Athletic Pubalgia and "Sports Hernia": Optimal MR Imaging Technique and Findings[1]

Imran M. Omar, MD • Adam C. Zoga, MD • Eoin C. Kavanagh, MD George Koulouris, MBBS, FRANZCR • Diane Bergin, MD • Angela G. Gopez, MD • William B. Morrison, MD • William C. Meyers, MD

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LEARNING OBJECTIVES

After reading this article and taking the test, the reader will be able to:

- Discuss the clinical definition and usage of the terms *athletic pubalgia, sports hernia, osteitis pubis,* and *rectus abdominis–adductor longus aponeurosis*.
- Identify common MR imaging findings in the region of the pubic symphysis in patients with athletic pubalgia.
- Develop a differential diagnosis for the spectrum of MR imaging findings remote from the pubic symphysis in active patients with refractory groin pain.

TEACHING POINTS
See last page

Groin injuries are common in athletes who participate in sports that require twisting at the waist, sudden and sharp changes in direction, and side-to-side ambulation. Such injuries frequently lead to debilitating pain and lost playing time, and they may be difficult to diagnose. Diagnostic confusion often arises from the complex anatomy and biomechanics of the pubic symphysis region, the large number of potential sources of groin pain, and the similarity of symptoms in athletes with different types or sites of injury. Many athletes with a diagnosis of "sports hernia" or "athletic pubalgia" have a spectrum of related pathologic conditions resulting from musculotendinous injuries and subsequent instability of the pubic symphysis without any finding of inguinal hernia at physical examination. The actual causal mechanisms of athletic pubalgia are poorly understood, and imaging studies have been deemed inadequate or unhelpful for clarification. However, a large-field-of-view magnetic resonance (MR) imaging survey of the pelvis, combined with high-resolution MR imaging of the pubic symphysis, is an excellent means of assessing various causes of athletic pubalgia, providing information about the location of injury, and delineating the severity of disease. Familiarity with the pubic anatomy and with MR imaging findings in athletic pubalgia and in other confounding causes of groin pain allows accurate imaging-based diagnoses and helps in planning treatment that targets specific pathologic conditions.

Abbreviations: NSAID = nonsteroidal anti-inflammatory drug, STIR = short inversion time inversion recovery

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[1]From the Department of Radiology, Northwestern Memorial Hospital, 676 N Saint Clair St, Suite 800, Chicago, IL 60611 (I.M.O.); Department of Radiology, Thomas Jefferson University Hospital, Philadelphia, Pa (A.C.Z., D.B., A.G.G., W.B.M.); Department of Radiology, Mater Misericordiae Hospital, Dublin, Ireland (E.C.K.); Gold Coast Medical Imaging, Queensland, Australia (G.K.); and Department of Surgery, Drexel University College of Medicine, Philadelphia, Pa (W.C.M.). Recipient of a Cum Laude award for an education exhibit at the 2006 RSNA Annual Meeting. Received November 30, 2007; revision requested February 25, 2008, and received March 27; accepted April 11. All authors have no financial relationships to disclose. **Address correspondence to** I.M.O. (e-mail: *imran.omar@nmff.org*).

Introduction

Groin pain is a common result of athletic injury, but it poses a diagnostic challenge for radiologists, athletic trainers, team physicians, and consulting surgeons. Athletes in sports that rely on quick acceleration, rapid changes in direction, kicking, and frequent side-to-side motions (eg, soccer, ice hockey, American- and Australian-rules football, fencing, track and field events such as high jumping, and baseball) may be particularly subject to injuries that lead to groin pain. Between 2% and 8% of all athletic injuries involve the groin, and up to 13% of soccer injuries are groin related (1–3). According to one report, 58% of soccer players had a history of groin injury (4).

Clinically, athletes frequently present with pain in the inguinal region, which may radiate to the thigh adductor muscle origins or to the scrotum and testicles. At physical examination, point tenderness is often localized to the external ring of the inguinal canal and the pubic tubercle, the lower rectus abdominis musculature, or the pubic symphysis, but there is no palpable hernia. Although groin injuries may be acute, they more often have an insidious onset and progress over a period of weeks or months. They are a significant cause of missed practice and playing time (5,6). Although many acute groin injuries are successfully treated with a conservative regimen including rest and a nonsteroidal anti-inflammatory drug (NSAID), groin injuries often recur and may lead to the premature termination of athletic careers.

The pathophysiologic conditions that cause groin pain are complicated and poorly understood. Misunderstandings may easily occur, leading to misdiagnoses, for several reasons. To begin with, the anatomy of the pubic symphyseal region includes a number of interrelated muscle attachments that are located in close proximity to one another. The interrelation of these muscle attachments causes complex interactions between the forces exerted through the muscles across the pubic symphysis. Furthermore, the differential diagnosis of groin pain in athletes is extensive because various pathologic entities may cause similar clinical signs and symptoms and overlapping findings at physical examination (Table 1). In addition, patients may be unable to precisely identify the location of their pain or to recall the mechanism of injury. Moreover, they may present with multiple coexisting injuries that could cause groin pain, a circumstance that makes it difficult to establish which injury is the major contributor. Given these complexities, it is not surprising that both conservative management and numerous invasive therapies, including herniorrhaphy, adduc-

Table 1
Differential Diagnosis of Groin Pain in Athletes

Visceral causes
Inguinal hernia
Other abdominal hernias
Testicular torsion
Hip-associated causes
Acetabular labral tear and femoroacetabular impingement
Osteoarthritis
Snapping hip syndrome and iliopsoas tendonitis
Avascular necrosis
Iliotibial band syndrome
Pubic symphyseal causes
Rectus abdominis strain
Adductor muscle-tendon dysfunction
Rectus abdominis–adductor longus aponeurosis tear
Osteitis pubis
Infectious causes
Septic arthritis
Osteomyelitis
Pelvic inflammatory disease
Prostatitis
Epididymitis and orchitis
Herpes infection
Inflammatory causes
Endometriosis
Inflammatory bowel disease
Pelvic inflammatory disease
Traumatic causes
Stress fracture
Tendon avulsion
Muscle contusion
Baseball pitcher–hockey goalie syndrome
Developmental causes
Apophysitis
Growth plate stress injury or fracture
Legg-Calvé-Perthes disease
Developmental dysplasia
Slipped capital femoral epiphysis
Neurologic causes
Nerve entrapment syndromes (eg, ilioinguinal nerve)
Referred pain
Sacroiliitis
Sciatic entrapment (piriformis syndrome)
Hamstring strain
Knee pain
Neoplastic causes
Testicular carcinoma
Osteoid osteoma

tor tenotomy, pelvic floor relaxation, and surgical repair of the posterior wall of the inguinal ring, have been applied with variable success to treat refractory groin pain. It also stands to reason that injuries with a poor surgical response may have been incorrectly or incompletely diagnosed, leading to a suboptimal treatment plan. The variety of terms used in the medical literature to describe entities that are either identical or at least close neighbors in the same spectrum of disease—including *sports hernia, sportsman's hernia, athletic pubalgia, Gilmore groin, hockey goalie syndrome, adductor dysfunction,* and *osteitis pubis*—likely adds to confusion in the diagnosis and treatment of groin pain.

In this article, we review the relevant anatomy and normal biomechanics of the pubic region and describe the pathophysiology of injuries in this region. We then discuss the magnetic resonance (MR) imaging features associated with athletic pubalgia and suggest techniques for improving the visualization of injuries. Imaging findings are correlated with clinical manifestations and treatment outcomes. Finally, we review many of the most common confounding causes of groin pain in which the clinical manifestations are similar to those of athletic pubalgia.

Normal Anatomy of the Pubic Symphysis

The pubic symphysis is an amphiarthrodial joint composed of the paired pubic bones and an intervening articular disk. The pubic bone forms the anterior portion of the innominate bone and is divided into the body, which is located medially, and the superior and inferior pubic rami. The medial border of the body forms the articular surface of the pubic symphysis. This surface is ovoid, covered by a thin layer of hyaline cartilage, and composed of transversely oriented alternating ridges and grooves that may help protect the joint from shear forces. From the upper margin of the body arises the pubic crest, which projects over the anterior surface of the body. The pubic tubercle, on which the inguinal ligament attaches, is an osseous process emerging from the lateral margin of the pubic crest. The rami are osseous struts radiating laterally from the pubic body. The superior pubic ramus contributes the anterosuperior one-fifth of the acetabular fossa as well as a portion of the obturator foramen, while the inferior pubic ramus bridges the pubic body and ischium (7,8).

There is no true joint capsule, although the articular disk and four ligaments provide soft tissue support to the osseous structures of the pubic symphysis. The interpubic disk is a fibrocartilaginous structure that is critical to the function of the pubic symphysis. It is interposed between the ridges and grooves of the pubic symphyseal articular surfaces, and its main function during normal motion is to absorb and dissipate axial and shear forces experienced at the joint (9). Approximately 10% of adults have a fluid-filled posterosuperior cleft located in the central portion of the disk. This cleft is not seen in children younger than 2 years and is believed to be developmental (10).

Functionally, the superior and arcuate (or inferior) pubic ligaments are more important, particularly for resisting shear forces, than the anterior and posterior pubic ligaments. The superior pubic ligament bridges the pubic tubercles. The arcuate ligament forms a fibrous arch along the inferior margin of the joint and blends with the articular disk. The arcuate ligament also merges inferiorly with the aponeuroses of the gracilis and adductor longus muscles. The anterior pubic ligament is composed of a deep layer that merges with the articular disk and a superficial layer that blends with the aponeurosis of the external oblique and rectus abdominis muscles. The least developed ligament is the posterior pubic ligament, which is formed by relatively few transversely oriented fibers (7,8).

The pubic symphysis has a number of important functions. First, it stabilizes the anterior pelvis, while allowing a small degree of movement (up to 2 mm in the craniocaudal direction, and up to 3.0° of rotation during walking) (11,12). The large contact area of the joint allows an even distribution of the superior and inferior shear forces generated during walking and running, thus helping protect the joint from injury. The rami also help perform this function by transmitting compressive forces generated at the symphysis to the remainder of the innominate bone (8). Finally, in women, laxity of the pubic symphysis under hormonal influences plays an important role in childbirth, allowing passage of the neonate through the birth canal.

Muscle Anatomy and Biomechanics of the Pubic Symphysis

The pubic symphysis is the centerpoint of numerous musculotendinous attachments that act to dynamically stabilize the position of the anterior innominate bone. The muscles that attach to the symphysis include the anterolateral abdominal muscles (external and internal oblique muscles, transversus abdominis, and rectus abdominis) and the thigh adductor muscles (pectineus, gracilis, adductor longus, adductor brevis, and adductor magnus). Of these, the most robust and most critical for maintaining the stability of the anterior pelvis are the rectus abdominis and the adductor longus (Fig 1).

Rectus Abdominis Muscle

The recti are paired ventral midline strap muscles that contribute to the stability of the anterior abdominal wall. The width of the muscle belly tapers near its caudal origin. In fact, the muscle is roughly three times wider at the site of its insertion on the lower rib cage than at its origin on the anterior pubic body, a factor that may concentrate forces generated by the muscle into a smaller area and thereby contribute to the greater frequency of rectus injuries near the pubic symphysis (13). The rectus abdominis contains three or four transversely oriented tendinous inscriptions. These fibrous bands are rarely complete, and their function is uncertain. Some anatomists have suggested that they may arise from the fusion of myotomes during embryologic development; others believe that they develop later. The medial and lateral tendons that arise from the anterior pubis contribute to the common muscle. The right and left medial tendons merge with the anterior pubic ligament. Classically anatomists have described the broader, lateral tendon as arising from the pubic crest and tubercle. The cranial attachment of the rectus abdominis is on the fifth, sixth, and seventh costal cartilages, as well as the inferior margin of the xiphoid process and the costoxiphoid ligaments. Most of its blood supply comes from the superior and inferior epigastric arteries, which are augmented by small branches of the posterior intercostal arteries, subcostal artery, posterior lumbar arteries, and deep circumflex iliac artery. The rectus abdominis is innervated by the lower costal and subcostal nerves, which arise from the caudal six or seven thoracic nerve roots. The main functions of the rectus abdominis are to allow flexing of the trunk; to provide muscle tone to the ventral abdominal wall, especially during straining; and to act as an antagonist to the diaphragm during respiration (14).

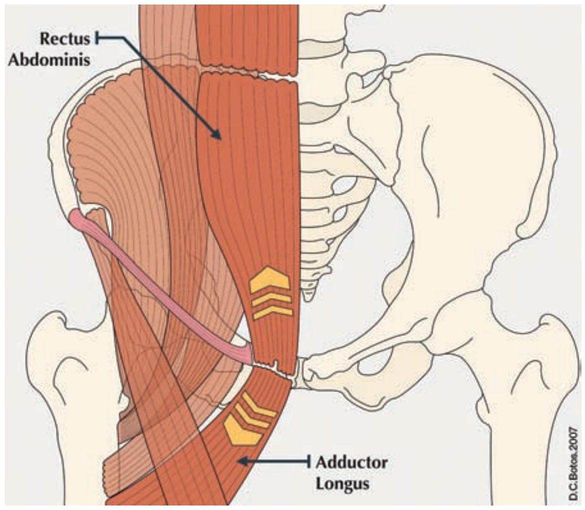


Figure 1. Normal anatomy of the pubic symphysis. Schematic shows the relations and points of attachment of the major muscles—the rectus abdominis and adductor longus—and the inguinal ligament to the pubic symphysis. Yellow arrowheads indicate the directions of major force vectors to which the pubic bone is commonly subjected during athletic activities.

Adductor Muscle Group

The principal functions of this muscle group are to allow adduction of the thigh and to work with the hip flexors (eg, iliopsoas and sartorius muscles) and external rotators (eg, obturator externus muscle) to stabilize the anterior pelvis during the swing phase of the gait (15).

Adductor Longus.—The adductor longus is the most anterior of the three adductor muscles and is posterior to the pectineus muscle. Its triangular belly arises from a narrow tendon off the anterior margin of the pubis, below the pubic crest. The part most often injured is the 2–4-cm-long proximal myotendinous junction, which represents the transition between muscle and tendon fibers. Cadaveric studies have shown that the anterior part of the proximal myotendinous junction is better developed than its posterior part, where the muscle attaches more directly to the bone. This arrangement may help explain why proximal adductor longus myotendinous injuries often initially involve the anterior fibers (15). Another factor may be the relatively poor blood supply of the proximal myotendinous unit, which reduces the ability of the tendon to resist strain and repair itself (15,16). The muscle belly broadens caudally as it inserts on the middle third of the femoral linea aspera. The deep femoral artery supplies most of the muscle belly through a branch referred to as the artery of the adductors, with additional blood flow derived from the femoral artery, medial femoral circumflex artery, and descending genicular artery. The muscle is innervated by the anterior branch of the obturator nerve from the L2, L3, and L4 nerve roots (7). The adductor longus acts to adduct the thigh and contributes to hip flexion and medial rotation (16).

Adductor Brevis.—The adductor brevis is located immediately posterior to the adductor longus and anterior to the adductor magnus. It has a narrow origin from the anterior pubic body and inferior pubic ramus and becomes broader as it travels inferiorly. It attaches on the linea aspera, at a site that is cranial to the adductor magnus. Like that of the adductor longus, its blood supply is mainly from the deep femoral artery and artery of the adductors, with the medial circumflex and obturator arteries providing minor contributions. It is innervated by the obturator nerve, which arises from the L2 and L3 nerve roots (7).

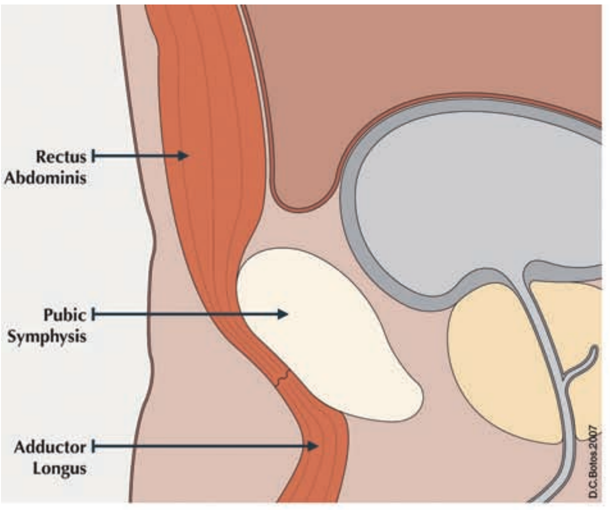
Adductor Magnus.—The adductor magnus is a large triangular muscle that originates at the lower margin of the inferior pubic ramus, the ischial ramus, and the ischial tuberosity. Different orientations of the muscle fibers arise from each of these sites. The fibers arising from the inferior pubic ramus are more anterior and more horizontally oriented and insert on the gluteal tuberosity of the femur, medial to the insertion of the gluteus maximus. The ischial ramus fibers travel obliquely and insert via an aponeurosis on the lower femoral linea aspera and medial femoral condylar ridge. The ischial tuberosity fibers taper to a rounded tendon that inserts on the adductor tubercle of the medial femoral condyle. Because the adductor magnus is so large, it is supplied by a number of arteries. The most important anterior vessel is the deep femoral artery; the medial circumflex femoral and popliteal vessels contribute to the posterior blood supply. The obturator nerve and tibial division of the sciatic nerve, which arise from the L2, L3, and L4 nerve roots, provide innervation for the muscle (7). While some anatomists consider the adductor magnus a member of the hamstring group, most group it with the other adductor muscles.

Gracilis.—The gracilis is the most medial muscle, and it overlies the adductors magnus and brevis. Its belly is thin and flat where it arises from the anterior aspect of the pubic body and the inferior pubic ramus; it narrows inferiorly to form a rounded tendon that crosses the medial femoral condyle. The tendon inserts on the upper anteromedial tibia as a contributor to the pes anserinus. The main blood supply to the gracilis muscle is the artery of the adductors, which branches from the deep femoral artery, and the muscle is innervated by the obturator nerve at the L2 and L3 levels. The gracilis functions principally in thigh adduction and plays minor roles as a hip flexor and medial rotator (7).

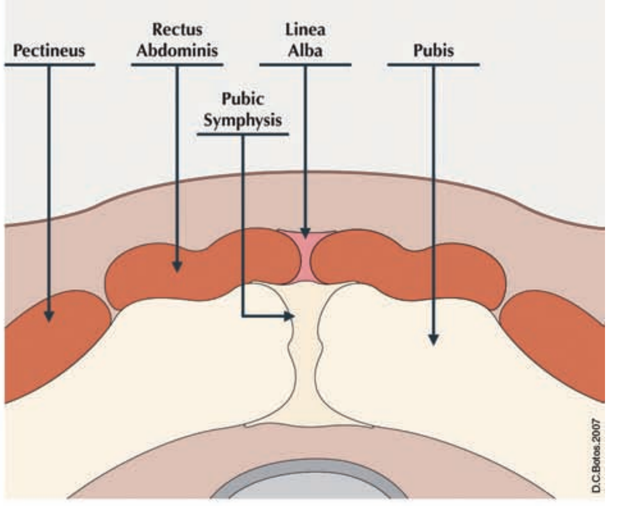
Pectineus.—The pectineus is a broad rectangular muscle that overlies the adductor longus. It arises from the pubic tubercle, pecten pubis, and a portion of the iliopectineal eminence, and it inserts on the posterior upper femur between the lesser trochanter and linea aspera. The medial circumflex artery provides its blood supply, with lesser contributions coming from the obturator and femoral arteries. It is innervated by the femoral nerve branch arising at the L2 and L3 levels, as well as by the accessory obturator nerve. The muscle may comprise two layers, with the dorsal layer receiving innervation from the obturator nerve and the ventral layer receiving innervation from the femoral nerve (7).

Biomechanics of the Pubic Symphysis

The rectus abdominis and adductor longus muscles are relative antagonists of one another during rotation and extension from the waist (Fig 2).



a.



b.

Figure 2. Sagittal **(a)** and axial **(b)** schematics of the pubic symphysis show the common aponeurosis of the rectus abdominis and adductor longus muscles, immediately anterior to the midline of the pubic body.

Contraction of the rectus abdominis muscle, in the presence of normal abdominal wall tone, places a posterior and superior force on the pubis and elevates the pubic region. Cadaveric studies have shown that transection of the rectus abdominis muscle origin causes an excessive downward tilt of the anterior pelvis, with a resultant increase in pressure in the adductor compartment (17). In contrast, the adductor longus muscle has an anterior-inferior force vector. MR images 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 aponeurosis that attaches to the periosteum of the anterior aspect of the pubic body and that likely merges with the anterior pubic ligament and interpubic disk (Figs 3, 4) (18). 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. We have routinely noted, both at cadaveric dissection and at high-resolution MR imaging, an intimate relation between the lateral border of the rectus abdominis–adductor longus aponeurosis and the external ring of the inguinal canal, which are separated by a distance of only 2–5 mm (Fig 5).

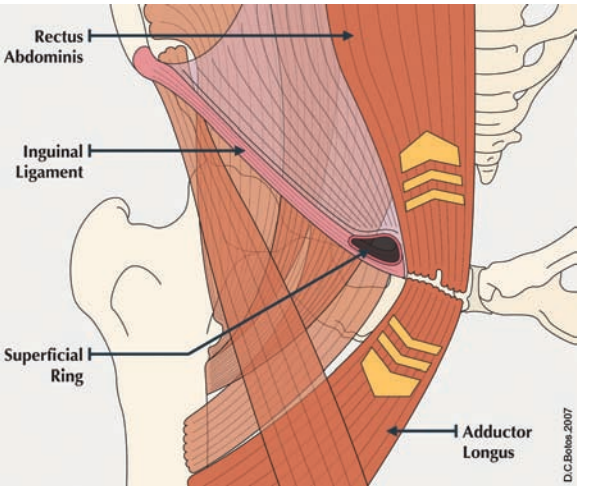
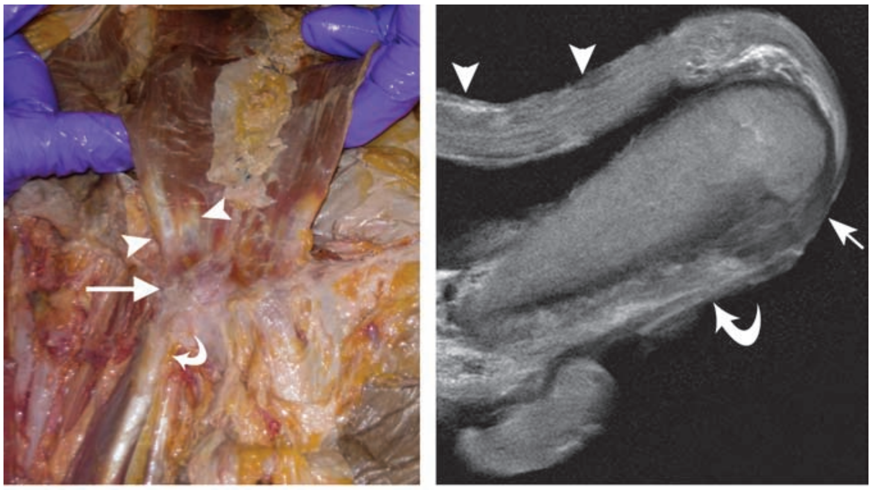


Figure 3. Lateral schematic of the pubic soft-tissue anatomy shows the superficial ring of the inguinal ligament, located a few millimeters from the lateral margin of the rectus abdominis–adductor longus aponeurosis. Yellow arrowheads indicate the directions of major force vectors to which the pubic bone is commonly subjected during sports.

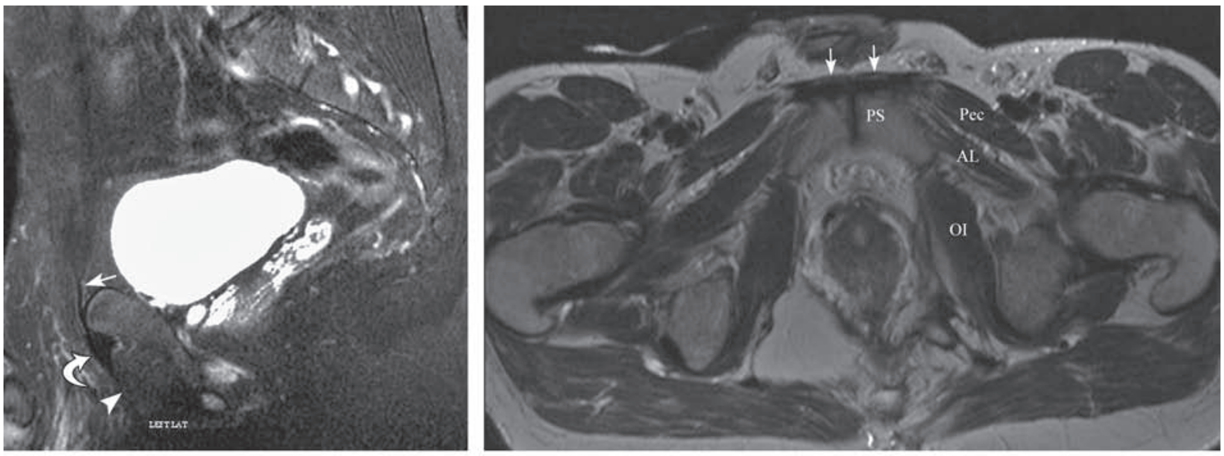
Athletic Pubalgia

Groin pain and pubalgia have long been recognized as significant causes of injury in high-level athletes (19,20). Most patients report an insidious onset of pubic and deep groin pain that is exacerbated by physical activity and that may radiate to the inguinal ligament, rectus abdominis, and perineum. Symptoms are most often unilateral but are not uncommonly bilateral. Patients



a. b.

Figure 4. **(a)** Photograph of a cadaveric specimen shows the common attachment (straight arrow) of the right rectus abdominis (arrowheads) and adductor longus (curved arrow) tendons. **(b)** Sagittal intermediate-weighted MR image obtained at 3 T shows the aponeurosis (straight arrow) of the rectus abdominis (arrowheads) and adductor longus (curved arrow) as a dark band of fibers extending along the anterior-inferior aspect of the pubic body, 1–2 cm from the symphyseal midline.



a. b.

Figure 5. Normal MR imaging appearance of the rectus abdominis–adductor longus aponeurosis. **(a)** Sagittal T2-weighted fat-suppressed image obtained 1–2 cm from the pubic symphyseal midline in a patient without injury shows the aponeurosis (curved arrow) of the rectus abdominis (arrow) and adductor longus (arrowhead) muscles. **(b)** Axial T2-weighted image of the pelvis shows the sites of muscle attachment in the anterior pubic region. The rectus abdominis–adductor longus *(AL)* aponeurosis (arrows) appears as a band of low signal intensity across the anterior-inferior margin of the pubic symphysis *(PS)*. *OI* = obturator internus, *Pec* = pectineus.

may experience alternating episodic exacerbations and periods of improvement, or they may have gradually progressive symptoms. Most patients have 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 or adductor longus muscle or at the external inguinal ring.

The terms *sports hernia* and *sportsman's hernia* were first used to describe inguinal pain experienced by athletes without evidence of an actual hernia at physical examination (21–23). Many authors initially used the term to refer to a weakness in the posterior wall of the inguinal canal, believing that this represented an incipient inguinal hernia (24,25). The exact location of this weakness or tear was disputed; some authors favored the external oblique muscle aponeurosis and conjoined tendon (26,27), while others believed it was in the transversalis fascia (28). In an effort to strengthen the posterior wall of the inguinal canal, several authors performed herniorrhaphies with various surgical techniques in their patients. Although many patients improved after this surgical treatment, the overall results were mixed. Other authors proposed nerve entrapment, particularly of the cutaneous branches of the ilioinguinal nerve and the genital branch of the genitofemoral nerve, as the causal mechanism of pain in sports hernias. These authors suggested that surgical manipulation of this area during hernia repair might release the entrapped nerve and thus bring about a resolution of symptoms (29–31).

Although some patients experience pain relief after herniorrhaphy with standard techniques, many others either experience little or no improvement in groin pain or develop recurrent symptoms that are detected at long-term follow-up. Because of this, other authors have suggested that the fundamental pathologic process in athletic pubalgia is unrelated or only marginally related to inguinal herniation. The association of this process with herniation may be misleading, and surgery performed to repair an inguinal hernia may not necessarily address the cause of groin pain (32). Several articles have proposed the use of the term *athletic pubalgia* rather than *sports hernia* to refer to a group of musculoskeletal processes that occur in and around the pubic symphysis and that share similar mechanisms of injury and common clinical manifestations (17,20,32–34). These authors have attributed these findings to chronic repetitive torque on the pubic symphysis during aggressive abduction of the thigh and hyperextension of the trunk. Most commonly, such movements injure the common aponeurosis of the rectus abdominis and adductor longus tendons, which is located along the anterior aspect of the pubic symphysis, and may lead to eventual avulsion of the tendon and a tear in the aponeurosis.

Teaching Point

At MR imaging and surgery in patients with clinical athletic pubalgia, we have most commonly observed injury along the lateral border of the rectus abdominis, just cephalad to its pubic attachment, or at the origin of the adductor longus. After an injury to either the rectus abdominis muscle or the adductor muscle, there is a repetitive unbalanced contraction in the other muscle (17). We postulate that the lack of opposing force leads to degeneration and tearing of the tendon not initially torn. Ultimately, the lesion extends confluently through the aponeurosis into both the rectus abdominis and the adductor longus. Most commonly, the extension of the lesion under the pubic periosteum causes frank disruption of the rectus abdominis–adductor longus aponeurosis from its pubic attachment. In other cases, the injury may extend into the adductor tendon origins, particularly the pectineus and adductor brevis, or may extend along the anterior pubic symphysis and across the midline to involve the contralateral rectus abdominis–adductor longus aponeurosis. In a severe injury, the tendons may be completely avulsed from the pubis. In most patients with clinical athletic pubalgia who are referred for MR imaging, changes are detected in the area of the pubic symphysis that represent pathologic processes that often have similar clinical manifestations; however, the detection of a true hernia is rare (35). Groin pain in patients with clinical athletic pubalgia may result from the initial injury to the tendon or aponeurosis as well as chronic repetitive injury to the opposing, adjacent, or contralateral tendons or the destabilized pubic symphysis. Hernia-like symptoms may be related to the proximity of the injury site to the medial margin of the superficial ring of the inguinal canal or to lesion extension through the superficial ring and resultant weakening of the posterior wall of the inguinal canal.

Teaching Point

Teaching Point

Patients with MR imaging findings and surgical findings of athletic pubalgia are predominantly male and generally under the age of 40 years. It has been suggested that the male predominance of athletic pubalgia is related to a disparity between the sexes in athletic participation or to the generation of stronger forces around the pubic symphysis in male athletes. An increasing number of female athletes around the world participate in professional and amateur sports that require quick acceleration and deceleration and side-to-side movements, yet the disparity between the numbers of male and female athletes with clinical athletic pubalgia persists. Informally, we have observed that female patients generally have larger and more robust caudal rectus abdominis attachments, with a convergence of aponeurotic fibers from both sides as they cross the midline along the anteroinferior pubic symphysis, a situation not seen in most male patients. In addition, the female pelvis is wider and has a larger subpubic angle than the male pelvis (36), properties that may aid the transference of forces away from the pubic region to the rest of the innominate

RadioGraphics

Table 2
Thomas Jefferson University 1.5-T MR Imaging Protocol for Athletic Pubalgia

Sequence	Plane	FOV (cm^2)	Matrix	Section Thickness /Gap (mm)	TR (msec)	TE (msec)	TI (msec)	BW (kHz)	ETL	NSA
STIR	Coronal	28–32	256 × 192	4/1	>2000	25	150	16	Eight	Three
T1-weighted SE	Coronal	28–32	256 × 256	4/0	700	Min	NA	16	NA	One
T2-weighted fat-suppressed fast SE	Axial	28	256 × 192	4/1	>2000	60	NA	16	Eight	Two
T2-weighted fat-suppressed fast SE	Sagittal	20	256 × 192	4/1	>2000	60	NA	16	Eight	Two
Intermediate-weighted fast SE	Axial oblique*	20	256 × 256	4/0	Max	25	NA	16	Four	Two
T2-weighted fat-suppressed fast SE	Axial oblique*	20	256 × 256	4/0	>2000	60	NA	16	Eight	Two

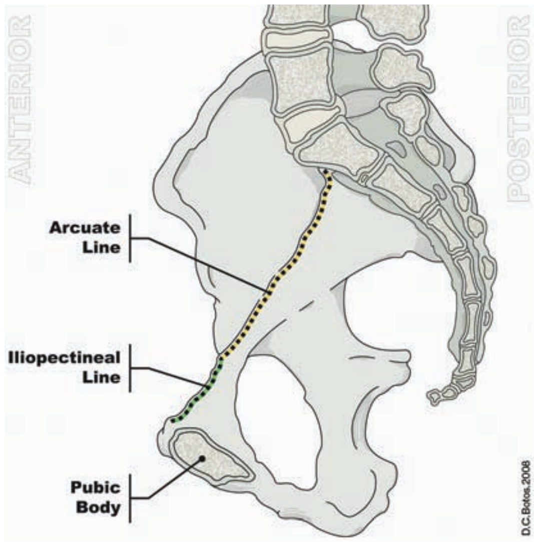
Note.—Indications for MR imaging with this protocol include suspicion of a rectus abdominis injury, adductor injury, osteitis pubis, or sportsman's hernia. The following procedure should be used: Before image acquisition, patients should be asked to empty their bladders. All sequences should be centered on the symphysis pubis. The first three (large-FOV) sequences should be applied while using a built-in body coil. The last three (high-resolution) sequences should be applied while using the same phased-array pelvic coil used for gynecologic imaging (a 5-inch surface coil is optimal). BW = bandwidth, ETL = echo train length, FOV = field of view, Max = maximum possible, Min = minimum possible, NA = not applicable, NSA = number of signals acquired, SE = spin echo, STIR = short inversion time inversion recovery, TE = echo time, TI = inversion time, TR = repetition time.
*The use of the axial oblique plane is recommended to maximize sensitivity for the detection of rectus abdominis–adductor longus myotendinous injuries.

bones or the lower extremities. The anatomic and biomechanical differences in the female pelvic structure may help stabilize the pubic region and contribute to the relative infrequency of athletic pubalgia injuries in female patients (17).

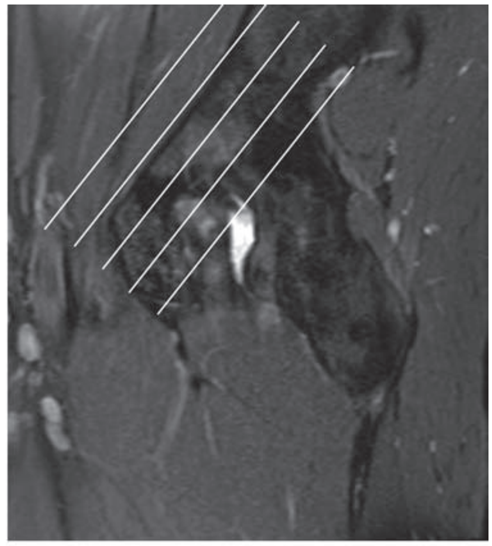
MR Imaging Technique and Findings of Athletic Pubalgia

Until recently, imaging was thought to be unreliable or of little use for the diagnosis of athletic pubalgia, and MR imaging was used mainly to exclude other possible causes of groin pain, such as stress fracture or acetabular labral tear (37,38). However, improved knowledge about anatomic structures, pathophysiologic changes, and clinical findings associated with athletic pubalgia has allowed improved imaging techniques. Centering of the MR imaging volume on the pubic symphysis and the use of a phased-array pelvic surface coil help greatly improve the signal-to-noise ratio in the anterior pubic region (35). Patients should empty their bladders before an MR imaging evaluation. Imaging usually can be performed while the patient rests comfortably in a supine position. Prone positioning may be necessary to eliminate significant respiratory artifacts, but such instances are rare in our experience. Frequently, clinicians have difficulty distinguishing between the possible causes of groin pain (eg, an acetabular labral tear or athletic pubalgia) at a physical examination. Because many pathophysiologic processes may manifest with pubic and inguinal pain, an MR imaging survey of the pelvis is recommended during the initial evaluation. Immediate review of the large-field-of-view images as they are acquired may reveal particular regions of suspected pathologic change and help direct further high-resolution small-field-of-view imaging. The combined use of non–fat-suppressed T1-weighted and fat-suppressed fluid-sensitive sequences is recommended. Because a number of relevant muscles are attached to a small area on the anterior pubic symphysis, fluid-sensitive sequences in the three standard orthogonal planes may be helpful to improve diagnostic accuracy (Table 2) (35). An axial oblique sequence has

Teaching Point



a.



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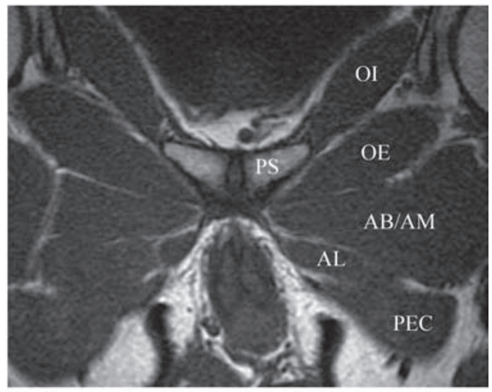


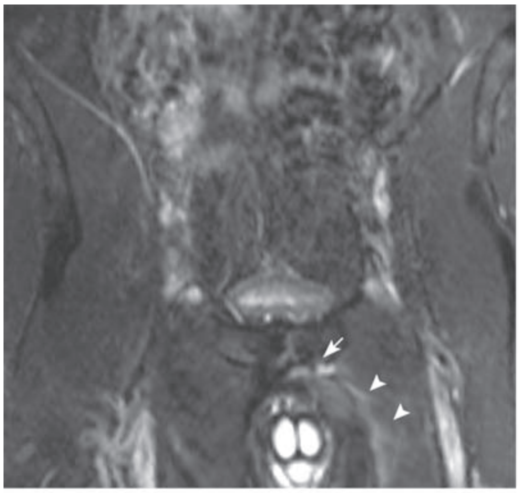
c.

Figure 6. Axial oblique MR image acquisitions and normal appearance of the pubic region. **(a)** Sagittal schematic shows orientation of the arcuate line along the medial surface of the hemipelvis. **(b)** Sagittal T2-weighted fat-suppressed turbo spin-echo image obtained near the medial acetabulum shows the plane (lines) prescribed for axial oblique MR imaging of the pubic region, which parallels the arcuate line. **(c)** Axial oblique T1-weighted image shows normal muscles around the pubic symphysis *(PS)*. *AB/AM* = adductor brevis and adductor magnus, *AL* = adductor longus, *OE* = obturator externus, *OI* = obturator internus, *PEC* = pectineus.

been described that allows visualization of the adductor tendon origins along their long axes. MR images are obtained with this sequence in off-midline sagittal planes parallel to the arcuate line of the pelvic inlet (Fig 6) (39). Often the diagnosis may be achieved on the basis of imaging in conventional orthogonal planes. However, axial oblique images may help improve diagnostic certainty about symphyseal changes and may better depict pathologic processes such as true inguinal herniation.

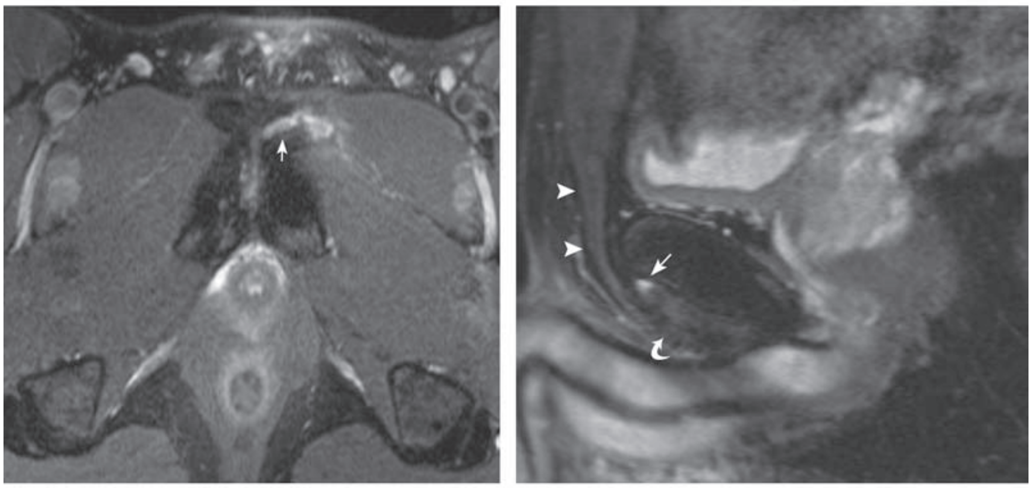
Once injury to the pubic region is confirmed or pathologic change in more remote areas is excluded on large-field-of-view images, dedicated imaging of the anterior pubic musculoskeletal structures is recommended to better characterize the location and severity of injuries. Frequently, images obtained with fluid-sensitive sequences allow direct visualization of tears involving the rectus abdominis–adductor aponeurosis, which appear as irregular areas with signal intensity like that of fluid undermining the aponeurosis. This tenoperiosteal disruption may be most visible on axial and sagittal fluid-sensitive images acquired approximately 1–2 cm lateral to the pubic symphysis (Fig 7). Other findings that are commonly associated with an aponeurotic lesion are abnormal marrow signal intensity isolated to the anterior-inferior aspect of the pubic body and deep to the rectus abdominis–adductor aponeurotic attachment (39) and the so-called secondary cleft sign, an apparent inferior extension of the central symphyseal fibrocartilaginous cleft along the anteroinferior margin of the pubic body (Figs 8, 9). The secondary cleft sign, which commonly appears on the side ipsilateral to the side

Teaching Point



a.

Figure 7. Tear of the left rectus abdominis–adductor longus aponeurosis in a 30-year-old man with left-sided athletic pubalgia. **(a)** Coronal STIR image of the pelvis demonstrates an accessory cleft sign alongside the left pubic body (arrow) and a grade 1 strain of the left adductor longus muscle (arrowheads). **(b, c)** Axial **(b)** and sagittal **(c)** T2-weighted fat-suppressed images obtained 1 cm lateral to the pubic midline show the typical appearance of a tear (straight arrow), with signal intensity similar to that of fluid, in the aponeurosis. In **c**, the relationship of the rectus abdominis (arrowheads) and adductor longus (curved arrow) muscles is more clearly visible.



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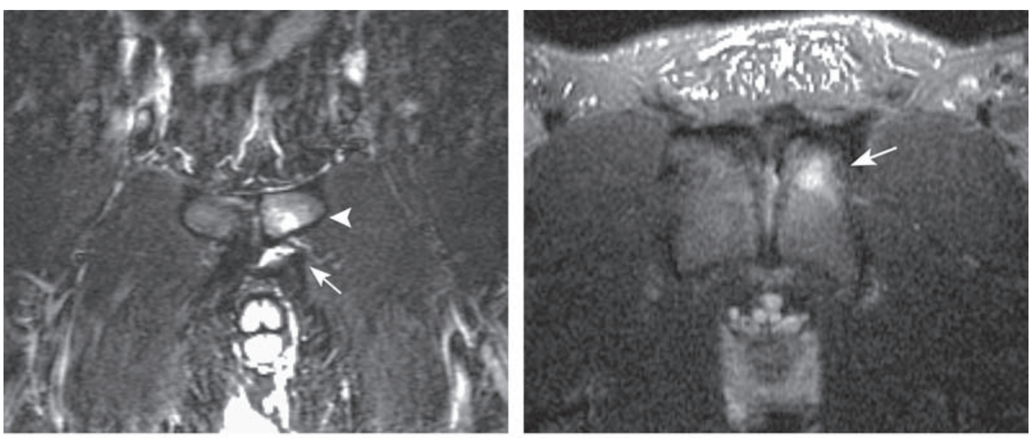


a. b.

Figure 8. Marrow edema associated with aponeurosis injury in a 24-year-old male football player. **(a)** Coronal STIR image of the pubic symphysis demonstrates disruption of the left rectus abdominis–adductor longus aponeurosis (arrow) and associated marrow edema in the pubic body (arrowhead). **(b)** Axial T2-weighted image shows the localization of marrow edema (arrow) to the anterior aspect of the pubic body.

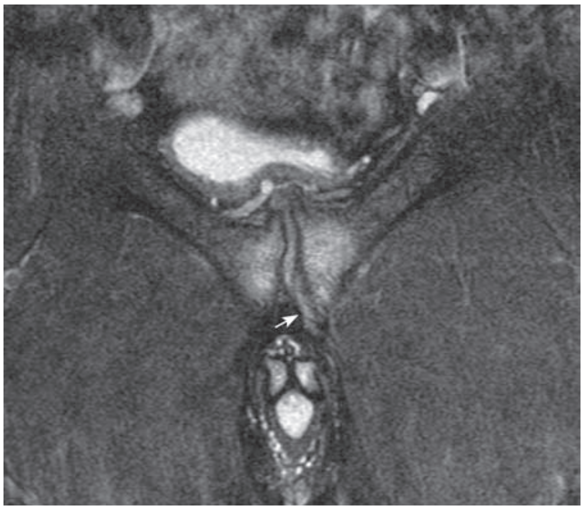


Figure 9. Secondary cleft sign in a 39-year-old male soccer player with left-sided inguinal pain. Coronal T2-weighted image of the pubic symphysis depicts a crescentlike area of hyperintense signal (arrow) that adjoins the high-signal-intensity interpubic disk along the anterior-inferior margin of the medial pubic body, near the rectus abdominis–adductor longus aponeurosis.

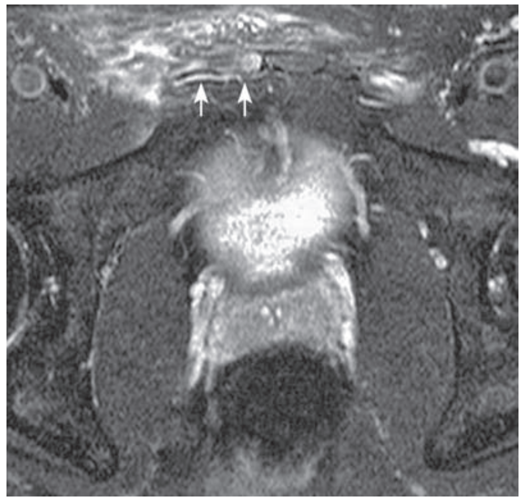


Figure 10. Injury to the rectus abdominis–adductor longus aponeurosis. Axial T2-weighted image of the pubic symphysis in a 31-year-old male baseball player shows moderate edema at the origin of the right rectus abdominis muscle (arrows).

of groin pain, is believed to reflect a microtear in the origin of the adductor longus and gracilis tendons (40). Although it was initially described at arthrography of the pubic symphysis, the secondary cleft sign is visible also on unenhanced MR images obtained with fluid-sensitive pulse sequences, on which it appears as a curvilinear region of high signal intensity adjoining the pubic symphysis (9,40,41). An aponeurotic lesion may be signaled also by an edematous or atrophic appearance of the rectus abdominis near its pubic tendinous attachment (Figs 10, 11). Alternatively, there may be frank disruption of the tendon, particularly at the pubic attachment of its lateral head (Fig 12). The adductor tendons, most commonly those of the adductor longus, may be disrupted or thickened, with intermediate or high signal intensity indicative of tendinosis, and the myotendinous junctions may appear edematous (42). This constellation of MR imaging findings is sometimes observed in conjunction with osseous productive changes and subchondral cysts in the pubic symphysis. In some patients, the initial tendinous injury precedes clinical symptoms and MR imaging findings of osteitis pubis. In these patients, it is likely that the symphysis was destabilized after the initial aponeurotic injury,

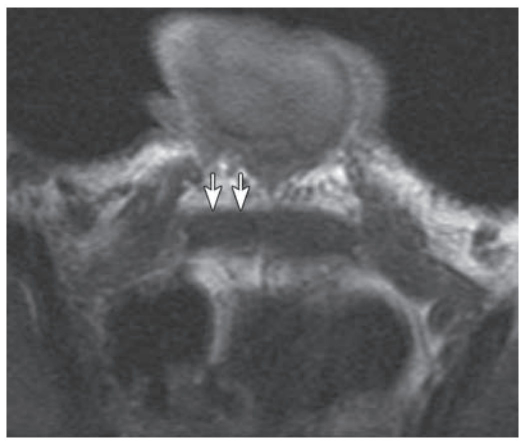


Figure 11. Injury to the rectus abdominis–adductor longus aponeurosis. Axial oblique T1-weighted image obtained in a 25-year-old male football player shows mild atrophy of the right rectus abdominis (arrows) in comparison with the left.

producing conditions that led to a secondary and potentially more symptomatic pubic symphyseal arthropathy.

Although athletic pubalgia is uncommon in women, aponeurotic injuries in female patients tend to be more severe than those in male patients. In many male patients, aponeurotic injuries remain unilateral, whereas in female patients they frequently start from the midline and propagate to both sides (Fig 13).

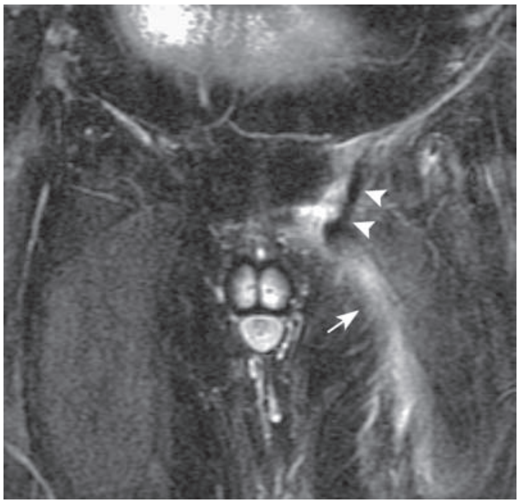


Figure 12. Adductor tendon avulsion. Coronal STIR image of the pubic symphysis in a 35-year-old male baseball player with an acute onset of left inguinal pain shows frank avulsion of the adductor longus tendon from the left lateral margin of the pubic body (arrowheads) and associated muscle strain (arrow).

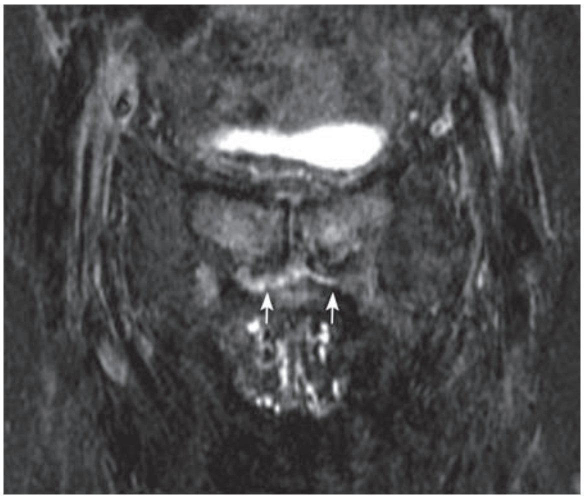


Figure 13. MR imaging appearance of athletic pubalgia in women. Coronal T2-weighted image of the pubic symphysis in a 30-year-old long-distance runner shows a broad tear of the rectus abdominis–adductor longus aponeurosis that involves both sides of the pubic symphysis (arrows).

Clinical Correlation and Treatment

Early efforts to image the pubic region had variable results. Often, MR images showed secondary findings (eg, marrow edema in the pubic symphysis; muscle strain or attenuation of the anterior abdominal muscles, leading to bulging) that led musculoskeletal radiologists to suspect injury to the pubic symphysis region and to localize that injury to one side or the other. However, the sites of injury were poorly visualized. Injuries to the lateral tendon of the rectus abdominis were less reliably visualized at MR imaging than were injuries of the adductor compartment at surgery (17,38). This result may have been due to an incomplete understanding of the biomechanics of the pubic symphysis and the relevant anatomy at the time, which might have led to the acquisition of images not tailored to the pubic region.

Conservative therapies for athletic pubalgia frequently include steroid injections of the pubic symphysis or the adductor tendon origins. While such injections have proved helpful for the transient relief of symptoms, patients often experience recurrent or refractory groin pain on resumption of athletic activity. Although a steroid injection at the site of pain may be an appropriate temporizing measure, it is unlikely to be an effective treatment of the underlying injury over the long term.

The repair of inguinal hernias in patients with athletic pubalgia but without physical manifestations of hernia has had variable success. Patients often have recurrent symptoms after these procedures and are unable to achieve their prior levels of athletic performance. Patients with athletic pubalgia who undergo herniorrhaphy often require additional surgery to repair the rectus abdominis or adductor longus myotendinous attachments. It has been proposed that the variable success of surgical repairs in these patients is due to the increasing stabilization of the pubic region because of progressive fibrosis, even though the underlying injury was not directly addressed by the surgical procedure. Alternatively, mesh stabilization of the superficial inguinal ring also may help stabilize the nearby rectus abdominis–adductor longus aponeurosis, providing incidental treatment of the primary injury (17).

Adductor tenotomy has been used to treat chronic groin pain at the adductor longus origin in athletes when pain is refractory to conservative treatment. However, in small series, only slightly more than 60% of patients were able to resume full athletic participation within 3–4 months (43). Tenotomy alone might be helpful in some patients, but it might not be sufficient to address underlying pubic instability or to prevent progressive injury.

Current approaches to the surgical management of athletic pubalgia are directed at repairing the site of injury and stabilizing the anterior pelvis.

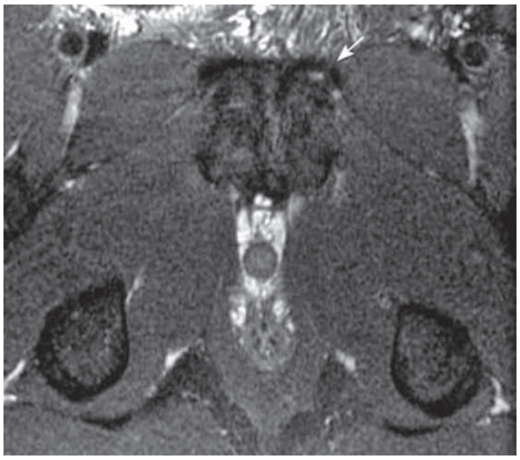


Figure 14. Adductor longus tendinosis. Axial T2-weighted fat-suppressed image obtained in a 24-year-old male football player shows mild thickening of the left adductor longus tendon with intrasubstance signal intensity changes (arrow).

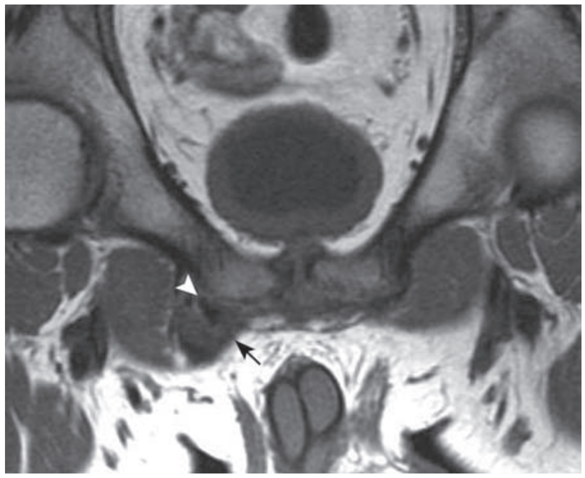


Figure 15. Adductor longus calcific tendinosis. Axial oblique T1-weighted image of the pubic symphysis in a 22-year-old male baseball player shows moderate right adductor longus tendon thickening (arrow) with a coarse intratendinous low-signal-intensity focus (arrowhead), a finding typical of calcium hydroxyapatite deposition.

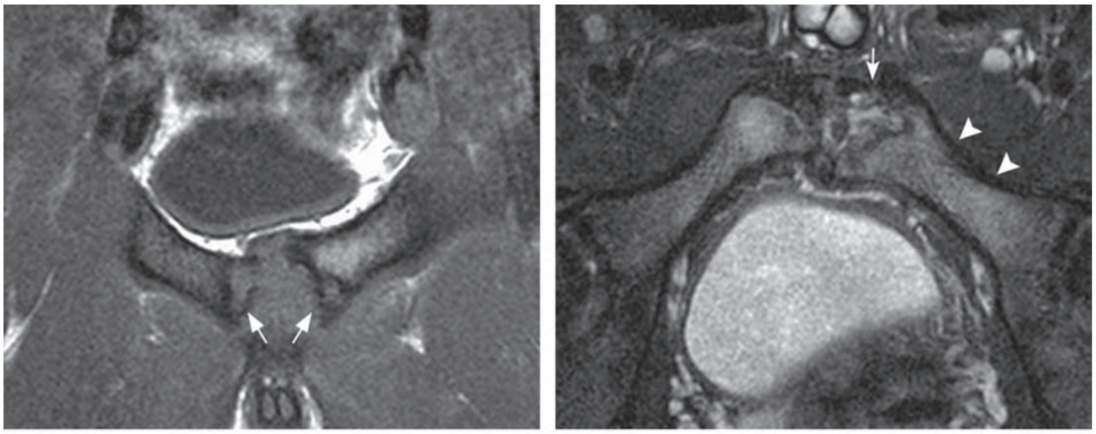
A commonly performed procedure is a pelvic floor repair similar to the modified Bassini repair technique. In this procedure, the inferolateral margin of the rectus abdominis is reattached to the fascia overlying the anterior pubis and the anterior pubic ligament. Unlike the classic Bassini technique, this repair technique does not affect the internal ring. The technique is frequently performed in conjunction with an adductor tendon release or tenotomy in which several longitudinal incisions are made in the anterior epimysial fibers of the adductor longus at its pubic attachment site (20). A 95% success rate was observed when these procedures were used, with athletes reporting complete resolution or a substantial improvement of symptoms, allowing return to pre-injury levels of athletic participation (17). Other techniques, such as repair of the aponeurosis of the external and internal oblique muscles, have been applied in conjunction with repair of the rectus origin to address potential weakness in the inguinal floor and restore the stability of the anterior pelvis (34,44).

Athletes and athletic trainers are incorporating training techniques such as sport-specific eccentric exercises designed to improve the stability of the anterior pelvis. Among the main benefits of strengthening so-called core muscles is the prevention of injuries in the pubic region. Low levels of training involving the abdominal and adductor muscles throughout the off-season have been associated with a two-thirds reduction in the risk for developing lower abdominal muscle strains in professional ice hockey players (3). Moreover, hockey players with less than 80% strength in the thigh adductors compared with the abductors have a significantly higher risk for developing adductor injuries, and strengthening of the adductor muscles has helped reduce the rates of occurrence of these injuries (45,46).

Other Pathologic Processes Associated with Groin Pain

Adductor Longus Tendinosis and Tenoperiostitis

Adductor tendinopathy is among the most common causes of groin pain in athletes. It most often occurs with chronic repetitive overuse of the adductor longus (43), although a minority of patients may present after acute eccentric contraction (47,48). Adductor tendinopathy is frequently related to a rectus abdominis–adductor longus aponeurotic injury; however, primary adductor tendon injuries also occur, and these are potentially more reversible with conservative therapies.



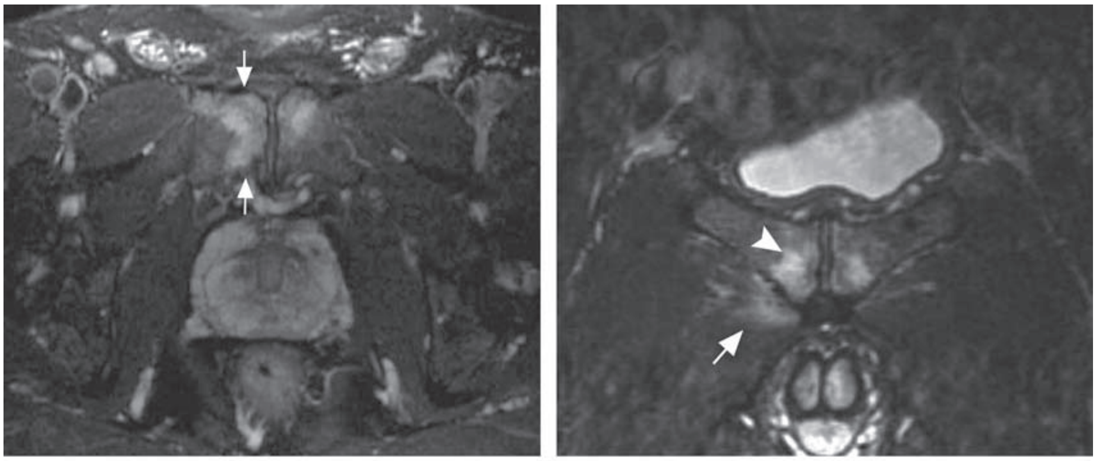
a. b.

Figure 16. Advanced osteitis pubis in a 19-year-old male soccer player. **(a)** Coronal T1-weighted image demonstrates pubic symphyseal widening with marked irregularities in the pubic articular surface (arrows). **(b)** Axial oblique T2-weighted image shows marrow edema that extends throughout both pubic bodies (arrow) and into the superior pubic rami (arrowheads).

The proximal myotendinous junction is the most frequent location of injuries. Patients present with groin pain isolated to the adductor longus tendon and pain in the upper medial thigh that is worse with resisted adduction of the hip. Physical examination may reveal tenderness along the proximal tendon. As in tendinopathy in other locations, MR imaging findings include thickening of the adductor longus tendon on the symptomatic side and intermediate intrasubstance signal intensity lower than that of fluid on images obtained with fluid-sensitive sequences (Figs 14, 15). Alternatively, MR images may show an intratendinous tear, calcification (as in the setting of hydroxyapatite deposition) (Fig 15), tendon avulsion, or a higher-grade and more distal adductor muscle strain. Cases in which there is no evidence of a tear or associated injuries of the rectus abdominis generally are managed conservatively, with rest and NSAIDs, followed by core muscle–strengthening exercises and a gradual return to full activity. The vast majority of patients respond to these measures, but a small number experience progressively worsening symptoms and require surgical procedures such as tendon release and pelvic floor repair (32,45).

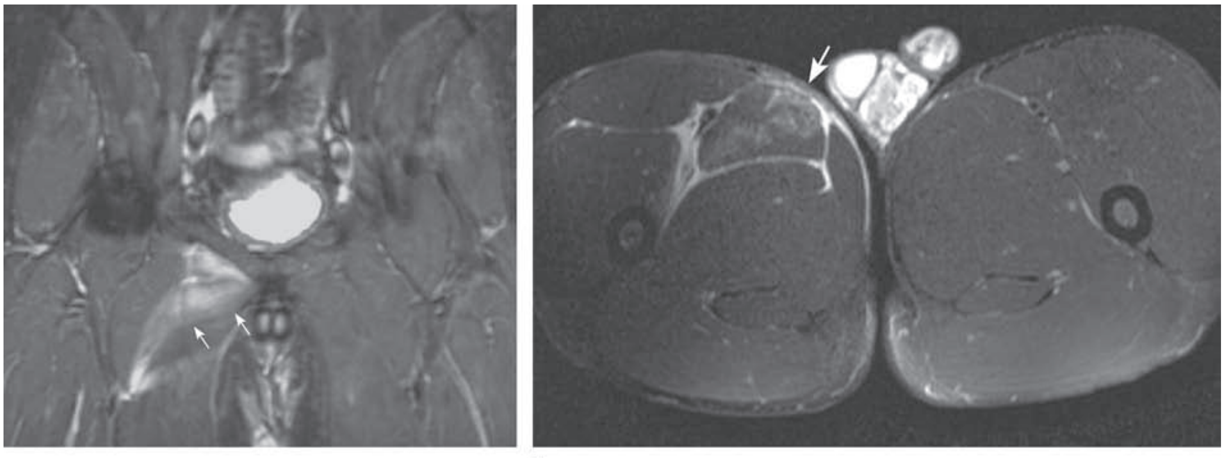
Osteitis Pubis

Osteitis pubis is common in soccer players, long-distance runners, and hockey players. 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. Most patients present with an insidious onset of pain over the pubis that may cause referred pain in the suprapubic region, adductor origin, and groin. This pattern frequently overlaps with rectus abdominis and adductor tendon dysfunction (49). In cases of acute onset, the symptoms and imaging findings may be indistinguishable from those in septic arthritis and osteomyelitis of the pubic symphysis. However, pubic symphyseal infection is uncommon in the athletic population. Radiographs of the pubic symphysis may show subchondral sclerosis, symphyseal irregularity, and bone resorption (50). MR images show diffuse marrow edema extending from the subchondral plate and often involving both pubic bodies (51,52). In addition, periostitis, articular surface irregularity, erosions, anterior and posterior osteophytes, and subchondral cysts may be seen on MR images (Fig 16) (53). A secondary cleft sign is commonly present. The myotendinous attachments are preserved unless there is coexistent tendinopathy (9). Unlike the marrow edema in rectus–adductor aponeurotic injuries,



a. b.

Figure 17. Mild osteitis pubis in a male ultramarathoner. **(a)** Axial T2-weighted image of the pubic symphysis shows marrow edema (arrows) that extends the full anteroposterior thickness of both pubic bodies. **(b)** Coronal STIR image shows a grade 1 strain of the right adductor longus muscle (arrow) as well as pubic marrow edema (arrowhead).



a. b.

Figure 18. Hockey goalie–baseball pitcher syndrome in a 35-year-old man. **(a)** Coronal STIR image of the pelvis shows right adductor longus edema (arrows). **(b)** Axial T2-weighted image of the upper thighs shows subtle herniation of the superficial fibers of the right adductor longus through a myofascial defect (arrow) several centimeters from the pubic symphysis.

which is confined to the anterior subcortical bone, the marrow edema in osteitis pubis extends across the entire anteroposterior dimension of the pubic body (Fig 17). Osteitis pubis is often self-limiting but may take more than 12 months to resolve. Initial management is conservative, consisting of progressive physical rehabilitation and NSAID therapy. In patients whose symptoms do not respond to this conservative therapy, steroid injections have been administered with variable results (47). Surgical treatment with symphyseal arthrodesis is reserved for those whose symptoms do not respond to conservative measures.

Hockey Goalie–Baseball Pitcher Syndrome

Groin pain in this unusual syndrome results from an epimysial or myofascial herniation of the adductor longus muscle belly several centimeters away from the site of its pubic attachment (32). Like the etiology of myofascial herniations at other anatomic sites, that of the fascial-epimysial defect in hockey goalie syndrome has not been established. Several authors have suggested a link with chronic repetitive stress at sites of neurovascular penetration (54). Patients with this condition often experience an acute onset of pain, which may be persistent or may intermittently intensify after stretching. Although many patients report groin pain, a thorough medical history and physical examination often lead to the identifi-

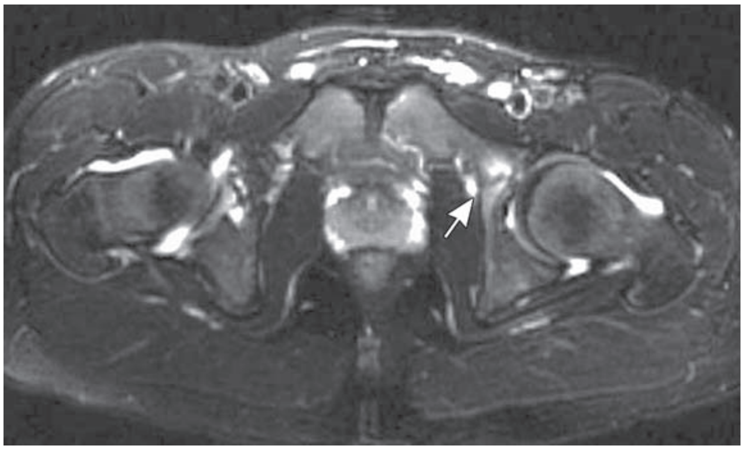


Figure 19. Pubic stress fracture in a 15-year-old male patient. Axial STIR image of the pelvis shows an incomplete fracture of the left superior pubic ramus (arrow) with surrounding marrow edema.

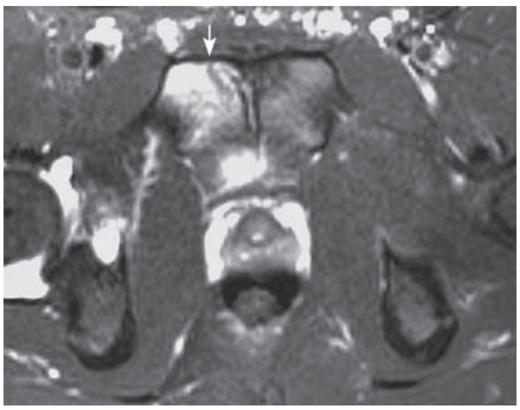


Figure 20. Parasymphyseal stress fracture in an 18-year-old male football player. Axial T2-weighted MR image shows high-signal-intensity marrow edema throughout the right pubic body and an incomplete fracture line paralleling the symphysis (arrow).

cation of a site of pain distal to the pubic symphysis, over the herniated muscle.

Hockey goalie syndrome is most often diagnosed on the basis of clinical signs and symptoms. Although patients with this syndrome frequently undergo imaging evaluations for pubic symphysis and hip abnormalities, there are no well-established MR imaging findings, and the imaging appearance often is normal. As in other myofascial herniations, the most common imaging findings are edema of the adductor longus muscle belly, which may occupy a central position in the herniated area, and a focal muscle bulge suggestive of herniation (Fig 18) (55). For treatment of recalcitrant pain, surgical epimysiotomy and débridement are necessary.

Pubic Stress Fracture

Fatigue fractures are often seen in athletes, most commonly in long-distance runners. They are believed to reflect abnormal chronic repetitive stress that outstrips the bone's ability to remodel itself. The most common pelvic site of stress fractures is the inferior pubic ramus; however, stress fractures of the femoral neck are more common and also may cause groin pain (56). Risk factors for stress fracture include female sex, nutritional deficits, and changes in training regimen that place greater stress on the bone. Patients present with a gradual onset of pain, which, at an early stage of injury, is exacerbated by exercise and relieved by rest. Persistent pain during rest indicates a more advanced stage of injury. There is often tenderness over the pubic ramus during palpation (6). Radiographs often are unrevealing, and the results of bone scans are false-positive (for tumor, infection, stress response without discrete fracture, bone infarction, or periostitis) in up to 30% of cases. MR imaging, the modality of choice, depicts areas of marrow edema on images obtained with fluid-sensitive sequences, findings that correspond to linear areas of marrow replacement on T1-weighted non–fat-suppressed images (Fig 19). Periosteal edema or calluses, and edema in the adjacent muscles and soft tissues, also may be present. Parasymphyseal stress fractures are less commonly encountered but usually are oriented parallel to the articular surface. They frequently occur with sacral stress fractures (Fig 20). Parasymphyseal fractures may mimic a neoplasm or infection, with areas of fragmentation or osteolysis (57,58). Treatment consists of conservative measures, including an initial period of rest followed by a gradual return to normal activity levels. Activity modification is essential to prevent a recurrence of symptoms, and healing may take 3–5 months (47).

Septic Arthritis–Osteomyelitis

Infection of the pubic symphysis usually is seen in postpartum female patients, patients with direct instrumentation of the pubic symphysis, and patients with pelvic malignancies but also

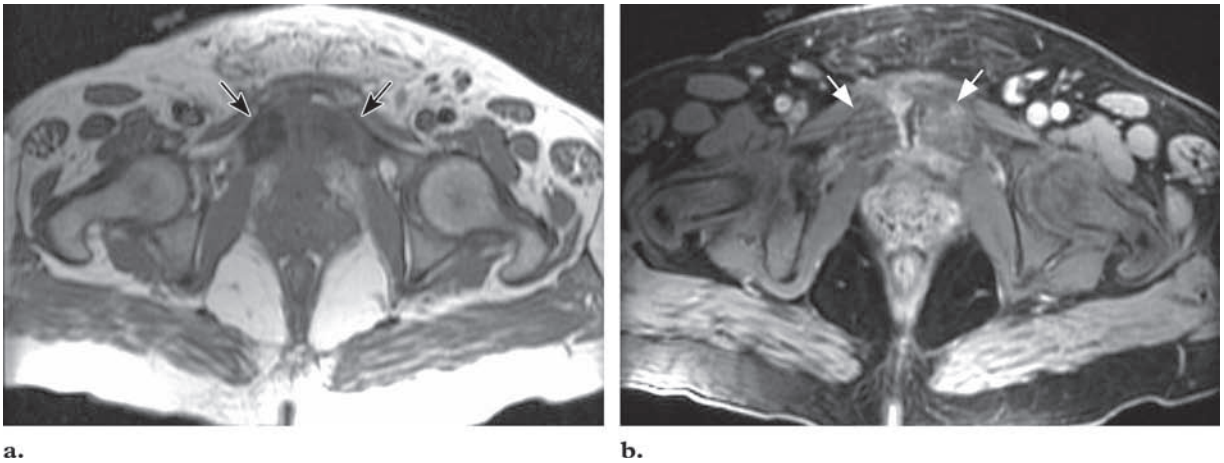


Figure 21. Pubic symphysis septic arthritis and osteomyelitis in a 43-year-old woman. **(a)** Axial unenhanced T1-weighted non–fat-suppressed MR image depicts a region of high signal intensity (arrows) indicative of the replacement of normal marrow in the pubic symphysis. **(b)** Axial contrast-enhanced MR image shows the high-signal-intensity symphyseal marrow (arrows) and enhanced signal intensity in the surrounding soft tissue.

has been reported in athletes without these risk factors (59). The infection is most often caused by *Staphylococcus aureus* and may result from hematogenous spread rather than direct inoculation. Patients often present with fever and an acute onset of pubic pain that may radiate to the groin. The radiographic and MR imaging features of pubic septic arthritis–osteomyelitis and osteitis pubis are similar (Fig 21), and clinicians may rely on the duration of symptoms and the presence of risk factors to help them distinguish between these possibilities. If the diagnosis is still uncertain, a biopsy is required. Treatment involves 10–14 days of intravenous antibiotic therapy, followed by 4 weeks of oral medications. Many patients require subsequent surgical débridement.

Acetabular Labral Tear

There is extensive overlap between the clinical manifestations of pathologic conditions of the hip and those of athletic pubalgia. The hip disorders that may cause groin pain include synovitis, osteoarthritis, intraarticular bodies, and, most commonly, acetabular labral tears. The anterior-superior part of the labrum is most susceptible to injuries, particularly during hyperextension and external rotation (33). The labrum is relatively poorly vascularized, and its anterior-superior aspect is considered to be particularly weak. Labral injuries predispose the hip to accelerated articular cartilage loss, especially adjacent to the tear, a condition that is thought to cause instability and alterations in contact forces of the articular cartilages (59). Abnormal morphology and signal intensity of the labrum at routine MR imaging of the hip are suggestive of the diagnosis. Paralabral cysts associated with acetabular labral tears can be seen on images obtained with fluid-sensitive sequences. In addition, MR imaging helps determine whether the morphologic features of the acetabulum or femoral head predispose a patient to femoroacetabular impingement and labral tears. Direct MR arthrography is widely used to improve the conspicuity of labral tears and labral detachments by distending the joint capsule and increasing intraarticular pressure (Fig 22). Arthrography also may help more accurately assess the articular cartilage for areas of subtle loss (60). Finally, the radiologist can inject a local anesthetic with the contrast agent into the hip joint in patients in whom pathologic changes both of the hip and the pubic region are suspected to have occurred. A marked improvement in or resolution of symptoms soon after the injection indicates that the cause of pain is related to the hip. Labral tears are initially managed conservatively with rest and NSAID therapy, which allow associated injuries to heal. If the symptoms resolve during this period, they likely are related to a cause other than a labral tear, such as internal snapping hip or iliopsoas bursitis. Patients with persistent symptoms often require surgical débridement of the labrum. If a labral detachment is repaired surgically, the surgeon might correct other morphologic abnormalities of the acetabulum or the proximal femur that predispose the patient to femoroacetabular impingement, to prevent progressive cartilage loss and osteoarthritis (61).

Internal Snapping Hip (Coxa Saltans)

Internal snapping hip is an occasional cause of pain in the anterior part of the hip and the inguinal region. Hip extension causes contact of the

Figure 22. Acetabular labral tear in a 24-year-old man with chronic inguinal pain. Sagittal T1-weighted fat-suppressed image from MR arthrography of the left hip shows intraarticular contrast material entering a focal anterosuperior labral detachment (arrow). MR images of the pubic symphysis showed no abnormality.

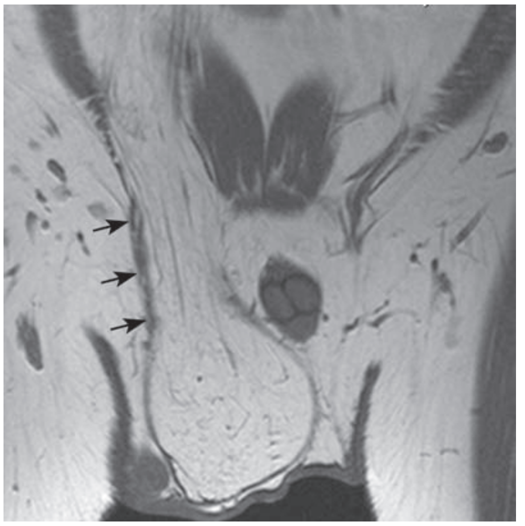
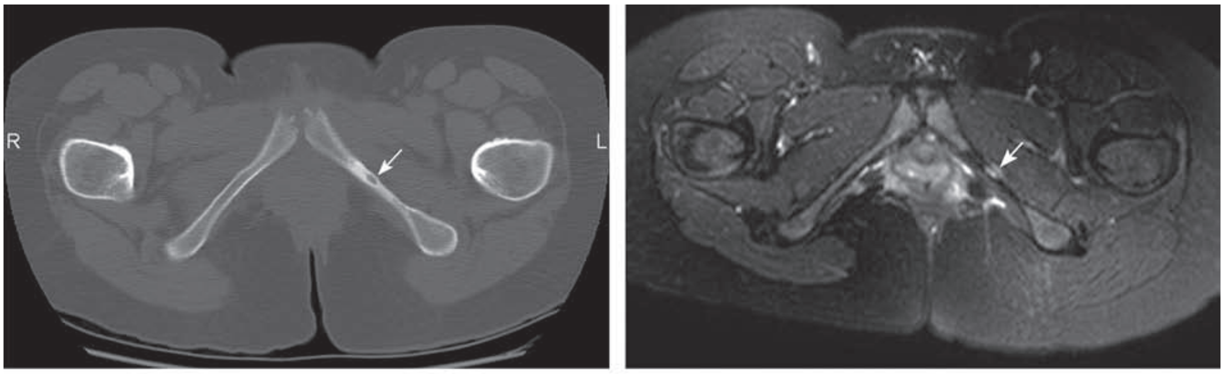


Figure 23. Inguinal hernia in a 25-year-old man with right-sided groin pain. Axial oblique T1-weighted non–fat-suppressed MR image depicts a fat-containing indirect right inguinal hernia (arrows). MR images of the pubic symphysis showed no abnormality.

iliopsoas tendon with an osseous protuberance, most commonly the iliopectineal eminence or an anterior-inferior iliac spinal process, as the tendon moves from an anterolateral to a posteromedial position. This partially obstructed movement may cause a snapping sensation, which frequently is accompanied by a snapping sound and which may be palpable during physical examination. With chronic repetitive motion, the patient may develop iliopsoas bursitis and tendinosis. MR images of the hip in a patient with internal snapping may appear normal, but iliopsoas bursitis frequently is present (62,63). Iliopsoas tendon thickening and intermediate intrasubstance signal intensity are uncommon findings, but when they are seen over the iliopectineal eminence or spinal process, they are suggestive of the diagnosis. Finally, an osseous spur arising from the iliopectineal eminence may predispose the patient to developing internal snapping. Ultrasonography (US) often is helpful for visualizing the tendon as it passes over the iliopectineal eminence during dynamic maneuvers as well as for detecting bursitis. Treatment consists of pain control with NSAID therapy and, possibly, corticosteroid injections in cases of bursitis. In addition, exercises may be performed to stretch the iliopsoas muscle and thereby correct the underlying abnormality that produces the symptoms. Surgical lengthening of the tendon occasionally is necessary in patients whose symptoms do not respond to conservative measures (59).

Inguinal Hernia

Inguinal hernias are very common, with more than 600,000 herniorrhaphies performed each year in the Unites States alone (64). Ninety-six percent of cases of groin herniation involve either a direct or an indirect inguinal hernia. In athletes, direct inguinal hernias and femoral hernias are most frequent (65). Patients often experience groin pain that worsens with straining, and a dull catching sensation. Frequently there is swelling in the inguinal region that is palpable on physical examination and can occasionally be reduced. Clinicians traditionally have relied on physical examination for the detection of inguinal hernias. However, when inguinal pain is present and the results of physical examination are indeterminate, many clinicians request an evaluation with US or MR imaging. Both modalities are effective for identifying the hernia sac and visualizing the relationship of the hernia to the inferior epigastric vessels. Real-time US scanning and dynamic MR imaging techniques allow direct visualization during provocative maneuvers such as Valsalva, which may help detect subtle hernias. At MR imaging, the hernia sac is often well depicted on coronal and axial non–fat-suppressed images of the inguinal region (Fig 23). Imaging also can



a. b.

Figure 24. Osteoid osteoma in a 23-year-old man with groin pain. **(a)** Axial CT image of the pelvis demonstrates a radiolucent oval-shaped nidus with surrounding sclerosis (arrow) in the left inferior pubic ramus. **(b)** Axial T2-weighted fat-suppressed MR image of the pelvis shows the high-signal-intensity nidus (arrow) and replacement of the adjacent marrow because of reactive sclerosis. (Case courtesy of Leon Rybak, MD, Hospital for Joint Disease, New York University, New York, NY.)

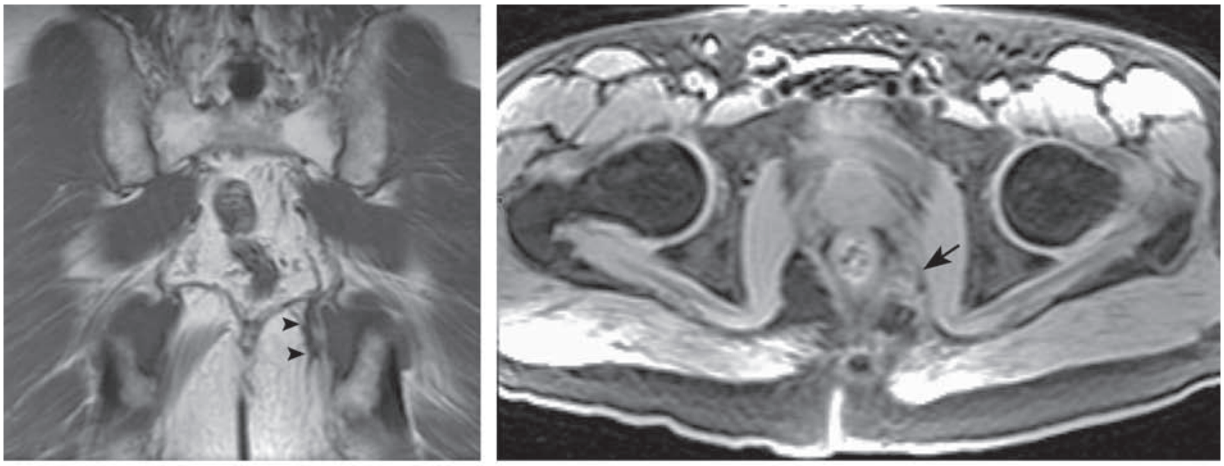
help differentiate between possible causes of a palpable inguinal abnormality and help identify less common hernias, such as a hernia through the obturator foramen, which may not produce a palpable mass (66,67). Because of the risk of bowel incarceration and strangulation, most inguinal hernias are surgically repaired, particularly if they are symptomatic (68).

Osteoid Osteoma

Osteoid osteoma is a benign bone-forming tumor usually seen in patients between the ages of 5 and 30 years. It is most common in the long bones, particularly the femur and tibia, and in the phalanges of the fingers and toes, but it also may be observed in other locations. It has a predilection for males (M/F ratio, 2:1) and often manifests in pain that is worse at night and that is relieved by NSAID therapy. Physical examination often reveals tenderness directly over the lesion. Osteoid osteomas that occur in the spine may cause painful scoliosis or produce pain suggestive of pathologic change in an intervertebral disk, whereas lesions that involve the pubic bones may mimic the symptoms of athletic pubalgia. Osteoid osteomas may occur in cortical, medullary, subcortical, or periosteal sites. They typically appear as a central radiolucent nidus with a variable degree of calcification, surrounded by zones of cortical thickening and nonaggressive periosteal reaction (Fig 24). Intramedullary lesions and lesions within a joint capsule often are accompanied by limited or no surrounding sclerosis because of the lack of contiguity with the adjacent periosteum. Radiography and CT are usually diagnostic for osteoid osteoma and may be used to guide biopsy and treatments such as percutaneous ablation (69). Alternatively, some lesions may be treated with a block excision. Total removal of the nidus generally results in a complete cure, while partial removal may lead to recurrent symptoms (70).

Nerve Entrapment Syndromes

Several nerves, including the obturator, femoral, iliohypogastric, genitofemoral, ilioinguinal, and lateral femoral cutaneous nerves, provide sensory and motor innervation to the groin and upper thighs. Entrapment of any of these structures may lead to groin pain mimicking athletic pubalgia. For instance, the obturator nerve passes along the medial margin of the psoas muscle into the obturator foramen, supplying the adductor longus and brevis muscles as well as a



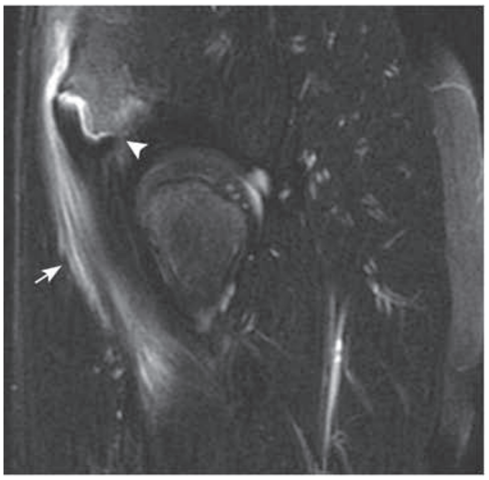
a. b.

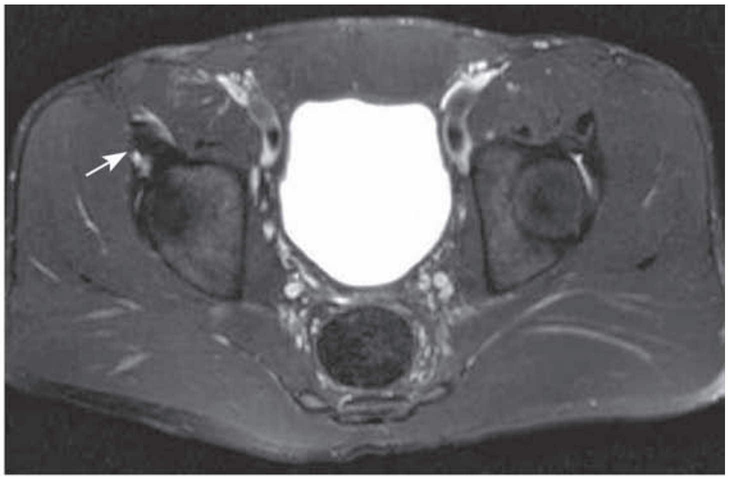
Figure 25. Nerve entrapment in a 34-year-old man with inguinal pain and a history of herpes infection. **(a)** Coronal T1-weighted non–fat-suppressed MR image of the pelvis shows an irregularity in the soft tissue at the lateral aspect of the left ischiorectal fossa, along the expected course of the left internal pudendal nerve (arrowheads). **(b)** Axial contrast-enhanced pelvic MR image shows marked enhancement in this area (arrow). Surgical exploration showed perineural fibrosis that was believed to correspond to the MR imaging findings and to result from the viral infection.

portion of the adductor magnus. Patients with obturator nerve entrapment often present with aching pain near the adductor origin that may radiate to the knee and worsen during exercise. The nerve entrapment has been attributed to fascial thickening of the adductor compartment, particularly along the anterior aspect of the adductor brevis (71,72). Other possible causes of obturator nerve entrapment include a mass effect from an obturator hernia, a pelvic fracture, and an acetabular paralabral cyst (73,74). Femoral nerve entrapment has been reported in patients after surgical procedures such as hip arthroplasty, herniorrhaphy, and abdominal hysterectomy, and entrapment of the ilioinguinal and genitofemoral nerves may be seen after abdominal surgery, in blunt trauma, or in muscle hypertrophy (5). Although the nerves in this region are difficult to detect at routine MR imaging, MR imaging may be helpful for diagnosing entrapment. Findings of muscle denervation-related edema or atrophy with a characteristic pattern may be suggestive of entrapment of a specific nerve. MR imaging also may be helpful for detecting sources of extrinsic compression, such as tumors or hernias. MR images obtained in patients with a history of trauma or surgery in the pubic region may show areas of scarring along the course of the nerves. Areas of scarring are represented by subtle and irregular perineural thickening and enhancement (Fig 25). The treatment of nerve entrapment syndromes often involves a surgical procedure performed to alleviate extrinsic compression, such as débridement of perineural scar tissue or division of constricting fascia (5).

Apophysitis

There are many pelvic apophyses that may be injured by forceful or repetitive muscle contractions during athletic activities before complete skeletal maturity is achieved. Apophysitis is most prevalent in patients between the ages of 12 and 22 years, predominantly in male patients (because females generally attain skeletal maturity earlier than males do). Groin pain mimicking athletic pubalgia may occur in inflammation of the apophyses of the anterior-inferior iliac spine, where the rectus femoris originates, and the anterior-superior iliac spine, at the origin of the sartorius and the tensor fascia lata (Fig 26). Athletes who





a. b.

Figure 26. Apophysitis in a 15-year-old male patient. **(a)** Sagittal T2-weighted fat-suppressed image of the right hip shows marrow edema in the anterior-inferior aspect of the iliac spine with intense edema in the apophysis (arrowhead) and associated edema in the rectus femoris muscle (arrow). **(b)** Axial STIR image of the pelvis shows thickening of the right rectus femoris tendon and peritendinous edema (arrow).

participate in sports that involve frequent kicking, in particular, have a tendency to develop painful apophysitis in these locations. Treatment is generally conservative and entails cessation of the offending activity to allow ossification at the zone of transitional cartilage (75).

Conclusions

The value of MR imaging for the clinical workup of athletic pubalgia increases with the radiologist's familiarity with and recognition of injury patterns in the anatomic structures surrounding the pubic symphysis. As the pathophysiology and anatomy of the pubic region come to be better understood, so too does the MR imaging appearance of common groin injuries in athletes who participate in sports with quick side-to-side movements, twisting and extension at the waist, and rapid acceleration and deceleration. Unenhanced MR imaging with a dedicated protocol for evaluating athletic pubalgia allows the diagnosis of subtle pathologic changes, identification of the structures involved, and determination of the extent of injuries in patients with activity-induced groin pain. The recommended MR imaging protocol for assessing the possible sources of referred groin pain includes both small-field-of-view high-resolution studies detailing the pubic symphysis and large-field-of-view pelvic surveys. Knowledge of the characteristic patterns of clinical and imaging findings in the various injuries that may produce athletic pubalgia, including primary injury of the rectus abdominis–adductor aponeurosis, allows the radiologist to accurately and precisely characterize the pathologic process and to help guide the referring clinician toward an appropriate treatment plan.

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Athletic Pubalgia and "Sports Hernia": Optimal MR Imaging Technique and Findings

Imran M. Omar et al

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Page 1422
The association of this process with herniation may be misleading, and surgery performed to repair an inguinal hernia may not necessarily address the cause of groin pain.

Page 1422
At MR imaging and surgery in patients with clinical athletic pubalgia, we have most commonly observed injury along the lateral border of the rectus abdominis, just cephalad to its pubic attachment, or at the origin of the adductor longus. After an injury to either the rectus abdominis muscle or the adductor muscle, there is a repetitive unbalanced contraction in the other muscle.

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Hernia-like symptoms may be related to the proximity of the injury site to the medial margin of the superficial ring of the inguinal canal or to lesion extension through the superficial ring and resultant weakening of the posterior wall of the inguinal canal.

Page 1423
Because many pathophysiologic processes may manifest with pubic and inguinal pain, an MR imaging survey of the pelvis is recommended during the initial evaluation. Immediate review of the large-field-of-view images as they are acquired may reveal particular regions of suspected pathologic change and help direct further high-resolution small-field-of-view imaging.

Page 1424
Frequently, images obtained with fluid-sensitive sequences allow direct visualization of tears involving the rectus abdominis–adductor aponeurosis, which appear as irregular areas with signal intensity like that of fluid undermining the aponeurosis. This tenoperiosteal disruption may be most visible on axial and sagittal fluid-sensitive images acquired approximately 1–2 cm lateral to the pubic symphysis.