ELSEVIER

Canadian Association of Radiologists Journal 63 (2012) 87–99

CANADIAN ASSOCIATION OF RADIOLOGISTS JOURNAL

www.carjonline.org

Musculoskeletal Radiology / Radiologies musculo-squelettique

Hip and Groin Pain in the Professional Athlete

Sean E. McSweeney, MB, FFRCSI[a], Ali Naraghi, MD, FRCR[a], David Salonen, MD, FRCPC[a], John Theodoropoulos, MD, FRCSC[b], Lawrence M. White, MD, FRCPC[a,*]

[a]*Joint Department of Medical Imaging, Mount Sinai Hospital, University Health Network and Women's College Hospital, University of Toronto, Toronto, Ontario, Canada*

[b]*Division of Orthopaedics, Mount Sinai Hospital, University Health Network and Women's College Hospital, University of Toronto, Toronto, Ontario, Canada*

Abstract

Hip and groin pain is a common condition in professional athletes and may result from an acute injury or from chronic, repetitive trauma. It is responsible for significant morbidity, which leads to time away from training and competition, and may result in a career-ending injury. The anatomic and biomechanical causes for hip and groin injuries are among the most complex and controversial in the musculoskeletal system. This makes clinical differentiation and subsequent management difficult because of the considerable overlap of symptoms and signs. This review article will evaluate several pathologic conditions of the hip and groin in athletes, divided into acute (secondary to single event) and chronic (secondary to altered biomechanical load or repetitive microtrauma) injuries, with an emphasis on imaging in the diagnosis of these injuries. Appropriate use of imaging along with clinical findings can allow accurate diagnosis and subsequent appropriate management of these patients to ultimately allow return to athletic activity.

Résumé

Les douleurs à la hanche et à l'aine sont monnaie courante chez les athlètes professionnels et peuvent être imputables aussi bien à une blessure grave qu'à un traumatisme chronique ou répétitif. Elles sont responsables d'une importante morbidité pouvant empêcher les athlètes de participer à l'entraînement ou à une compétition, voire mettre fin à leur carrière. Les causes anatomiques et biomécaniques des blessures à la hanche et à l'aine figurent parmi les plus complexes et controversées de l'appareil musculosquelettique, l'important chevauchement de symptômes et de signes compliquant la différentiation clinique et la gestion subséquente. L'article évalue plusieurs pathologies de la hanche et de l'aine chez les athlètes, regroupées dans les catégories grave (secondaire à un événement unique) et chronique (secondaire à une charge biomécanique modifiée ou à un microtraumatisme répétitif), et s'intéresse tout particulièrement au rôle de l'imagerie dans leur diagnostic. L'utilisation appropriée de l'imagerie et des examens cliniques peut contribuer à un diagnostic précis, à une gestion subséquente adéquate des patients et éventuellement à la reprise des activités athlétiques de ces derniers.

Key Words: Hip pain; Groin pain; Athletic pubalgia athlete; Imaging

Hip and groin pain is a common condition in professional athletes and may result from an acute injury or from chronic, repetitive trauma. It is responsible for significant morbidity, which leads to time away from training and competition, and may result in career-ending injury. Furthermore, if athletes are unable to return to their sport, then this problem may result in significant economic impact on professional sporting clubs and organizations.

The anatomic and biomechanical causes for hip and groin injuries are among the most complex and controversial in the musculoskeletal system. This makes clinical differentiation and subsequent management difficult because of the considerable overlap of symptoms and signs. In addition, athletes may have one or more coexisting conditions, which makes diagnosis and treatment further problematic [1–3]. In clinical practice, the term "athletic pubalgia" is often used as the catch-all term to describe exertional pubic or groin pain that might be secondary to a number of different pathologic conditions [4,5].

The Role of Imaging

Conventional radiographs are an essential first-line investigation in the diagnosis of acute and chronic hip and groin pain, and often are the only studies required when

* Address for correspondence: Lawrence M. White, MD, FRCPC, Department of Medical Imaging, Mount Sinai Hospital, 600 University Avenue, Toronto, Ontario M5G 1X1585, Canada.

E-mail address: lwhite@mtsinai.on.ca (L. M. White).

0846-5371/$ - see front matter © 2012 Canadian Association of Radiologists. All rights reserved.
doi:10.1016/j.carj.2010.11.001

a fracture is identified. Computed tomography (CT) adds further information in the presence of complex or subtle fractures, avulsion fractures, and osteoarthritis. Ultrasound (US) is a valuable tool in focused assessment of groin pain and allows dynamic assessment, and is also is invaluable in image-guided intervention. Magnetic resonance imaging (MRI) of the hip, particularly after the intra-articular administration of gadolinium, as well as imaging of the groin and symphyseal region, has proven to be extremely valuable in the diagnosis of radiographically occult osseous abnormalities as well as soft-tissue injuries, such as pubalgia, musculotendinous abnormalities, and bursitis. This article will review several pathologic conditions of the hip and groin in athletes, divided into acute (secondary to a single event) and chronic (secondary to altered biomechanical load or repetitive microtrauma) injuries (Table 1), with an emphasis on imaging in the diagnosis of these injuries.

Acute Injury

Muscle Injuries

Muscle injuries that account for hip and groin pain are among the most commonly encountered injuries in clinical practice and form a substantial portion of referrals for MRI. Injury mechanism can be divided into 3 groups: (1) direct blunt trauma, (2) forceful contraction, and (3) microtrauma by repetitive injury, and subsequently result in muscle contusions, avulsions, tears, and strains. It has been shown that preseason hip strength testing of professional ice hockey players can identify players at risk of developing muscle strains. A player was 17 times more likely to sustain an adductor muscle strain if his adductor strength was less than 80% of his abductor strength [6].

Muscle contusions. Muscle contusions are usually caused by direct blunt trauma and result in muscle belly being compressed against underlying bone and are most frequently seen in sports in which there is relatively little protection, such as rugby and soccer [6]. Common sites of injury include iliac crest, proximal thigh, and oblique muscles of the abdominal wall. These injuries are often clinically diagnosed without difficulty, but US and MRI are often used when patients symptoms are not resolving as expected. The MRI appearance of an intramuscular hematoma depends on the age of the injury. There is often enlargement of the muscle without muscle fiber discontinuity or laxity [7,8]. If there is sufficient force or contusion to a large muscle, such as the quadriceps, then myonecrosis or myositis ossificans are potential complications [7,9]. The diagnosis of myositis ossificans is best made on conventional radiographs and CT in which the peripheral zone of ossification and/or calcification is best demonstrated [10].

Muscle tears. The most common injuries about the hip and groin that result from athletic competition are muscle tears. These often occur in muscles that cross 2 joints and during an eccentric contraction (in which external load exceeds muscle force). Tears frequently occur at the myotendinous junction, which is the weakest part of the muscle tendon unit, but is also commonly seen in the muscle belly [2,3]. The same mechanism of injury that results in a muscle tear in an adult may cause an apophyseal avulsion in an adolescent [2,3]. There is a well-established clinical grading system for muscle tears, which has 3 components, from grade 1 (no loss of function or strength), grade 2 (severe, with some weakness) to grade 3 (complete muscle tear and complete functional loss) [1,10].

On imaging with US and MRI, grade 1 muscle tears can show normal appearances or a small area of focal disruption (<5% of the muscle volume), with hematoma and perifascial fluid relatively common. A grade 2 injury corresponds to a partial tear, with muscle fiber disruption seen (>5%) but not affecting the whole muscle belly (Figure 1). Grade 3 injuries are complete muscle tears with frayed margins and bunching and/or retraction of the torn muscle fibers [1,7,10].

Conventional radiographs are useful to rule out an avulsion injury. MRI is ideally suited to assess these injuries and allows assessment of the entire myotendinosis unit in multiple planes [2,7]. In the setting of acute myotendinosis muscle strains and/or tears, MRI typically shows focal high signal intensity on T2-weighted or short-time inversion recovery sequences, with oedema and hemorrhage at the myotendinous junction (Figures 1–3). Oedema may track along muscle fascicles and create a feathery pattern. If there is complete disruption of the muscle or myotendinous unit, then MRI shows discontinuity of muscle fibers and retraction, with a focal fluid collection filling the gap [7,9,10]. Investigators have demonstrated that a cross-sectional injury area (as a percentage score), the superior-inferior extent of the injury on MRI, and injury outside of the musculotendinous junction are independently associated with increased recovery time, with the best prognostic indicator from MRI being the longitudinal length of the injury [11,12].

In the acute setting, US is as sensitive as MRI, which demonstrates the muscular architecture at a higher resolution and allows dynamic muscle assessment. However, in athletes with large muscle bulk, the depth of resolution can limit visualization, and, when prognostic indicators are required, MRI is often more useful [1,11].

The hamstrings are the most common site of muscle strain injury in athletes, particularly football, soccer, and basketball

Table 1
Common pathologic conditions of the hip and groin

Acute	
Muscle injuries	Contusions; tears and strains; avulsion and apophyseal injuries
Bony injuries	Hip dislocation and subluxation; hip fractures (acute and stress)
Joint	Cartilage; labrum; femoral acetabular impingement; developmental dysplasia of the hip
Chronic (overuse)	
Groin pain	Athletic pubalgia; common adductor/rectus abdominis injury; osteitis pubis; hernias; snapping hip syndrome; greater trochanter pain syndrome; bursitis

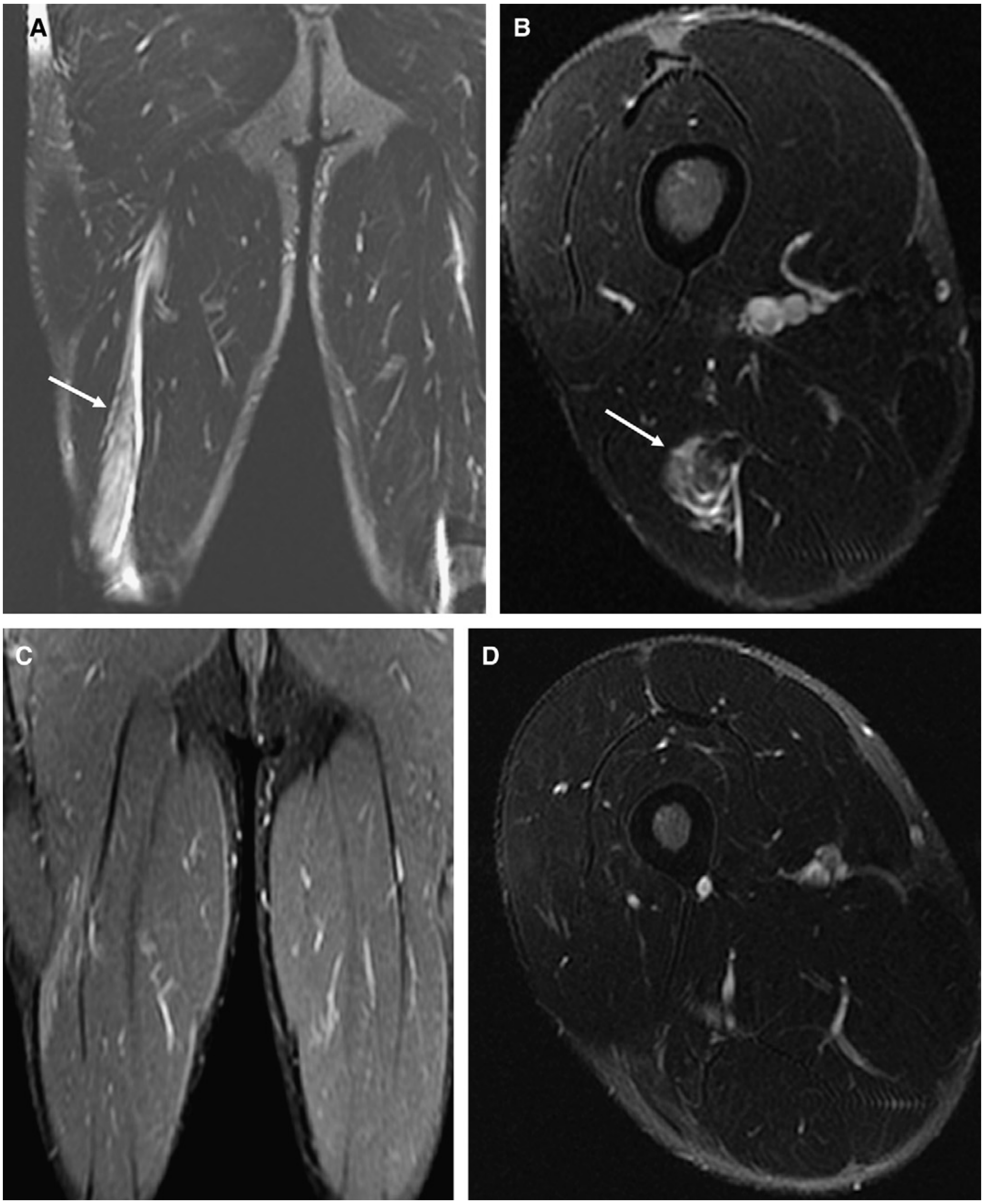

Figure 1. Musculotendinous junction injury of the long head of the biceps. Axial and coronal fat-saturation fast spin-echo T2-weighted magnetic resonance imaging (A, B), demonstrating high-grade partial tear of the distal musculotendinous junction (white arrows) of the long head of the biceps. (C, D) Interval resolution (5-month follow-up) of the previously demonstrated oedema and fluid in and adjacent to the biceps femoris and semitendinous muscles with healing and scarring without progression; the patient returned to professional basketball.

players, and they are often prone to recurrent injury. Acute injuries are more frequent in older players, during preseason training and/or conditioning; in those with a previous injury; and in setting of fatigue at the end of a period of play. In particular, the myotendinosis junction of the long head of biceps femoris (Figure 1) is particularly susceptible, because it spans 2 joints and arises from more than 1 head. There is an association between rehabilitation time and MRI measurements of muscle injury, such as the percentage of the cross-sectional area of the abnormal muscle [12]. The amount of time lost from competition is not influenced by the specific hamstring muscle injured or by the intramuscular location of the injury [12].

Most cases of quadriceps muscle (in particular rectus femoris) injury are seen in football and soccer players involved in sprinting or kicking, and often follows trauma such as stretching or overuse. As with hamstring tears, the central myotendinosis unit of the rectus femoris is the most common site of tear, with location important, because involvement of the central aponeurosis has been shown to be associated with prolonged convalescence compared with tears of the peripheral myotendinous unit (Figure 2) [13,14].

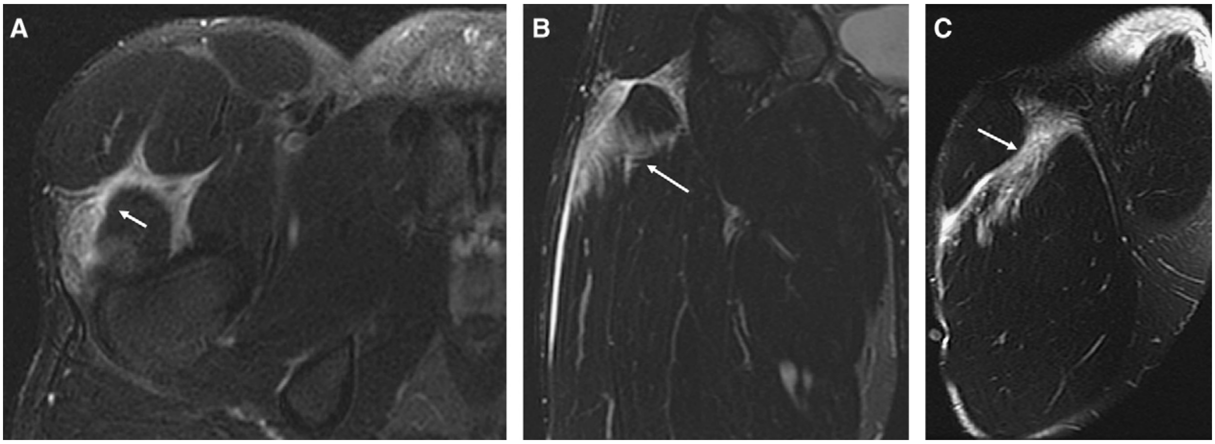

Figure 2. Musculotendinous junction injury of vastus lateralis. (A, B, C) Axial, coronal and sagittal fat-saturation fast spin-echo T2-weighted magnetic resonance imaging, demonstrating a grade 2 partial injury at the proximal musculotendinous junction of the vastus lateralis (white arrows). There is a crescentic fluid collection just deep to the tensor fascia lata and superficial fascia of the thigh. The patient received nonsurgical treatment and returned to professional hockey.

Anterior abdominal wall muscle injuries are most commonly seen in hockey and racket sports, because trunk rotation plays a significant role in generating the force required to hit a puck or a ball. Resultant injury leads to pain, tenderness, and withdrawal from training and competition. US can be useful to evaluate muscle tears of the rectus abdominis, which commonly occur in the deep fibers below the umbilicus. MRI can show muscle disruption, with associated muscle oedema and hemorrhage [1].

The adductor muscles are frequently involved in athletic muscle tears related to the groin, especially in hockey, football, and soccer players (Figure 3). Groin or medial thigh pain is the most common complaint, particularly when the patient is asked to adduct the leg against resistance [2]. Such injuries uncommonly present acutely for imaging and are more commonly identified in evaluation of chronic groin pain, with many investigators concluding that adductor dysfunction is the most common cause of "athletic pubalgia" [15,16].

Avulsions. Avulsion injuries about the pelvis are more common in patients who are skeletally immature [17]. Such injuries can occur at essentially every major muscle attachment and are commonly the result of a violent muscle contraction, which is usually eccentric in nature. The single most common site of avulsion is the ischial tuberosity (origin of hamstrings and hamstring portion of adductor magnus) and tends to occur between puberty and age 25 years [17,18]. Other sites of commonly seen avulsion injury include the anterior superior iliac spine (sartorius), anterior inferior iliac spine (rectus femoris), greater trochanter (gluteus), and lesser trochanter (iliopsoas) [6]. Chronic avulsion injuries or apophysitis are usually the result of repetitive microtrauma and commonly lack a history of acute injury [17,18].

In the setting of an avulsion injury, localized tenderness, swelling, and eventual ecchymosis are common clinical findings. Resisted contraction or stretch of the involved muscle usually reproduces the pain. Conventional

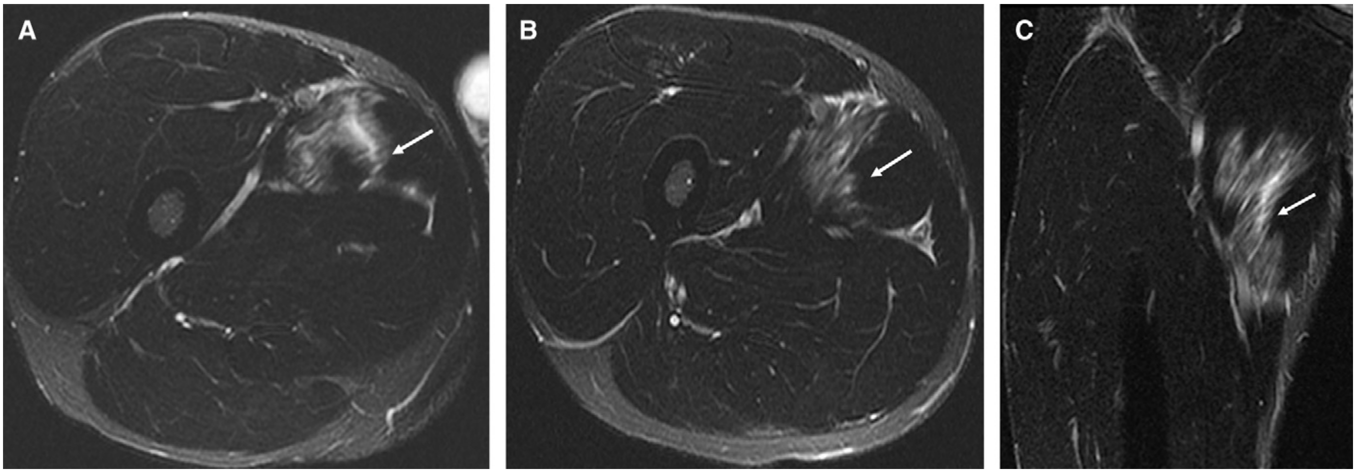

Figure 3. Adductor longus muscle injury. (A, B, C) Axial and coronal fat-saturation fast spin-echo T2-weighted magnetic resonance imaging, demonstrating a grade 2 muscle tear of the proximal adductor longus muscle (white arrows), which demonstrates 50% −60% circumferential involvement of the muscle belly. The craniocaudal extent of the tear measures approximately 16 cm. The patient received nonsurgical treatment and returned to professional hockey.

radiographs, including comparison views, are commonly all that is required to identify the injury if the fragment is visible [2]. However, the index of suspicion of such injuries should be high in children and adolescents with clinical findings of avulsive injuries despite the lack of visualized avulsion fracture on radiographs because secondary ossification centres may have not yet begun ossification. Healing or chronic avulsion injuries can mimic an aggressive bony lesion (infective or neoplastic process) with mixed sclerosis and lysis [7]. In such instances, clinical history and knowledge of common attachments is required to avoid misinterpretation of an avulsion as an aggressive lesion that requires biopsy. CT can be useful in the acute setting if plain films are nondiagnostic or in case of healing or chronic avulsion [10,18].

In the acute setting, MRI can be helpful in identifying subtle avulsion injuries by demonstrating an increased signal between apophysis and adjacent bone (Figure 4). MRI is most useful in identifying associated soft-tissue injuries such as muscle tears and/or strains. In chronic or healing avulsion, MRI commonly shows prominent bone attachment site, callus and heterotopic bone formation, and possible tendinopathy, but there should be no evidence of adjacent bony destruction [18]. Treatment of avulsive injuries is commonly conservative, but consideration of surgical repair may be given in a setting of a large osseous fragment large enough to hold fixation hardware and if displacement is greater than 2 cm [2].

Bony Injuries

Osseous injury that results in athletic hip and groin pain varies, depending on sport participation and age of athlete and includes dislocation, subluxation, and fractures (acute and stress).

Hip dislocation and subluxation. Complete dislocation of the hip is uncommon in athletes, but subluxation is likely more frequent but is poorly recognized or appreciated.

Dislocation of the hip is rare and occurs in high velocity or impact sports, such as skiing, rugby, and American football. Most dislocations (85%−90%) are posterior, except in alpine skiing in which anterior dislocations are more common [2,19]. Conventional radiographs are commonly performed before and after reduction to assess for associated fractures. CT is indicated to assess for failure of reduction, to evaluate intra-articular fracture fragments or associated acetabular fracture. MRI is usually reserved for the subacute phase to assess for soft-tissue injury, such as osteochondral or chondral injury, intra-articular cartilaginous bodies, and labral tears, and for evaluation of potential complications, such as avascular necrosis of the femoral head [2,10,20].

Hip subluxation in athletes is likely underdiagnosed or misdiagnosed because of its subtle presentation [20]. Subluxation can occur with minimal injury such as a fall forward on a flexed knee or impact from behind while on all fours. As with hip dislocations, the most common direction of hip subluxations is posterior [10]. Imaging, in particular MRI, can demonstrate acute fracture or contusion of the femoral head or the posterior acetabulum, with associated tearing of the labrum and iliofemoral ligaments. Chondrolysis and avascular necrosis also are described in the setting of traumatic subluxation of the hip [2,10,20]. The pathognomonic radiographic imaging and MRI triad of posterior hip subluxation is the presence of a posterior acetabular lip fracture, iliofemoral ligament disruption, and hemarthrosis [21]. Patients in whom osteonecrosis is diagnosed at 6 weeks after injury are at risk for subsequent femoral head collapse and joint degeneration, and they should be advised against returning to sports [21].

Stress fractures. Stress fractures are either fatigue fractures, which occur in normal bone that is subjected to repeated stress, with each biomechanical insult being less than that required to cause acute fracture; or insufficiency fracture, which occurs when normal stress is applied to abnormal bone [1]. Although stress and/or fatigue fractures occur as a result of chronic stress, they often arise as an acute fracture to a site previously weakened over time.

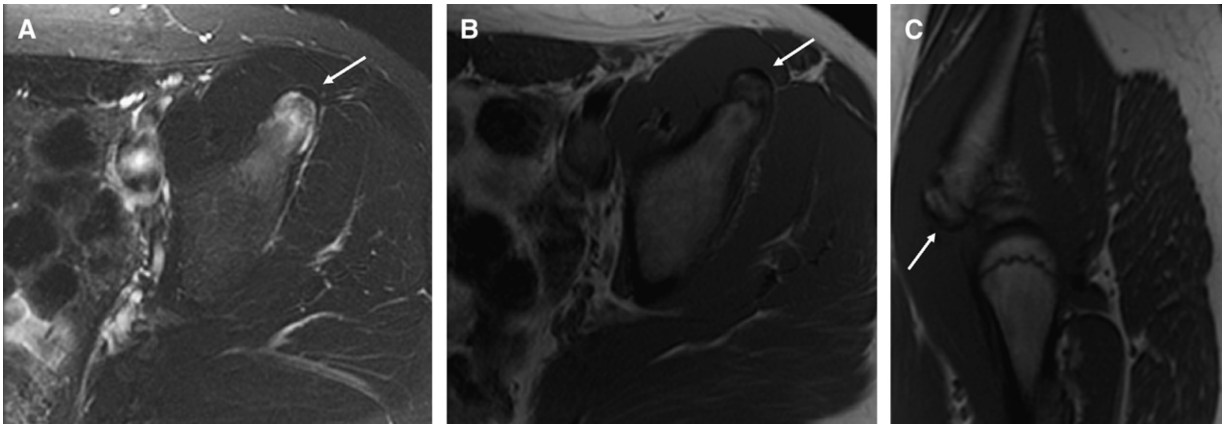

Figure 4. Avulsion fracture of the left anterior inferior iliac spine. (A) Axial fat-saturation fast spin-echo (FSE), T2-weighted magnetic resonance imaging (MRI), and (B, C) axial and sagittal FSE T1-weighted MRI, demonstrating avulsion fracture of the left anterior inferior iliac spine at the insertion of the rectus femoris (white arrows).

Insufficiency fractures commonly occur in young female athletes with osteoporotic or osteomalacic bone secondary to nutritional or hormonal deficiency or both [1].

Initial conventional radiographs are often normal, and follow-up studies may only demonstrate abnormalities in 50% of cases [22]. Because of its superior specificity, MRI has replaced bone scintigraphy as the modality of choice in the evaluation of stress injuries [23]. In the early phase (<3 weeks of the onset of symptoms), bone marrow oedema and hemorrhage may be identified on fluid-sensitive sequences (Figure 5, A and B). After 3 weeks, after resolution of oedema, a pattern of hypointense signal secondary to sclerosis at the site of fracture may be observed and is best visualized on a T1-weighted spin-echo sequence without fat saturation in which the hypointense line is contrasted against normal hyperintense marrow fat (Figure 5C).

Stress fractures can be graded with MRI as grade 1, endosteal marrow oedema; grade 2, periosteal and endosteal marrow oedema; grade 3, muscle, periosteal, and endosteal marrow oedema; grade 4, fracture line; grade 5, callus in cortical bone [22,24]. Grades 1 and 2 MRI changes may be present in asymptomatic athletes [25]. On follow-up, after conservative management or rest, MRI usually demonstrates a bone marrow signal intensity that has returned to normal on fluid-sensitive sequences at 3 months; bone scintigraphy is less useful in documentation of subacute resolution after conservative treatment because abnormal uptake may persist for up to 8–10 months [26].

Joint

Recently, there has been increasing emphasis on injuries within the hip joint, including the articular cartilage and the fibrocartilaginous labrum. In the athlete, specific underlying anatomic conditions may predispose to labral and hyaline cartilage injury at the hip, including femoroacetabular impingement (FAI) and developmental dysplasia of the hip.

Cartilage. The articular cartilage of the hip is difficult to assess by imaging for several reasons, including the relatively thin nature of cartilage of the hip (particularly when compared with the knee) and the hip's curved structure, and, in addition, the hip is a deeper articulation than other joints, which makes signal-to-noise ratio on MRI less favorable and makes resolution of the thin articular cartilage difficult.

MRI and MR arthrography (MRA) of the hip are the most commonly used techniques for assessment of intra-articular pathology (labral and hyaline cartilage injury) (Figure 6). Results of multiple studies have shown increased accuracy of direct MRA (postintra-articular injection of gadolinium) compared with noncontrast MRI, with sensitivity increasing from 30%–90% and accuracy increasing from 36%–91% [27,28].

3T MRI without intra-articular injection of gadolinium has the potential to improve the detection and diagnosis of early grades of cartilage injury and labral pathology because of its enhanced signal-to-noise ratio and higher spatial resolution, which allows greater resolution of intrinsic joint structures (Figure 7) [29].

Osteochondral traumatic lesions may occur after hip dislocation or subluxation, usually at the site of impaction, with suspected pathology being chondral injury and underlying microfracture of subchondral bone [30], which can predispose to osteoarthritis in later years. The MRI findings in such injuries have the characteristic appearance of a traumatic chondral lesion and are typically characterized by irregularity and/or tearing of the surface cartilage with focal abnormal signal (high T2-weighted and low T1-weighted signal) in the subchondral bone, often with an associated joint effusion (Figure 6) [31].

The MRI classification for osteochondral lesions of the hip is as follows: grade 1 shows intact cartilage with subchondral signal, grade 2 shows a partial detachment of cartilage with a subchondral signal, grade 3 shows complete detachment of a nondisplaced fragment, and grade 4 shows a detached and displaced fragment [30,32]. Grades 3 and 4 are more accurately depicted by MRA than grades 1 and 2, and much research is currently geared towards detection of these earlier lesions.

Labrum. Acetabular labral tears have become a commonly recognized cause of intra-articular hip pain. Such injuries are most common in runners and in athletes who play sports that involve twisting, extreme hip rotation, and flexion but can also occur after significant injury, such as subluxation or dislocation. As with the imaging evaluation of articular cartilage, direct MRA has been shown to

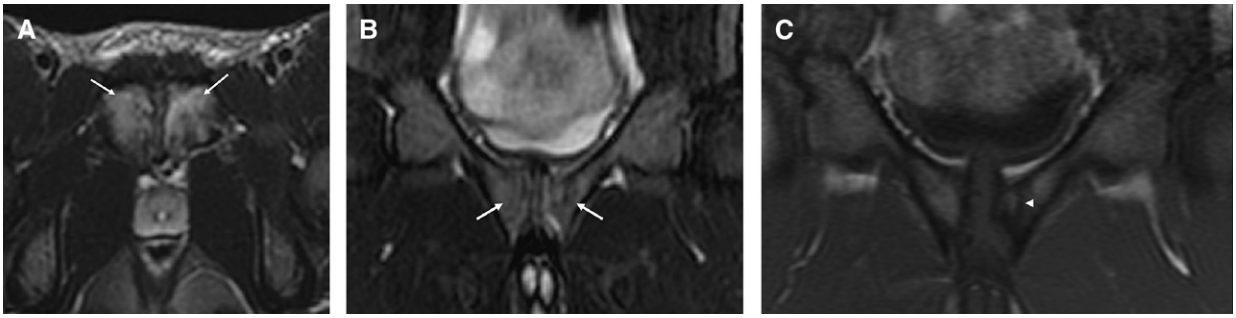

Figure 5. Stress reaction and/or fracture of the pubis. (A, B) Axial and coronal fat-saturation fast spin-echo T2-weighted magnetic resonance imaging (MRI), demonstrating a marked increased T2 signal within the pubis suggestive of a stress reaction (white arrows), and (C) coronal T1-weighted MRI, confirming the presence of a fracture of the left pubis (white arrowhead). The patient received nonsurgical treatment and returned to professional soccer.

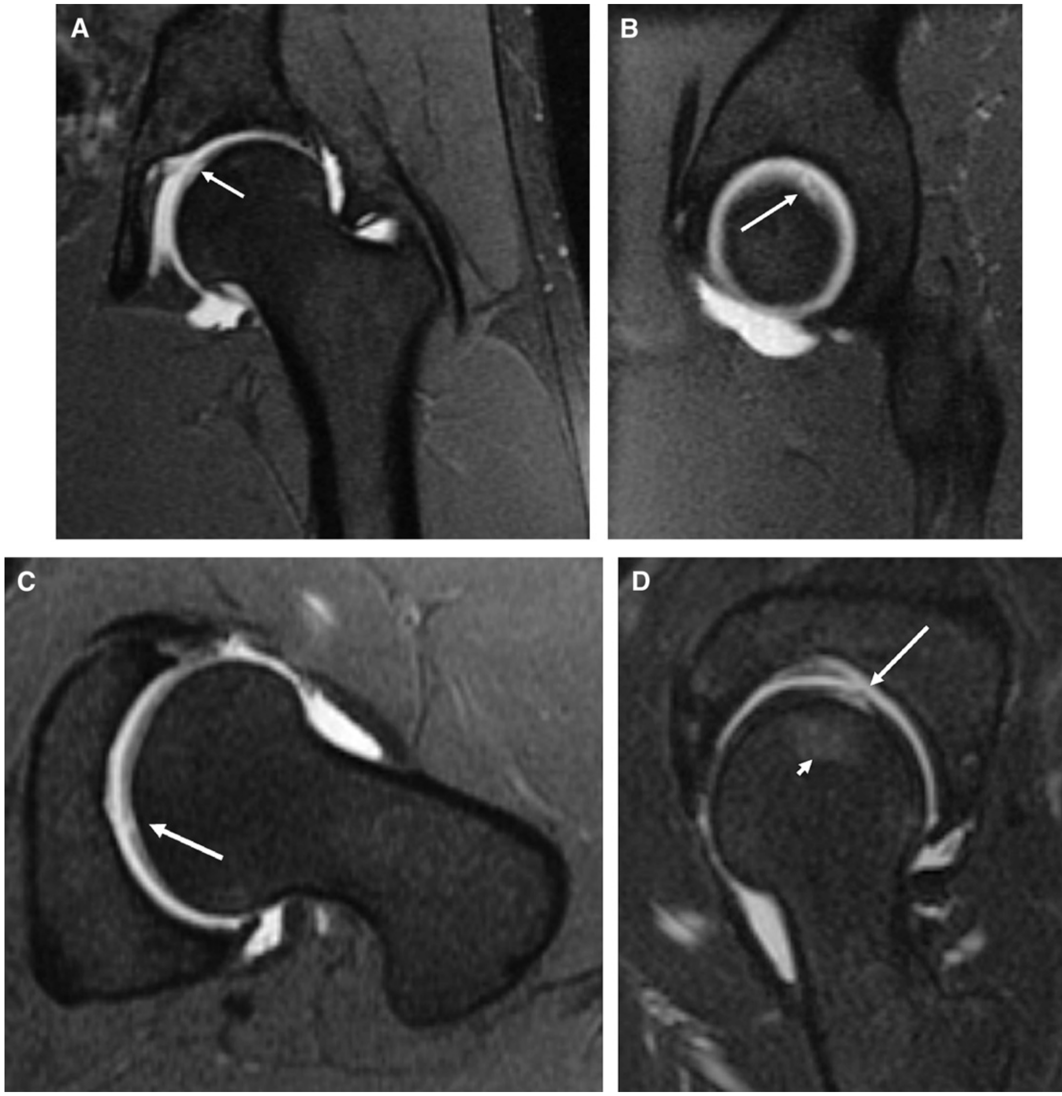

Figure 6. Traumatic chondral injury. (A, B, C) Coronal, sagittal, and axial fat-saturation T1-weighted magnetic resonance (MR) arthrographic image, demonstrating a focal chondral tear (white arrows) filled with gadolinium, involving the central aspect of the articular surface of the femoral head with delaminating component. (D) Sagittal fat-saturation fast spin-echo (FSE) T2-weighted MR imaging, again showing a delaminating chondral injury (white arrow) with oedema-like signal intensity (white arrowhead) in the underlying subchondral bone, which was confirmed at the time of arthroscopy; the patient returned to professional hockey.

be the best imaging modality for assessment of labral pathology [30].

Biomechanically, the labrum increases the depth of the acetabular socket and helps maintain stability of the hip joint. When torn or detached, forces are transmitted to the subjacent cartilage at the labral-chondral junction, which suggests a role in the development of chondrosis and arthritis [33]. Anatomically, the labrum is triangular in shape, with its base attached to the acetabular rim and its apex extending laterally along the capsular side of the acetabular rim. The acetabular labrum extends nearly circumferential around the horseshoe-shaped acetabulum and blends with the transverse acetabular ligament inferiorly. The labrum demonstrates typical MRI features of organized collagen, with decreased low signal on T1- and T2-weighted images [33].

The majority of the athletic and traumatic tears of the labrum occur in the anterior, anterosuperior, or superior portion, with some minor variations as a result of the different types of impingement or injury [30]. Tears are separated into 3 major groups: detached, intrasubstance, and degenerative.

Detached tears demonstrate separation of the labrum from its acetabular base, which can be complete or partial, and may be displaced or nondisplaced. Detached tears with displacement on MRA demonstrate linear fluid or contrast signal gap interposed between the base of the labrum and the bony acetabular rim, and are best seen on coronal images in the setting of superior predominant tears and oblique axial images for anterior predominant tears (Figure 7) [33].

Intrasubstance labral tears classically demonstrate intrasubstance fluid or contrast signal, usually extending to the

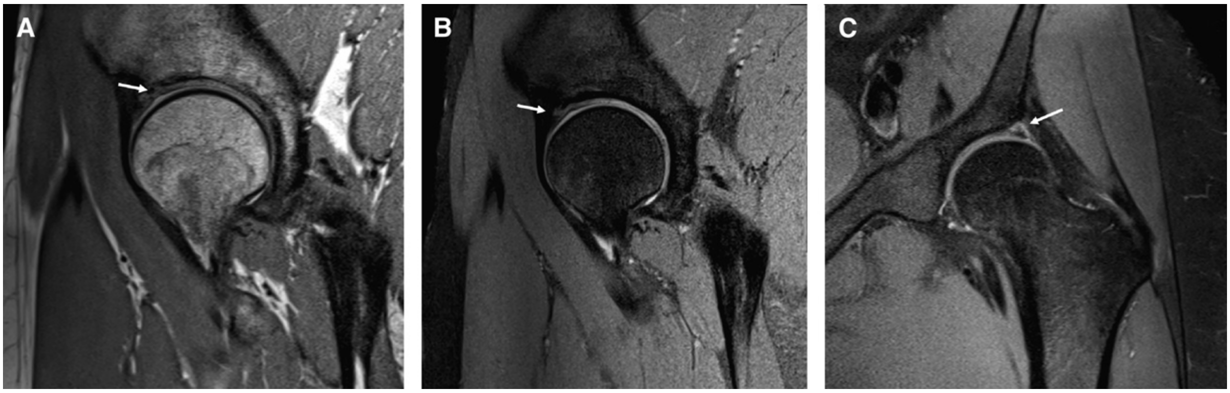

Figure 7. Labral tear. (A) Sagittal turbo spin-echo (TSE) proton density (PD)-weighted 3T magnetic resonance imaging (MRI) and (B, C) sagittal and coronal fat-saturation TSE PD-weighted 3T MRI of the left hip, showing a small anterosuperior labral tear (white arrows).

articular side of the labrum (sometimes the capsular side), which is often oblique or curvilinear in shape. However, the signal may also be complex and extend in multiple directions in the long and short axis of the labrum [33]. Increased signal alone within the labrum can be seen without frank fluid or contrast signal in the setting of labral tears with opposed surfaces [34].

A labrum with abnormal irregular contours and a thin morphology, with or without intrasubstance fluid or a contrast signal that extends to the free margin, is considered a degenerative-type tear. In athletes, it is not uncommon to have a combination of detached or intrasubstance tears with superimposed degenerative components [33].

FAI. In the athlete, FAI is a major cause of hip pain, reduced range of motion, and decreased performance [35]. FAI is characterized by abutment of the femoral neck and the acetabulum, and occurs by 2 mechanisms known as ‘‘cam’’ and ‘‘pincer’’ impingement but commonly is a combination of the both. Cam-type FAI is characterized by abnormal morphology of the femoral head-neck junction against often normal acetabulum, while pincer type FAI is characterized by abnormal acetabulum against often normal femoral head neck junction [36]. The etiology of symptoms of FAI in athletes is still unclear, and it remains to be seen whether certain sports induce abnormality or simply exaggerate the underlying abnormality by using specific biomechanical-physiological range of motion such as internal rotation of the flexed hip (hockey goalkeeping stance).

Several imaging modalities, including conventional radiographs, CT, and MRI can be used to identify the imaging findings of FAI. Conventional radiograph findings of FAI have been well described and include flattening of the femoral head-neck junction, commonly known as the ‘‘pistol grip deformity,’’ prior trauma, or congenital deformity of the femoral head-acetabulum, synovial herniation pits, or decreased femoral head-neck offset (best demonstrated on the lateral view) (Figure 8) [37]. Synovial herniation pits are commonly located in the subcapital region of the anterior femoral neck and are well seen on radiographs as regions of decreased bone density with well-defined borders.

CT or MRI of the hip affected by FAI may show an increased alpha angle on oblique axial images and increased width of the femoral neck relative to the diameter of the femoral head. The oblique axial imaging plane is obtained by prescribing the cross-sectioning parallel to the femoral neck and is a cross-sectional equivalent to a lateral radiograph of the femoral neck with the cassette parallel to the femoral neck. The alpha angle is used as an objective representation of the prominence of the anterior femoral head-neck junction, with the more prominent the alpha angle (>50°), the greater the predisposition for impingement (Figure 9) [37,38]. Patients with clinical symptoms of FAI have also been found to have increased ratios of femoral neck size relative to the femoral head compared with patients without clinical symptoms of FAI [38]. CT can also show ossification or calcification along the acetabular margin in the region of impingement and bony sclerosis and/or subchondral cyst formation seen in early onset degenerative change.

The MRI appearance of FAI includes the loss of femoral head-neck junction offset, anterosuperior acetabular labral damage and associated MRI evidence of corresponding impaction damage at the superior-superolateral femoral

Figure 8. Femoral acetabular impingement (FAI). Conventional radiograph, showing the characteristic flattening of the femoral head-neck junction, commonly known as the ‘‘pistol grip deformity’’ of FAI.

head-neck junction and adjacent chondrosis, which is often associated with subchondral cyst formation, bony sclerosis, and osteophyte formation, and correlates with surgical and radiographic findings (Figure 9) [37,39]. Different patterns of cartilage loss have been correlated with different types of FAI. Pincer-type FAI typically results in diffuse, shallow chondral injury, whereas cam-type FAI results in primarily deep anterior chondral injury [33]. Acetabular rim syndrome in hip dysplasia is characterized by similar MRI findings in an identical location as FAI. In contrast to the flexion and impingement mechanism proposed for FAI, hyperextension and torsional forces, such as those seen in jogging, soccer, and pivoting sports, are believed to produce these cartilage injuries in those with underlying developmental dysplasia of the hip [40].

Chronic (Overuse)

Groin Pain

Groin pain in professional athletes is much more prevalent than such injuries in the general public. In clinical practice, the term ‘‘athletic pubalgia’’ is often used as a catch-all term and is the preferred label to describe exertional pubic or groin pain in the athlete [4,5]. A variety of other terms (adductor dysfunction, hockey goalie syndrome, osteitis pubis, sports hernia, and Gilmore’s groin) are used in the medical literature, which adds to the controversy in the etiology, diagnosis, and management of the condition [3,5].

In reality, complex crossover probably exists with many or all of the preceding conditions, with chronic shear forces acting through the symphysis pubis via the adductor tendons, abdominal muscles, and medial inguinal structures. Presumably, an initial low-grade chronic injury leads to an imbalance of stresses with propagation of injury as the athlete continues to train and play [3].

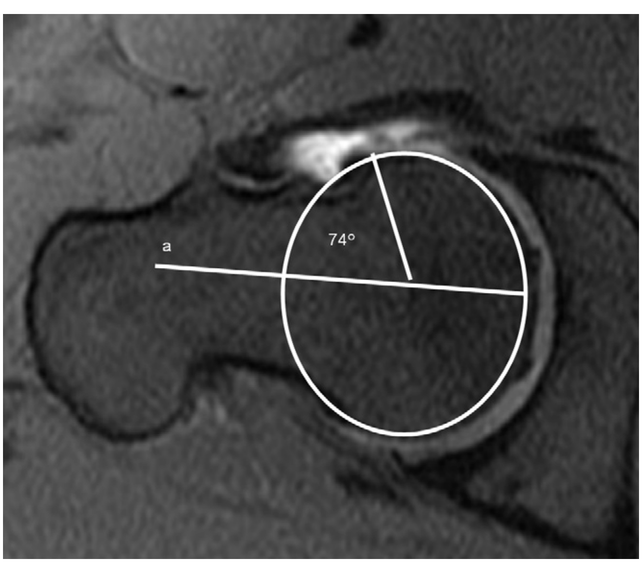

Figure 9. Femoral acetabular impingement. Axial oblique fat-saturation T1-weighted magnetic resonance arthrographic image, showing an abnormal alpha angle. A best-fit circle is drawn, which outlines the femoral head. The angle is calculated as the angle formed between line that bisects the femoral neck (line a) and the point where the femoral head protrudes anterior to the circle.

Most athletes with athletic pubalgia report an insidious onset of exertional pubic and deep groin pain, which often radiates to the inguinal ligament, rectus abdominis, or perineum. Symptoms are commonly unilateral but can be bilateral. Athletes may experience alternating episodes of exacerbation and improvement, or symptoms may gradually progress over time, with most having symptoms for months or years before a clinical diagnosis is obtained. Physical examination frequently reveals pain with resisted hip adduction or sit-ups, as well as focal tenderness at the pubic attachment of the rectus abdominis, adductor longus muscle, or at the external inguinal ring [5].

MRI has been found to be both sensitive (98%) and specific (89%−100%) in athletes with groin pain for injuries that involve the rectus abdominis, adductor tendon origins, and articular disease of the pubic symphysis [16].

Common adductor and/or rectus abdominis injury. Most investigators conclude that the most common cause of athletic pubalgia in athletes is injury to the hip adductors (adductor longus, brevis and magnus, and gracilis), because this is the strongest muscle group acting in the region [15,16]. The rectus abdominis and common adductor muscles are relative antagonists of one another during rotation and extension from the waist. MRIs obtained in cadaveric specimens and in patients without evidence of groin injuries routinely show the fibers of the rectus abdominis and adductor longus origins blended together to form a common anatomic and functional unit, referred to as an aponeurosis. This aponeurosis in turn attaches to the periosteum of the anterior aspect of the pubic body, which appears to merge with the anterior pubic ligament, interpubic articular disk, and elements of the inguinal canal, termed the prepubic aponeurotic complex [5,15]. An injury to one of these tendons predisposes the opposing tendon to injury by both altering the biomechanics and disrupting the anatomic contiguity of the tenoperiosteal origins. In turn, such disruption leads to instability of the pubic symphysis [3,5].

Conventional radiographs of common adductor-rectus abdominis injuries are generally normal, with enthesopathy of its origins being the earliest sign, which, if severe enough, may show erosive change or, if chronic, may show a mixed lytic and sclerotic appearance [41]. US has the ability to depict erosive change with interruption of the hyperechoic cortex at the site of rectus and adductor origins. Further hypoechoic areas may also be visualized within the adjacent tendons and may represent tendinosis, whereas discrete anechoic clefts may represent partial thickness tendon tears. Specificity of US is also increased by variable degrees of examiner-related pressure with the US probe at imaging eliciting tenderness in region [41].

MRI is the modality of choice in the depiction of common adductor-rectus abdominis and aponeurotic injuries. Fluid-sensitive fat-saturation sequences in axial and coronal plains commonly demonstrate 3 patterns of injury: (a) the most frequently encountered pattern is injury to the rectus abdominis alone, (b) injury that involves both the rectus abdominis and the thigh adductors, or (c) thigh adductor injury alone, with or without pubic bone marrow oedema (Figure 10) [16].

Injury to the rectus abdominis when present is commonly observed along the lateral border of its insertional fibers, just cephalad to its pubic attachment. Adductor injury often demonstrates pubic bone marrow oedema (usually asymmetric and predominately anterior), combined with the secondary cleft sign, fluid signal that extends from the intra-articular primary cleft, which likely represents aponeurotic complex injury with tear or partial avulsion of adductor longus origin (Figure 11) [16].

After an injury to either the rectus abdominis muscle or the adductor muscle, there is a repetitive unbalanced contraction in the other muscle, which may lead to degeneration and tearing of the tendon not initially torn; this is commonly observed on MRI. Thus, ultimately, the injury can extend confluently through the aponeurosis, with resultant involvement of both the rectus abdominis and the adductor longus [5,15].

Patients with rectus abdominis origin injury on MRI typically have a perceptible injury or defect on clinical examination, and nearly all undergo surgery for pelvic floor reconstruction. Nonoperative management with rest is the common mode of treatment for common adductor injuries [15,41].

Osteitis pubis. Osteitis pubis or pubic bone stress injury is common in athletes, particularly soccer players, long-distance runners, and hockey players. Patients commonly complain of pain with kicking, running, jumping, or twisting, which may radiate suprapubically or into the groin [2]. It is believed to result from instability of the pubic symphysis because of chronic repetitive shear and distraction injuries and unbalanced tensile stress from the muscle attachments of the pubic symphysis. The resultant alteration in biomechanics may produce an inflammatory response, with osteitis and periostitis [3,5]. Radiographs of the pubic symphysis in the osteitis pubis may show subchondral sclerosis, symphyseal irregularity, and bone resorption [5]. MRI typically demonstrates symmetric bone marrow oedema, which spans the pubic symphysis anterior to posterior, a high frequency of bony erosive and/or productive changes, and no imaging findings of rectus abdominis or adductor tears [13,16]. Treatment usually includes rest and nonsteroidal anti-inflammatory medications and, if not responding, corticosteroid joint injection with image guidance [2].

Hernias. Sports players with pain in the groin could have a hernia. An indirect inguinal hernia that becomes irreducible can produce groin pain. Patients with a direct inguinal hernia notice discomfort, particularly with prolonged standing and walking as opposed to during more energetic sporting activities. Occasionally, a patient will have a femoral hernia and rarely an obturator hernia. Patients with an inguinal hernia classically present with a palpable lump with a cough impulse on standing, whereas femoral hernias are commonly irreducible and present as a lump below and lateral to the pubic tubercle.

The terms sports hernia and sportsman's hernia were first used to describe inguinal pain experienced by athletes secondary to acquired inguinal-wall deficiency not of sufficient severity to result in discrete hernia formation [42]. It is best conceptualized simplistically, involving either the anterior inguinal wall (external oblique muscle and aponeurosis), the posterior inguinal wall (transversus abdominis and internal oblique muscles), or both.

Anterior inguinal-wall deficiency is classically known as "Gilmore's groin," and the pathology found at the surgery is varied [43,44]; however, the main features are the consequence of degeneration and partial tearing of the external oblique aponeurosis, which result in dehiscence between the aponeurosis and inguinal ligament and causes dilatation of the superficial inguinal ring. Almost all patients are male patients, with tenderness to physical examination located precisely at the superficial inguinal ring. The thin fascial nature of the external oblique aponeurosis makes imaging findings rarely seen, but hyperintensity of the superficial inguinal ring on fluid-sensitive MRI sequences has been cited as potential imaging features in such patients [41].

Repeated overuse injury of the posterior inguinal wall may result in degeneration and weakness of the transverses abdominis and internal oblique muscles. Because the posterior inguinal wall attaches onto the anterior sheath of the rectus abdominis muscle, posterior inguinal-wall deficiency can be seen in association with rectus abdominis abnormalities. Imaging findings of posterior inguinal-wall deficiency have been described on dynamic sonography. The athlete is asked to strain with the probe placed over the medial aspect of the inguinal region and initially imaged along the plane of the inguinal canal and then rescanned 90° to this. The test is positive if abnormal ballooning of the posterior inguinal wall exists and produces symptoms that correspond to the athlete's presenting condition [41,45]. However, similar findings may also be observed in asymptomatic patients, which makes imaging features nonspecific.

Snapping hip syndrome. Snapping hip syndrome is a clinical entity characterized by painful snapping or clicking at the hip joint caused by motion and is commonly seen in athletes such as long-distance runners, gymnasts, and soccer players. There are many subtypes of snapping hip syndrome, but, broadly, the etiologic features can be divided into intra- and extra-articular causes. Causes of intra-articular snapping hip syndrome include acetabular labral tears, articular cartilage injury, intra-articular bodies, synovial osteochondromatosis, and recurrent dislocation. Extra-articular causes are commonly secondary to tendon pathology and are further divided into internal (medial), external (lateral), and posterior, depending on tendons involved [13].

The internal (medial) form of snapping hip syndrome is the most commonly encountered. It occurs as the hip is extended and the iliopsoas tendon moves from a relative anterolateral to a more posteromedial position and passes over and catches on the iliopectineal eminence of the pubis

Figure 10. Left rectus abdominis and left adductor longus muscle tear. (A, B) Coronal and (C, D) axial fat-saturation fast spin-echo T2-weighted magnetic resonance imaging, demonstrating a longitudinal tear in the lateral aspect of the distal left rectus abdominis muscle (arrowheads), with intramuscular oedema and fluid in the fascial plane that surrounds the muscle, with complete tear at the origin of the left adductor longus muscle at the pubis (arrows). The patient received nonsurgical treatment and returned to professional hockey.

or the femoral head. An associated iliopsoas bursitis is often seen with this type of snapping hip syndrome [2].

External (lateral) causes include the iliotibial band snapping over the greater trochanter or catching of the iliofemoral ligaments as they slide over femoral head with hip flexion and extension. Posterior snapping is commonly caused by the long head of biceps femoris sliding over the ischial tuberosity, again on flexion and extension of the hip [2,13]. Dynamic US during hip motion focused upon the tendon closest to where the athlete describes symptoms may demonstrate abnormal gliding or subluxation of the tendon with a palpable or audible click [2,13].

MRI allows for assessment of potential causes of the intra-articular snapping hip syndrome, which cannot be evaluated with US. MRI can also demonstrate findings in patients with an extra-articular snapping hip such as focal tendinosis of a tendon adjacent to the bony protuberance at the previously described sites. Conservative management is commonly undertaken, including rest, reassurance, and activity modification, and, in some instances, US-guided steroid injection can be used [13].

Greater trochanter pain syndrome. Greater trochanter pain syndrome caused by tendinopathy or tears of gluteal muscles and peritrochanteric bursitis are common causes of lateral hip pain [46]. Greater trochanter pain syndrome is diagnosed clinically by the presence of pain in the buttock and the lateral thigh exacerbated by movement with point tenderness over the greater trochanter and is commonly called trochanteric bursitis [47].

MRI can be used to evaluate athletes with suspected greater trochanter pain syndrome with findings that include peritrochanteric T2 hyperintensity, bursal fluid, and gluteal tendon pathology. MRI has been found to have high sensitivity for diagnosing trochanteric pain syndrome but, unfortunately, is not specific and is a poor predicator, because a high percentage of patients without lateral hip pain can have peritrochanteric MRI abnormalities that may be

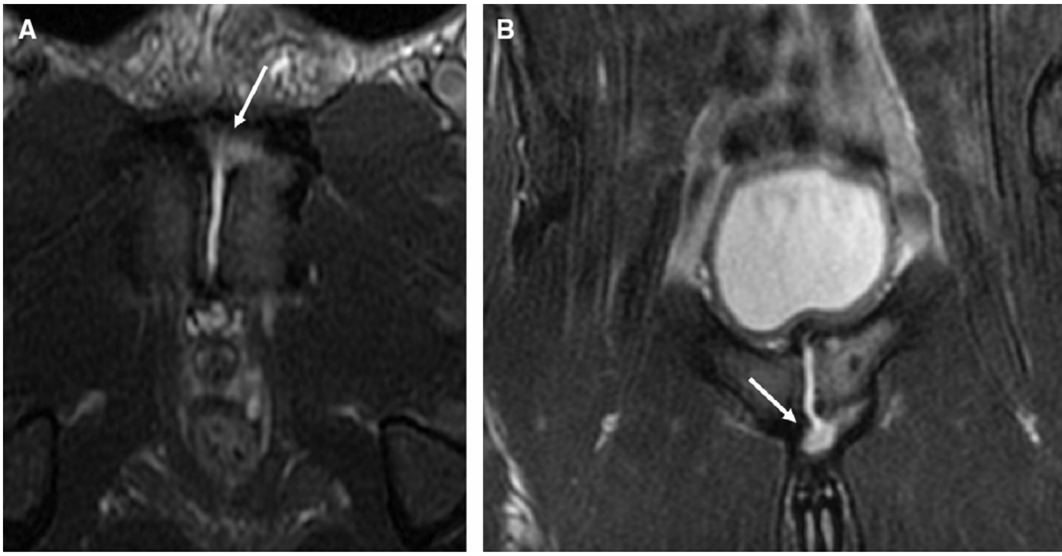

Figure 11. Secondary cleft sign. (A, B) Axial and coronal fat-saturation fast spin-echo T2-weighted magnetic resonance imaging, demonstrating abnormal pubic bone marrow oedema combined with an adjacent linear region of high T2 fluid signal (secondary cleft sign, arrow), which extended from the intra-articular primary cleft secondary to an aponeurotic complex injury and partial avulsion of left adductor longus origin. Findings were confirmed at the time of surgery, and the patient subsequently returned to professional soccer.

attributed to normal bursae in the region [46]. Management of patients with greater trochanter pain syndrome is usually conservative but may require US-guided corticosteroid injection [13].

Conclusion

The soft-tissue and bony abnormalities briefly discussed in this review represent those most commonly considered in the differential diagnosis of hip and groin pain in the athlete. Although controversy exists in the etiology and management of groin pain in the athlete, there is probably considerable overlap in the different pathological conditions causing symptoms. Appropriate use of imaging, along with clinical findings, can allow accurate diagnosis and subsequent appropriate management of these patients to ultimately allow return to athletic activity.

References

[1] Davies AG, Clarke AW, Gilmore J, et al. Review: imaging of groin pain in the athlete. Skeletal Radiol 2010;39:629–44.
[2] Anderson K, Strickland SM, Warren R. Hip and groin injuries in athletes. Am J Sports Med 2001;29:521–33.
[3] Robinson P, White LM. The biomechanics and imaging of soccer injuries. Semin Musculoskelet Radiol 2005;9:397–420.
[4] Ahumada LA, Ashruf S, Espinosa-de-los-Monteros A, et al. Athletic pubalgia: definition and surgical treatment. Ann Plast Surg 2005;55:393–6.
[5] Omar IM, Zoga AC, Kavanagh EC, et al. Athletic pubalgia and ‘‘sports hernia’’: optimal MR imaging technique and findings. Radiographics 2008;28:1415–38.
[6] Tyler TF, Nicholas SJ, Campbell RJ, et al. The association of hip strength and flexibility with the incidence of adductor muscle strains in professional ice hockey players. Am J Sports Med 2001;29:124–8.
[7] Shelly MJ, Hodnett PA, MacMahon PJ, et al. MR imaging of muscle injury. Magn Reson Imaging Clin N Am 2009;17:757–73.
[8] Napier N, Shortt C, Eustace S. Muscle edema: classification, mechanisms, and interpretation. Semin Musculoskelet Radiol 2006;10:258–67.
[9] Nelson EN, Kassarjian A, Palmer WE. MR imaging of sports-related groin pain. Magn Reson Imaging Clin N Am 2005;13:727–42.
[10] Marshall N, Koulouris G. Traumatic injuries of the hip. Magn Reson Imaging Clin N Am 2009;17:681–96.
[11] Connell DA, Schneider-Kolsky ME, Hoving JL, et al. Longitudinal study comparing sonographic and MRI assessments of acute and healing hamstring injuries. AJR Am J Roentgenol 2004;183:975–84.
[12] Slavotinek JP, Verrall GM, Fon GT. Hamstring injury in athletes: using MR imaging measurements to compare extent of muscle injury with amount of time lost from competition. AJR Am J Roentgenol 2002;179:1621–8.
[13] Kavanagh EC, Koulouris G, Ford S, et al. MR imaging of groin pain in the athlete [review]. Semin Musculoskelet Radiol 2006;10:197–207.
[14] Cross TM, Gibbs N, Houang MT, et al. Acute quadriceps muscle strains: magnetic resonance imaging features and prognosis. Am J Sports Med 2004;32:710–9.
[15] MacMahon PJ, Hogan BA, Shelly MJ, et al. Imaging of groin pain. Magn Reson Imaging Clin N Am 2009;17:655–66.
[16] Zoga AC, Kavanagh EC, Omar IM, et al. Athletic pubalgia and the ‘‘sports hernia’’: MR imaging findings. Radiology 2008;247:797–807.
[17] Sanders TG, Zlatkin MB. Avulsion injuries of the pelvis. Semin Musculoskelet Radiol 2008;12:42–53.
[18] Stevens MA, El-Khoury GY, Kathol MH, et al. Imaging features of avulsion injuries. Radiographics 1999;19:655–72.
[19] Pallia CS, Scott RE, Chao DJ. Traumatic hip dislocation in athletes [review]. Curr Sports Med Rep 2002;1:338–45.
[20] Cooper DE, Warren RF, Barnes R. Traumatic subluxation of the hip resulting in aseptic necrosis and chondrolysis in a professional football player. Am J Sports Med 1991;19:322–4.
[21] Moorman 3rd CT, Warren RF, Hershman EB, et al. Traumatic posterior hip subluxation in American football. Bone Joint Surg Am 2003;85:1190–6.
[22] Spitz D, Newberg A. Imaging of stress fractures in the athlete. Radiol Clin N Am 2002;40:313–31.
[23] Sofka CM. Imaging of stress fractures. Clin Sports Med 2006;25:53–62.
[24] Fredericson M, Bergman G, Hoffman KL, et al. Tibial stress reaction in runners: correlation of clinical symptoms and scintigraphy with a new magnetic resonance imaging grading system. Am J Sports Med 1995;23:472–81.
[25] Kornaat PR, de Jonge MC, Maas M. Bone marrow edema-like signal in the athlete. Eur J Radiol 2008;67:49–53.

[26] Slocum KA, Gorman JD, Puckett ML, et al. Resolution of abnormal MR signal intensity in patients with stress fractures of the femoral neck. AJR Am J Roentgenol 1997;168:1295−9.
[27] Guanche CA. Clinical update: MR imaging of the hip. Sports Med Arthrosc 2009;17:49−55.
[28] Czerny C, Hofmann S, Neuhold A, et al. Lesions of the acetabular labrum: accuracy of MR imaging and MR arthrography in detection and staging. Radiology 1996;200:225−30.
[29] Ramnath RR. 3T MR imaging of the musculoskeletal system (part II): clinical applications. Magn Reson Imaging Clin N Am 2006;14: 41−62.
[30] Philippon MJ, Kuppersmith DA, Wolff AB, et al. Arthroscopic findings following traumatic hip dislocation in 14 professional athletes. Arthroscopy 2009;25:169−74.
[31] Weaver CJ, Major NM, Garrett WE, et al. Femoral head osteochondral lesions in painful hips of athletes: MR imaging findings. AJR Am J Roentgenol 2002;178:973−7.
[32] Overdeck KH, Palmer WE. Imaging of hip and groin injuries in athletes. Semin Musculo Radiol 2004;8:41−53.
[33] Armfield DR, Towers JD, Robertson DD. Radiographic and MR imaging of the athletic hip. Clin Sports Med 2006;25:211−39.
[34] Ziegert AJ, Blankenbaker DG, De Smet AA, et al. Comparison of standard hip MR arthrographic imaging planes and sequences for detection of arthroscopically proven labral tear. AJR Am J Roentgenol 2009;192:1397−400.
[35] Philippon MJ, Stubbs AJ, Schenker ML, et al. Arthroscopic management of femoroacetabular impingement: osteoplasty technique and literature review. Am J Sports Med 2007;35:1571−80.
[36] Ganz R, Parvizi J, Beck M, et al. Femoroacetabular impingement: a cause for osteoarthritis of the hip. Clin Orthop 2003;417:112−20.
[37] Beall DP, Sweet CF, Martin HD, et al. Imaging findings of femoroacetabular impingement syndrome. Skeletal Radiol 2005;34:691−701.
[38] Notzli HP, Wyss TF, Stoecklin CH, et al. The contour of the femoral head-neck junction as a predictor for the risk of anterior impingement. J Bone Joint Surg Br 2002;84:556−60.
[39] Kassarjian A, Yoon LS, Belzile E, et al. Triad of MR arthrographic findings in patients with cam-type femoroacetabular impingement. Radiology 2005;236:588−92.
[40] Black BR. Chong le R, Potter HG. Cartilage imaging in sports medicine. Sports Med Arthrosc 2009;17:68−80.
[41] Koulouris G. Imaging review of groin pain in elite athletes: an anatomic approach to imaging findings. AJR Am J Roentgenol 2008;191:962−72.
[42] Smedberg SG, Broome AE, Gullmo A, et al. Herniography in athletes with groin pain. Am J Surg 1985;149:378−82.
[43] Gilmore OJA. Gilmore's groin: a ten years experience of groin disruption. Sports Med Soft Tissue Trauma 1991;3:5−7.
[44] Gilmore J. Groin pain in the soccer athlete: fact, fiction, and treatment. Clin Sports Med 1998;17:787−93.
[45] Orchard JW, Read JW, Neophyton J, et al. Groin pain associated with ultrasound finding of inguinal canal posterior wall deficiency in Australian Rules footballers. Br J Sports Med 1998;32:134−9.
[46] Blankenbaker DG, Ullrick SR, Davis KW, et al. Correlation of MRI findings with clinical findings of trochanteric pain syndrome. Skeletal Radiol 2008;37:903−9.
[47] Williams BS, Cohen SP. Greater trochanteric pain syndrome: a review of anatomy, diagnosis and treatment. Anesth Analg 2009;108:1662−70.