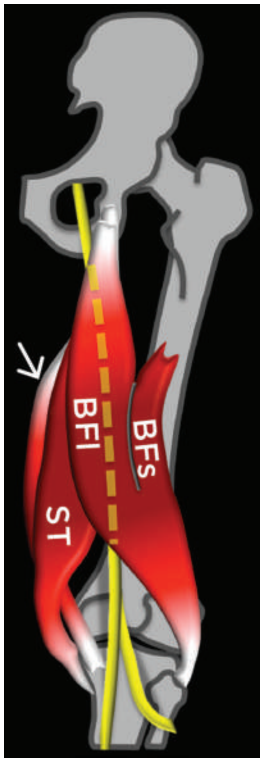


Figure 21. Normal anatomy of the hamstring muscle complex. The conjoint tendon of the long head of the biceps femoris *(BFl)* and the semitendinosus *(ST)* as well as the semimembranosus (arrow) tendon originate at the ischial tuberosity. The short head of the biceps femoris *(BFs)* originates from the linea aspera of the femur and joins the long head more distally. The muscles have distal attachments around the knee joint. Note the close association of the sciatic nerve (yellow) with the hamstring muscle group.

Posterior Compartment

Hamstring Muscle Group

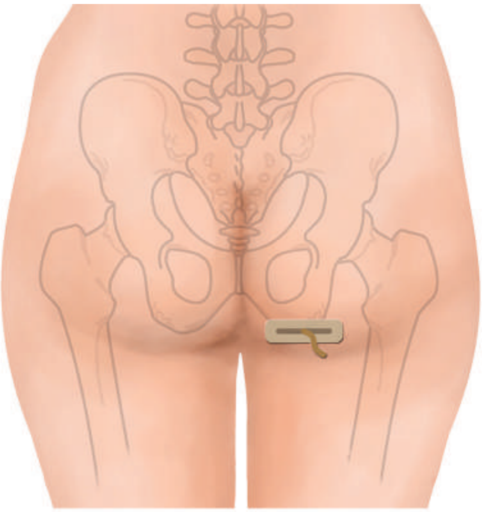
Diagnostic Landmark Approach.—The hamstrings mainly originate at the ischial tuberosity (Fig 21), whose surface can be divided into an upper region and a lower region, with a vertical osseous ridge separating the upper region into medial and lateral facets (71). The inferomedially located medial facet harbors the origin of the conjoint tendon of the long head of the biceps femoris and the semitendinosus muscle, which separate more distally into respective tendons. The semitendinosus also has direct muscular attachments onto the ischial tuberosity, and a raphe divides its muscle bulk into two portions.

The semimembranosus muscle originates more anteriorly at the lateral facet of the upper region of the ischial tuberosity and proximally is in close association with the conjoint tendon, separating from it more distally through an extensive comma-shaped aponeurosis that proceeds toward the muscle belly. The sciatic nerve can be identified lateral to the hamstrings' origin at the ischial tuberosity, lying superficial to the quadratus femoris muscle and deep to the gluteus maximus muscle. Although not visible in the absence of disease, the ischial bursa lies directly superficial to the hamstrings' origin.

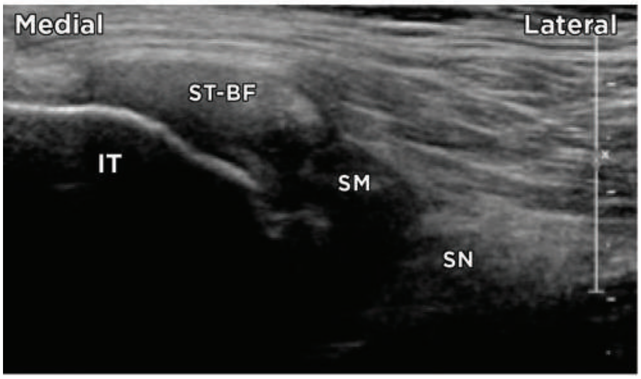
The long head of the biceps femoris and the semimembranosus have extensive proximal and distal overlapping musculotendinous junctions, averaging 12–15 cm in length (71). The short head of the biceps femoris originates from the linea aspera of the femur and joins the long head distally before inserting onto the head of the fibula. Except for the short head of the biceps femoris, the hamstring muscles are biarticular and contribute to hip extension and knee flexion as well as internal rotation of the leg (72). Through eccentric contraction, they also provide static and dynamic support of the hip and knee joint (72).

For US evaluation of the proximal hamstrings, the patient is placed in a prone position, and the probe is placed in a transverse plane over the ischial tuberosity (Fig 22). This allows visualization of the conjoint tendon of the long head of the biceps and the semitendinosus and of the semimembranosus and sciatic nerve found more laterally. Differentiating the conjoint tendon from the semimembranosus tendon may be more easily achieved when moving the probe more distally, with further differentiation between the components of the conjoint tendon (Fig 23). At the distal thigh, the short head of the biceps femoris is seen lateral to the long head, and the vastus lateralis is visualized adjacently (Fig 24).

Common Pathologic Conditions.—Hamstring injuries are one of the most common injuries in sports, particularly prevalent in activities requiring rapid acceleration, deceleration, and changing of direction such as during jumping, sprinting, and hurdling in football and athletics (72–74). Opposing tensile forces withstood by the hamstring muscle group during eccentric contractions predispose it to injuries (72). Other biomechanical risk factors of hamstring injuries include the muscles' large proportion of type II fibers producing tension at a



a.



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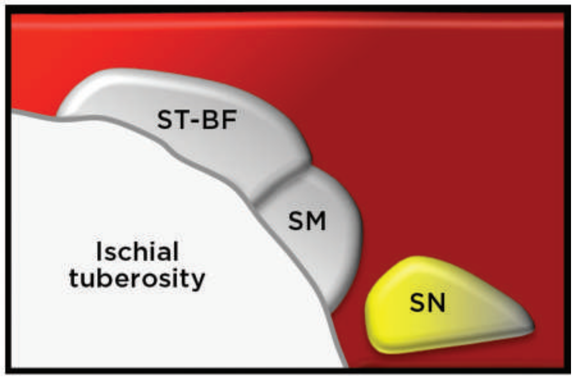

c.

Figure 22. US assessment of the proximal hamstring tendons. **(a)** The patient lies in a prone position, with the probe in a transverse plane overlying the ischial tuberosity for proximal hamstring assessment. **(b, c)** Transverse US image at the ischial tuberosity *(IT)* **(b)** and corresponding diagram **(c)** show the conjoint tendon *(ST-BF)* and laterally the semimembranosus tendon *(SM)* and sciatic nerve *(SN)*, which appear somewhat hypoechoic compared with the conjoint tendon because of anisotropy and their deeper location.

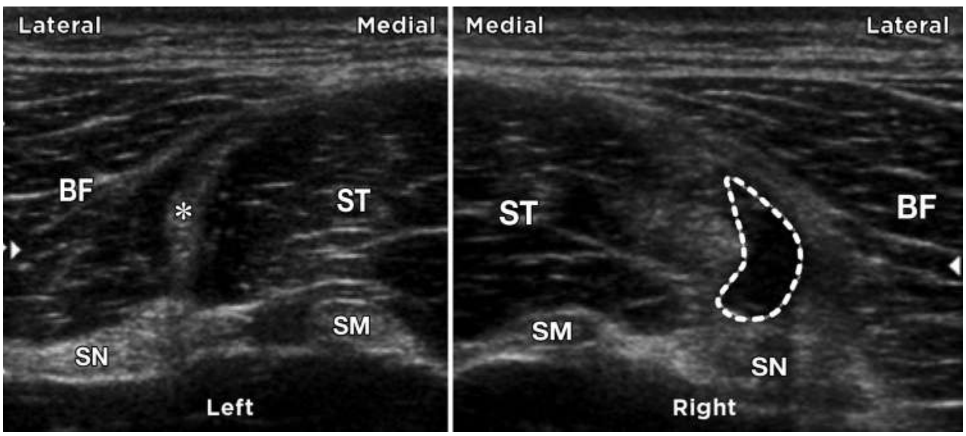

Figure 23. US assessment of the proximal hamstrings muscles. The probe is moved slightly distally as compared with Figure 22, immediately below the buttock fold, to demonstrate a differentiation between the components of the conjoint tendon. Transverse composite US image of the proximal thighs shows the normal anatomy on the left and a split tear of the conjoint tendon on the right. On the left, note the normal appearance of the conjoint tendon (*) between the biceps femoris *(BF)* and semitendinosus *(ST)* muscles. On the right, a hypoechoic split tear of the conjoint tendon (dashed white line) is shown superficial to the sciatic nerve *(SN)*. *SM* = semimembranosus tendon.

faster rate and their biarticular nature (72). Injuries can occur at several anatomic regions and have different patterns, which can be broadly classified into proximal disease (high hamstring injuries) and musculotendinous junction and myofascial injuries.

High Hamstring Injuries.—Proximal hamstring pathologic conditions include tendon enthesopathy, peritendinous inflammation, partial tendon tears (sprains), and tendon avulsions. These are sometimes referred to under the umbrella term

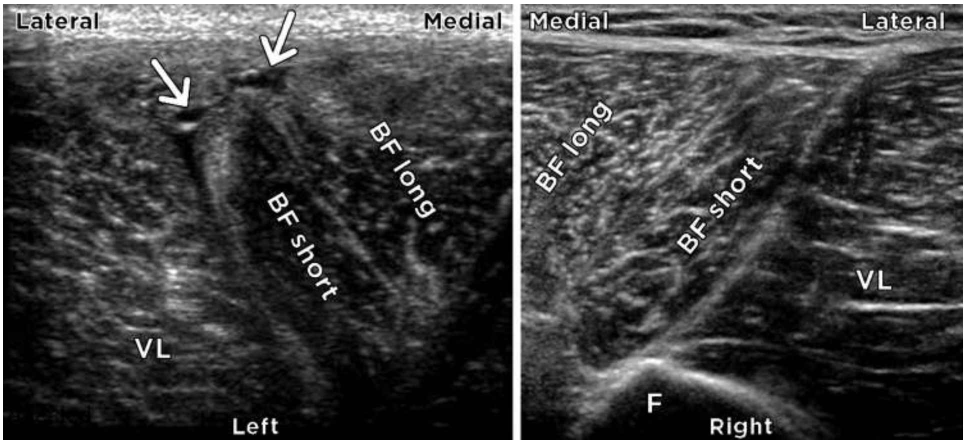

Figure 24. Strain of the short head of the biceps femoris in a 23-year-old basketball player with increasing pain in the distal posterior left thigh while sprinting. Transverse US image at the distal left thigh shows a rounded appearance of the short head of the biceps femoris muscle *(BF short)* surrounded by hypoechoic fluid (arrows), consistent with a myofascial strain. The normal distal right thigh is shown for comparison. *BF long* = long head of the biceps femoris muscle, *F* = femur, *VL* = vastus lateralis muscle.

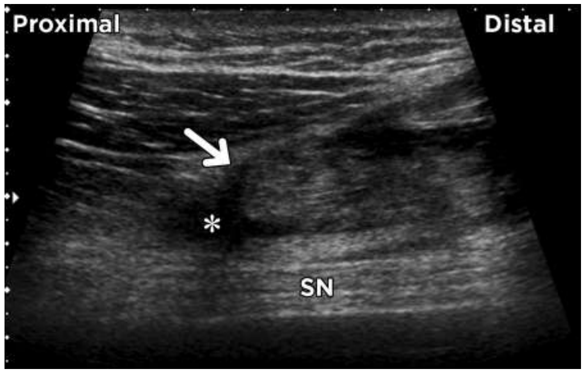

Figure 25. Tear of the conjoint tendon in a 21-year-old male soccer player with acute onset of pain and tearing sensation in the posterior right thigh while sprinting. Longitudinal US image of the proximal posterior thigh, distal to the ischial tuberosity, shows a large retracted tear of the semitendinosus and biceps femoris conjoint tendon. Note the subacute hypoechoic hematoma (*) and the bell-shaped retracted muscle belly (arrow). *SN* = sciatic nerve.

high hamstring tendinopathy owing to similar clinical manifestations (75). They occur less commonly than more distal injuries, and patients usually experience indolent deep buttock or thigh pain exacerbated by repetitive activity and sitting (75).

Tendinopathic changes associated with entheseal degeneration occur with repetitive trauma. The presence of peritendinitis as manifested by fluid or edema adjacent to the hamstring origins is a common finding in symptomatic patients (75). Proximal hamstring sprains usually affect the conjoint tendon (Fig 23), are associated with combined extreme hip flexion and knee extension, and are especially prevalent in athletes performing kicking and front splits (74). Avulsion injuries in adults most commonly involve the conjoint tendon, and unlike in skeletally immature athletes, they do not usually involve an osseous avulsion fragment (Fig 25).

In patients with high hamstring tendinopathy, the most common US finding is peritendinous fluid, followed by signs suggestive of tendinopathy (tendon hypoechogenicity with loss of fibrillar structure, hypertrophy, and calcifications). MR imaging has been shown to be more sensitive than US in detecting peritendinous fluid and tendinopathy (75). US is also less reliable in assessment of hamstring avulsions owing to the frequent co-occurrence of large hematomas and the deep nature of the injury, thus precluding determination of the degree of muscle retraction with a high degree of confidence (72).

Musculotendinous Injuries.—The musculotendinous junction is the most vulnerable area of the hamstring muscle complex in adults and is easily predisposed to strain injuries. The long head of the biceps femoris is the most commonly implicated, followed by the semitendinosus and semimembranosus muscles in equal measure (72,74). It is believed that this distribution of injuries among individual muscles is related to differences in neuromuscular coordination between the biceps femoris and semitendinosus, as well as the dual nerve supply of the biceps femoris (72).

The different portions of the extensive musculotendinous junction are affected with varying frequency, with the proximal zone injured most commonly, followed by strains of the intramuscular, distal, and myofascial portions, respectively (74). In one-third of cases, more than one muscle is injured (74). Patients experience a sudden snapping sensation in the posterior thigh followed by severe pain and may present with focal tenderness and changes in muscle bulk (74).

US findings of musculotendinous strains include fibrillar pattern disruption, perilesional edema, and intrasubstance anechoic clefts (Fig 25). US evaluation of musculotendinous injuries is highly sensitive in the presence of edema and hemorrhage in the acute settings of moderate to severe strains; however, mild strains with minor edema and absence of macroscopic myofibrillar damage may be inconspicuous at US (72). Moreover, the sensitivity of US in diagnosing musculotendinous strains is reduced in patients with large body habitus.

Management and Return to Activity.—Treatment of high hamstring injuries initially involves the RICE protocol, followed by anti-inflammatory medications for pain control and progressive rehabilitation. US-guided percutaneous corticosteroid injections and tendon fenestration have been shown to be effective in the short term (75). As demonstrated in a video article by Strickland (76) and in a technical note by Wisniewski et al (77), these interventions can be performed safely and effectively under US guidance by choosing a needle trajectory that avoids the sciatic nerve. Avulsion injuries of the hamstring muscle group are treated surgically.

Management of musculotendinous strains of the hamstring muscle group consists of initial rest, analgesics, and progressive early rehabilitation. Corticosteroid and platelet-rich plasma injections are commonly employed; however, their use is based on low-quality evidence, as is use of US-guided aspiration of liquefied intramuscular or intermuscular hematomas (74). Injuries nonresponsive to conservative measures may be amenable to surgical repair.

US features potentially associated with return to activity after hamstring injuries have received less attention compared with MR imaging findings; however, a recent literature review concluded that there was conflicting evidence on the efficacy of either US or MR imaging in predicting the duration of absence from activities (78). In professional Australian football players, greater extent of the injured area assessed at US expressed as a percentage of the cross-sectional area, presence of an intermuscular hematoma, and involvement of the long head of the biceps femoris were associated with a longer recovery time after acute musculotendinous hamstring injuries (79).

In track-and-field athletes with acute hamstring strains, a cross-sectional injury area greater than 25% and the presence of a hematoma as determined with US were associated with a longer recovery time (80). In another study, the length of acute hamstring injuries in association football players, as determined with US, did not correlate significantly with time to return to activity; interestingly, there was also no statistically significant difference between groups with and without US findings of hamstring injuries in terms of time to return to activity (81).

Conclusion

As a stand-alone assessment or combined with other imaging modalities, US evaluation adapted to the patient's clinical presentation and based on a compartmentalized approach and surface anatomy landmarks provides essential diagnostic information when evaluating soft-tissue injuries around the hip in amateur and professional athletes. Moreover, US is useful to guide point-of-care interventions in the spectrum of management of sports-related hip pathologic conditions. The prognostic value of US findings in the management of sports-related hip injuries remains limited. Currently, return to activity guidelines are not evidence based or standardized and are subjectively influenced by the severity of the lesion at imaging and by the relative risk of reinjury of certain musculotendinous structures.

US elastography is a new technique that evaluates tissue elasticity and has the potential to provide additional biomechanical information to the morphologic changes conveyed by conventional US images. US elastography was recently used to monitor the healing response over time in an animal model of Achilles tendon transection (82). Although promising, these are preliminary results, and further high-quality research is needed before this new technique can be translated to clinical practice.

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