0363-5465/101/2929-0521$02.00/0
THE AMERICAN JOURNAL OF SPORTS MEDICINE, Vol. 29, No. 4

Current Concepts

Hip and Groin Injuries in Athletes

Kyle Anderson,*† MD, Sabrina M. Strickland,‡ MD, and Russell Warren,‡ MD

*From the *Center for Athletic Medicine, Henry Ford Health System, Detroit, Michigan, and the ‡Department of Orthopaedic Surgery, The Hospital for Special Surgery, New York, New York*

ABSTRACT

Although athletic injuries about the hip and groin occur less commonly than injuries in the extremities, they can result in extensive rehabilitation time. Thus, an accurate diagnosis and well-organized treatment plan are critical. Because loads of up to eight times body weight have been demonstrated in the hip joint during jogging, presumably even greater loads can occur during vigorous athletic competition. The available imaging modalities are effective diagnostic tools when selected on the basis of a thorough history and physical examination. Considerable controversy exists as to the cause and optimal treatment of groin pain in athletes, or the so-called "sports hernia." There has also been significant recent attention focused on intraarticular lesions that may be amenable to hip arthroscopy. This article briefly reviews several common hip and groin conditions affecting athletic patients and highlights some newer topics.

Athletic injuries about the hip and groin occur at a low frequency relative to injuries at the more distal lower extremities. Epidemiologic studies have shown that injuries to the hip region compose approximately 5% to 9% of the injuries in high school athletes.[15,30] Rehabilitation times can be prolonged, making early and accurate diagnosis essential.

The anatomic and biomechanical considerations for injuries in these areas are among the most complex in the musculoskeletal system, making the management of these injuries very challenging. The immature skeleton can add to this complexity and broaden the differential diagnosis.

Loads of up to eight times body weight have been demonstrated in the hip joint during jogging, with potentially greater loads present during vigorous athletic competition.[13] The structures about the hip are uniquely adapted to transfer such forces. The body's center of gravity is located within the pelvis, anterior to the second sacral vertebra; thus, the loads that are generated or transferred through this area are important in virtually every athletic endeavor.

Imaging modalities continue to be developed and refined to help clinicians diagnose more accurately, and these often provide prognostic information. These imaging studies are most effective when selected on the basis of a thorough history and physical examination. Both nonoperative and operative treatment options for injuries to the hip and groin have improved. For example, the importance of trunk stability rehabilitation is being increasingly recognized. Among the many surgical advances for these injuries are the use of hip arthroscopy for intraarticular abnormalities and laparoscopy for lower abdominal injuries.

It should be emphasized that many hip and groin injuries frequently require the involvement of several different medical and surgical specialists. A preplanned, multidisciplinary approach is often necessary for optimal management of these complex athletic injuries. This article briefly reviews the pertinent anatomy and biomechanics about the hip and describes the evaluation and management of the more common conditions affecting athletes. These conditions are categorized according to the typical onset, acute or insidious. Table 1 shows a brief outline of the injuries that will be discussed.

ANATOMY AND BIOMECHANICS

The sacrum and two innominate bones form the pelvis. The ilium, ischium, and pubis are typically fused by the late teenage years, but the ischial tuberosity and anterior superior iliac spine may not be fused until the middle of the 3rd decade of life. The secondary ossification centers of the proximal femur appear at an early age, particularly that of the femoral head (4 to 6 months), and are generally

†Address correspondence and reprint requests to Kyle Anderson, MD, William Clay Ford Center for Athletic Medicine, 6525 Second Avenue, Detroit, MI, 48202.

No author or related institution has received financial benefit from research in this study.

TABLE 1
Common Disorders of the Hip and Groin Area

Acute onset
Muscle strains
Contusions (hip pointer)
Avulsions and apophyseal injuries
Hip dislocations and subluxations
Acetabular labral tears and loose bodies
Proximal femur fractures
Insidious onset
Sports hernias and athletic pubalgia
Osteitis pubis
Bursitis
Snapping hip syndrome
Stress syndrome
Osteoarthritis
Other disorders
Lumbar spine abnormalities
Compression neuropathies

fused by the late teenage years. Femoral anteversion undergoes a gradual decrease through childhood to an average of 10° to 15° in adulthood. The femoral neck-shaft angle averages 130° to 135°.

The blood supply to the femoral head and neck is primarily from retinacular branches of the medial and lateral circumflex arteries from the profunda femoris. The lateral epiphyseal vessels, along the posterosuperior neck, appear to be the single most important suppliers of blood to the femoral head. In adults, the contribution of the obturator artery via the ligamentum teres femoris is variable. It supplies a substantial portion of the femoral head in only 30% of patients.[83]

The major ligaments of the pelvis and hip are known to be the strongest in the body and are well adapted to the forces transferred between the spine and the lower extremities. The acetabular labrum deepens the acetabulum and increases articular congruence. The anterior iliofemoral ligament (inverted Y-ligament of Bigelow) extends from the anterior inferior iliac spine to the intertrochanteric line of the femur (Fig. 1). This ligament prevents hyperextension of the hip. The inferiorly positioned pubofemoral ligament prevents excessive abduction. The ischiofemoral ligament, which originates posteriorly along the ischium and travels anteriorly to the neck of the femur, is tightened by flexion.[26] Thin anterior and strong posterior and interosseous ligaments stabilize the sacroiliac joints. Sacrospinous ligaments divide the greater and lesser sciatic foramen. The sacrotuberous ligaments travel from the lower sacrum to the ischial tuberosity.

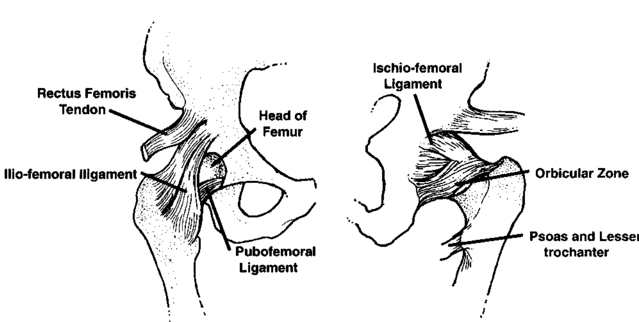

Figure 1. Major ligaments of the hip joint. Left, anterior view demonstrating primarily the iliofemoral ligament (inverted Y-ligament of Bigelow) and the pubofemoral ligament. Right, posterior view shows that the ischiofemoral ligament is the predominant structure from this view.

The detailed relationships of the muscles about the hip joint are most easily thought of in groups according to their primary functions (Table 2) (Fig. 2).

Much of our understanding of the biomechanics of the hip joint has been obtained through simple static diagrams, gait analysis, and through the insertion of force-measuring implants.[5] The muscles about the hip joint are generally at a mechanical disadvantage because of a relatively short lever arm and must produce forces across the joint that are several times body weight. It has been calculated that level walking can produce forces of up to six times body weight and that jogging with a stumble increased these forces to up to eight times body weight.[13] Although forces, when measured in vivo, tend to be less than the calculated values, very high forces would be anticipated during vigorous sports activities.[7] The normal hip joint is capable of a flexion/extension arc of approximately 140°, but one study has shown that slow-paced jogging used only about 40° of this arc.[63] This increases somewhat as pace increases. Analysis of EMG activity shows that the rectus femoral and iliac muscles are very active with swing-phase hip flexion, while the hamstring muscles act eccentrically to control hip flexion and decelerate knee extension.[57] It is of note that, when running, the body is propelled forward primarily through hip flexion and knee extension rather than by pushoff with ankle plantar flexion.

The relationship of the abdominal musculature and the erector muscles of the spine, along with their role in stabilization of the lumbosacral spine, are being studied extensively because of the high incidence of low back pain in our society. Decreased spinal mobility and trunk muscle strength have been identified in patients with recurrent low back pain.[69] These muscles must also be considered for their role in conditions that affect pelvic tilt and the hip joint. The balance of the muscles of the upper thigh, particularly the adductor muscles, with those of the lower abdomen requires further study. Conditioning programs have traditionally focused on strengthening of the extremities. Only recently have there been rehabilitation programs designed to address the power and endurance of the trunk and postural muscles.[48,73]

COMMON HIP AND GROIN CONDITIONS AFFECTING ATHLETES

Acute Onset

Muscle Strains. The most common injuries about the hip and groin resulting from athletic competition are muscle strains. These often occur in muscles that cross two joints and during an eccentric contraction (in which external load exceeds muscle force). Strain or tear frequently

TABLE 2
Muscles of the Hip Joint: Anatomy and Function

Muscle group	Muscle	Origin	Insertion	Innervation
Hip flexors	Iliac and psoas	Iliac wing and lumbar spine	Lesser trochanter	Femoral nerve
	Pectineus	Pubis	Pectineal line of femur	Femoral nerve
	Rectus femoris	Anterior inferior iliac spine and acetabular rim	Tibial tubercle	Femoral nerve
	Sartorius	Anterior superior iliac spine	Pes anserinus	Femoral nerve
Adductors	Adductor brevis and longus	Pubic ramus	Linea aspera of femur	Obturator nerve
	Adductor magnus	Pubic ramus and ischial tuberosity	Linea aspera and adductor tubercle	Obturator nerve and tibial branch of the sciatic nerve
	Gracilis	Symphysis pubis	Pes anserinus	Obturator nerve
External rotators	Gluteus maximus	Iliac wing	Iliotibial band and femur	Inferior gluteal nerve
	Piriformis Obturator externus Obturator internus Superior and inferior gemellus	Pelvis	Medial aspect of the greater trochanter	Lumbosacral plexus via the greater sciatic foramen
Abductors	Gluteus medius and minimus	Ilium	Greater trochanter	Superior gluteal nerve
	Tensor fascia lata	Iliac wing	Iliotibial band, Gerdy's tubercle	Superior gluteal nerve

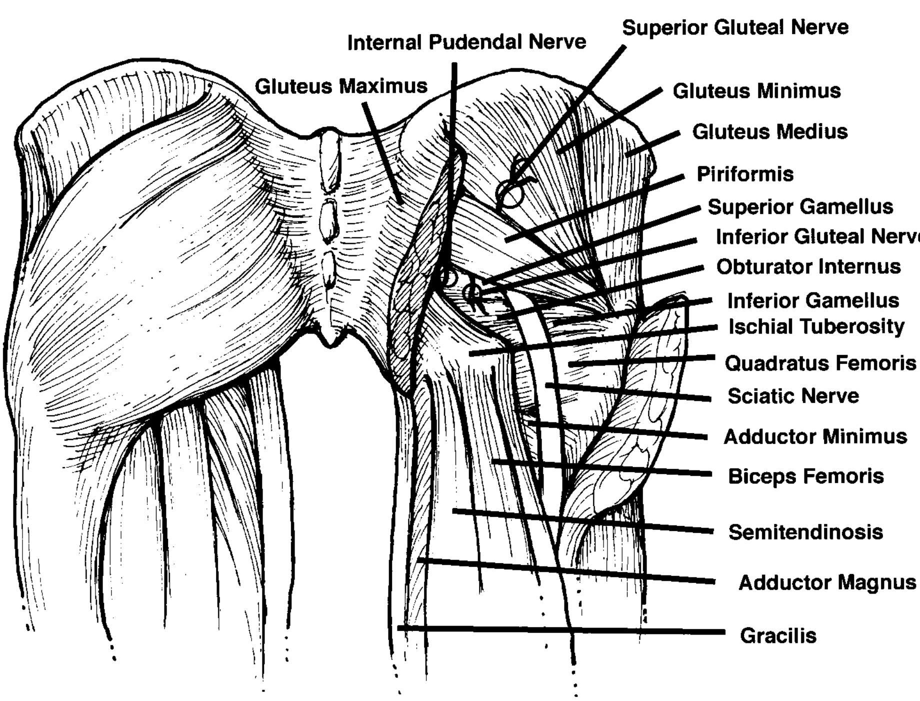

Figure 2. Posterior view of the thigh and hip muscles.

occurs at the myotendinous junction, but is also commonly seen in the muscle belly.[27,28,79] The same mechanism that results in a muscle strain in an adult may cause an apophyseal avulsion in an adolescent. Prevention of these injuries has become a topic of interest among athletic trainers and physicians. Strengthening with consideration of appropriate agonist and antagonist relationships, stretching, and appropriate warmup are important components of prevention. Many of these injuries occur early in the athletic season. The adductor muscles are frequently involved, especially in hockey, football, and soccer players. Groin or medial thigh pain is the most common complaint, particularly when the patient is asked to adduct the leg against resistance. Focal tenderness and swelling are detected; with more severe injuries, a defect may be palpable. Objective weakness may be difficult to ascertain, depending on the muscle involved. Potential avulsions should be ruled out by analysis with an AP pelvis radiograph. Magnetic resonance imaging may be useful diagnostically, and may even yield prognostic information.[64] Greater than 50% cross-sectional area involvement, fluid collections, and deep muscle tears were among the factors associated with longer recovery time.

Strains of the rectus femoris muscle result in palpable swelling and tenderness in the anterior thigh, 8 to 10 cm below the anterior superior iliac spine. These types of strains result from an explosive hip flexion maneuver, such as sprinting or kicking, or from eccentric overload as the hip is extended. Further examination reveals painful and possibly weak knee extension or hip flexion. Strain or rupture of the iliopsoas muscle can also occur during resisted hip flexion or passive hyperextension (eccentric overload).[58] Soccer players often suffer from this type of injury when they are hit as they extend their leg to kick. A study has been reported in which gymnasts sustained a proximal avulsion of the iliac muscle.[31] These injuries may be associated with significant swelling and are potentially a cause of femoral nerve palsy.

Initial treatment of muscle strains involves control of hemorrhage and edema with a compressive wrap, ice, and rest. Once pain is absent, gentle range of motion exercises may be started. Nonsteroidal antiinflammatory medications should be used judiciously. There is evidence that, while short-term recovery is reduced with this treatment, long-term function of the muscles may be adversely affected.[55] After full range of motion is achieved, strengthening becomes the focus. Return to full activity should be closely monitored and should be done only when the athlete is pain-free. Recurrences may be more severe, requiring even longer rehabilitation time than that required with the initial injury.

Hip and Thigh Contusions. An iliac crest contusion (hip pointer) is the result of a direct blow to the iliac crest, typically occurring in football, but it can result from a fall in any activity. Point tenderness, ecchymosis, and muscle spasm are common findings with this injury. Deep bleeding and swelling can be subperiosteal, intramuscular, or subcutaneous. The iliac crest has multiple muscle origins and insertions, including the internal and external oblique, latissimus dorsi, paraspinal muscles, and fascia from the gluteus medius muscle. Avulsion of these muscles can be difficult to differentiate from a contusion. Resisted contraction of these muscles, if avulsed, may exacerbate symptoms to a greater degree than would a contusion. One potentially serious consequence would be hematoma formation with pressure on adjacent nerves, such as the femoral or lateral femoral cutaneous nerve (meralgia paraesthetica). Treatment initially focuses on minimizing swelling and bleeding with compression and ice. The hip can be rested in a position of comfort and the patient should ambulate with crutches. Gradual stretching and strengthening of adjacent muscles should be performed before resuming premorbid activity. Padding modifications may allow earlier participation in contact sports. Many physicians would also consider the judicious use of local anesthetic injection to allow continued participation in sports.

Proximal thigh contusions are also very common athletic injuries and are particularly encountered in football as a result of direct trauma. The muscle is typically compressed between the external force and the subjacent bone. There is often significant hemorrhage and swelling. Specific treatment protocols have been developed to minimize complications such as myositis ossificans or loss of motion and to improve functional outcome.[67] The initial treatment for an anterior thigh contusion involves rest, immobilization in knee flexion, ice, and compression to maintain motion and minimize hematoma formation. Weightbearing is limited until the patient has good quadriceps muscle control and 90° of pain-free knee motion. Functional rehabilitation and nonimpact sports are allowed when the arc of motion has reached 120° and there is no residual muscle atrophy. Return to full activity is allowed when there is normal strength and range of motion. This duration averages about 3 weeks, but with more severe injuries the athlete should be prepared for a longer recovery time.

Occasionally, severe injuries will cause a large hematoma, which can markedly limit range of motion. If an athlete struggles to regain motion, MRI will demonstrate the size and location of the hematoma. Evacuation or aspiration of the hematoma in these unusual cases can be considered. Protection with padding over the involved area to avoid repeat injury is important. The development of myositis ossificans depends on the severity of the initial injury but is also frequently seen with repeated trauma. Nonsteroidal antiinflammatory medications may be useful for prevention of contusions.[16,56] When there is hematoma formation, mesenchymal cells undergo a process similar to fracture callus formation (Fig. 3). This process may appear histologically similar to osteosarcoma, but the history is usually distinct and the periphery of myositis is mature. Treatment of myositis ossificans is generally nonoperative, but if a mature osseous mass interferes with function or range of motion, it may be excised. A minimum interval of 6 months, but preferably 12 months, after injury is necessary to reduce the likelihood of recurrence. Scintigraphy is theoretically helpful in the assessment of maturity of the lesion. There are conflicting reports on the value of MRI for evaluation of myositis ossificans and its suitability for excision.[6,62]

High-energy contusions should be monitored closely in the acute phase because thigh and even gluteal compartment syndromes can develop. Pressure criteria are similar to those of other anatomic regions, typically within 30 mm Hg of the diastolic pressure. Emergent fasciotomies are rarely necessary, but serial examinations are an absolute requirement.

Avulsion and Apophyseal Injuries. Avulsion injuries about the pelvis are more common in skeletally immature patients. These occur at essentially every major muscle attachment (Fig. 4) and are the result of a violent muscle contraction, which is usually eccentric. Thorough history-taking, including ascertaining mechanism of injury, is

Figure 3. Myositis ossificans near the femur after a severe anterolateral thigh contusion.

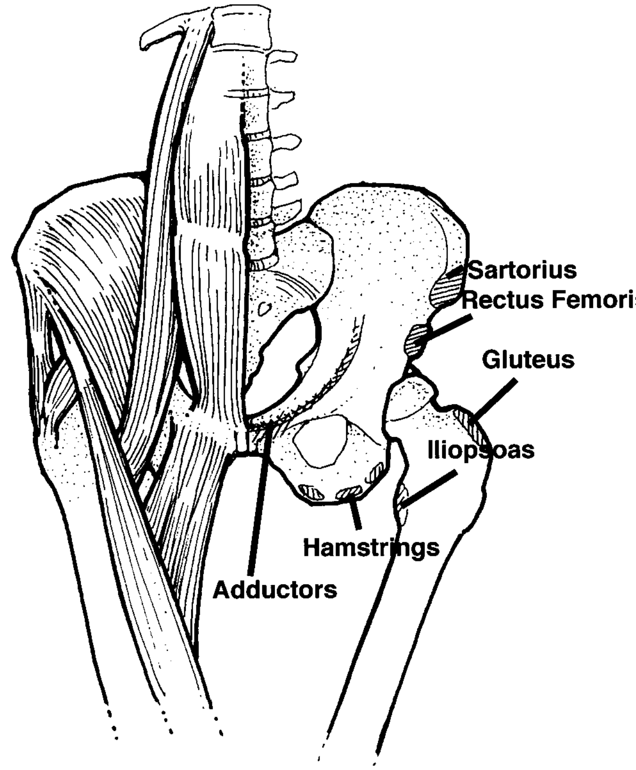

Figure 4. Locations of several major muscle origins and insertions of the pelvis and proximal femur. Avulsion injuries have been reported at each of these sites.

usually the key to the diagnosis. Patients will maintain a position that reduces tension on the involved muscle(s). Localized tenderness, swelling, and eventual ecchymosis are common findings. Resisted contraction or stretch of the involved muscle usually reproduces the pain. Plain radiographs, including comparison views, can usually identify the injury if the fragment is visible. However, the index of suspicion should be high in children and adolescents because secondary ossification centers may have not yet appeared. Fortunately, the periosteum and surrounding fascia often limit severe displacement. Avulsion of the anterior superior iliac spine is the result of tension from the sartorius muscle, while avulsion of the anterior inferior iliac spine is from a pull of the direct head of the rectus femoris muscle. Avulsion of the lesser trochanter occurs with vigorous contraction of the iliopsoas tendon during hip flexion (that is, kicking). When these injuries occur in adults and there is not a clear history of trauma, a neoplasm must be suspected.[1,42] Consideration may be given to surgical fixation if the fragment is of sufficient size to contain hardware and the displacement is 2 cm or greater.

Few data are available to help with the decision of a surgical versus nonsurgical approach. In one report of a ballet dancer, the pain did not improve until surgical intervention.[65] Most often, initial treatment includes comfortable positioning with protected weightbearing with crutches until the patient is pain-free.[52] Once the pain subsides, light stretching and weightbearing can be advanced. After full, pain-free range of motion is achieved, strengthening can begin. Patients should not return to competition until full strength and motion are restored. Chronic or healing injuries may mimic other processes such as infection or tumor (Fig. 5).[70] Ischial tuberosity fractures or "hurdler's fractures" occur as the result of hip flexion with knee extension, causing excessive hamstring muscle tension. These fractures also frequently occur during water skiing.[68] The mean age of patients with ischial tuberosity avulsions ranges from 18 to 40 years, and these patients have a history of acute trauma at the beginning of their symptoms.[68] Generally, these injuries are managed nonoperatively.[68] Avulsions can cause prolonged pain with referred pain to the posterior parts of the thigh, and

Figure 5. Ossification near the obturator foramen (arrow) resulting from a chronic adductor avulsion. These lesions have often been difficult to distinguish from infections or neoplasms.

may require operative intervention.[43,84] Late sciatic nerve palsy that responded to mass excision and neurolysis has been reported.[74] For ischial avulsions, changes in seated weightbearing distribution may also be a concern. Finally, avulsions may occur at the origin of the adductor magnus muscle in cheerleading and other activities during "the splits." Treatment is similar to that for other types of avulsions.

Hip Dislocation and Subluxation. Although complete dislocation of the hip is uncommon in athletics, subluxation may be more frequent but is poorly recognized. In primary dislocations, those occurring in the posterior direction are significantly more common. Anterior dislocations account for only 8% to 15% of the total number.[71] This injury tends to occur secondary to a collision in skiing and contact sports. Patients with the more common posterior dislocation present with the leg flexed, adducted, and internally rotated; and those with anterior dislocations present with the leg in external rotation, abduction, and either extension or flexion. Typically, a force is transferred axially along the femur; therefore, the ipsilateral knee should be carefully evaluated. This injury is a surgical emergency requiring immediate neurovascular examination followed by reduction and follow-up examinations. Most often, closed reduction can be achieved with intravenous sedation or, if necessary, general anesthesia. Dislocations are usually well demonstrated on an initial AP pelvis radiograph. After reduction, a CT or MRI scan is recommended to assure a concentric reduction without loose fragments in the joint.

In dislocations without associated fractures, the patient may be treated with crutches and partial weightbearing for 6 to 8 weeks with gradual range of motion and strengthening afterward. The most common complication is osteonecrosis, which occurs in 10% to 20% of patients, depending on the patient's age, severity of injury, and the rapidity of reduction. Osteonecrosis can occur even after hip subluxation.[11] A follow-up MRI should be performed at 3 months to rule out osteonecrosis. Loose osteochondral fragments that result from a subluxation or dislocation are amenable to removal by hip arthroscopy as discussed in the next section (Fig. 6). Sciatic nerve injury is rarely associated with posterior dislocations and, likewise, femoral nerve injury is rarely associated with anterior dislocation.

Hip subluxation is a more recently recognized injury that may be surprisingly subtle in its presentation.[11] A simple fall onto a flexed knee with the hip adducted forces the femoral head posteriorly onto, but not over, the rim of the acetabulum, allowing spontaneous reduction to occur. This can also occur when an athlete stops quickly and pivots over the weightbearing extremity. There is frequently a fracture of the posterior acetabulum. Judeh views are helpful in evaluating an acetabular lip fracture. An MR image will demonstrate the acute fracture and contusion of the femoral head. We have recommended a rehabilitation protocol of crutches, nonweightbearing for 6 weeks, followed by a repeat MRI. Chondrolysis and avascular necrosis have been noted in some of our patients. A return to sport is allowed at 6 to 12 weeks if the MRI is negative and if there is pain-free range of motion. Also, preexisting idiopathic osteonecrosis or Perthes disease in younger patients may become symptomatic as a result of athletic participation.

Labral Tears. Improved imaging techniques and a higher index of suspicion have increased the recognition of acetabular labral injuries. Historically, labral tears were associated only with major trauma such as posterior hip dislocations; however, there is now evidence that they are

Figure 6. Coronal MRI obtained after a traumatic hip subluxation. Note the osteochondral loose body (arrow) in the inferior recess.

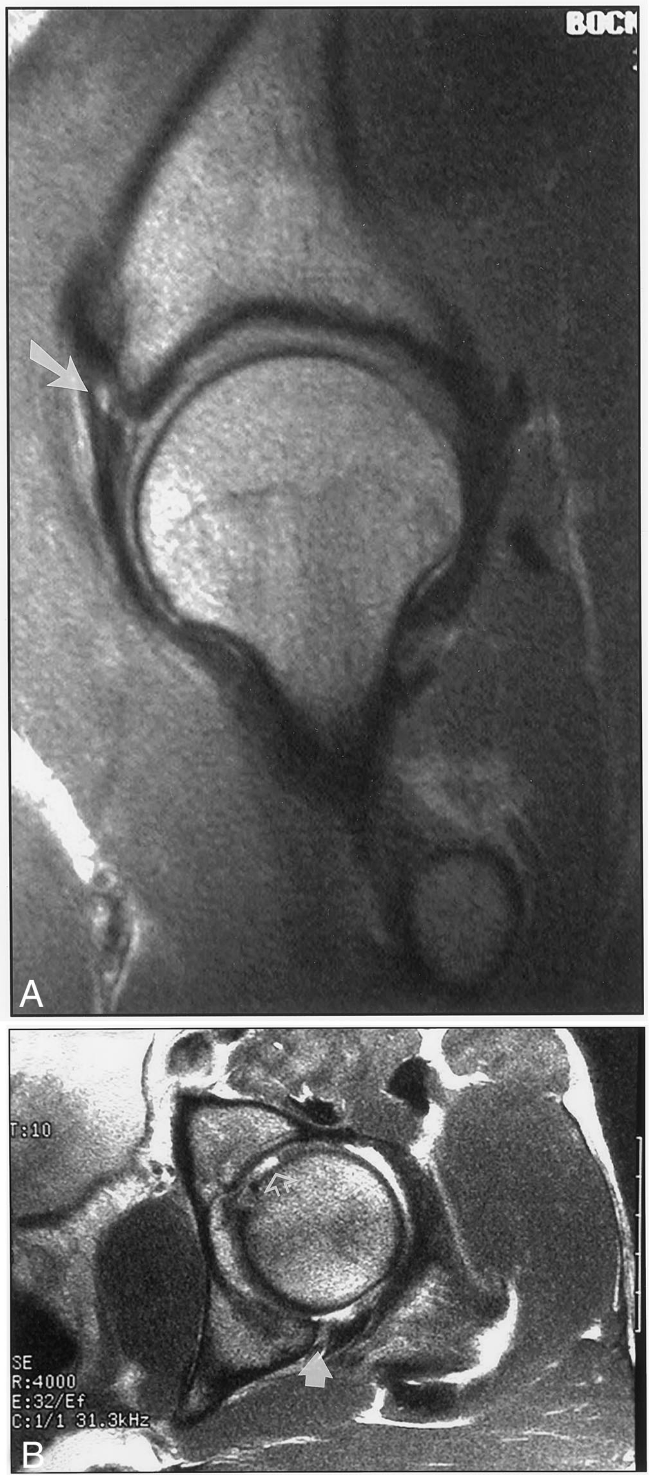

Figure 7. A, noncontrast sagittal MR image demonstrating a labral tear (arrow) that was confirmed arthroscopically. B, an axial MR image shows a posterior labral detachment (solid arrow) as well as an anterior chondral shear injury (open arrow) off of the femoral head.

related to subluxations and underlying acetabular dysplasia.[17] Acetabular dysplasia results in lateral uncovering of the femoral head and places excessive stress on the lateral aspect of the labrum.

Young, active patients present with a catching type of pain after a twisting or slipping injury. However, most of these patients experience relatively minor injuries, and many do not recall any trauma. In older patients with preexisting degenerative arthritis, there will usually be an acute episode of symptom exacerbation without a change in the radiographic analysis. Symptoms may begin at the time of injury or gradually appear over time. Patients tend to report groin pain, an audible or palpable click, along with mild limitation of motion. The predominant finding on physical examination is reproduction of their hip pain with specific types of manipulation. An anterior labral tear can be identified with sharp, catching pain with the following maneuver: hip flexion, external rotation, and abduction followed by extension with internal rotation and adduction. Patients with a posterior labral tear experience sharp pain with passive flexion, internal rotation, and a posterior load.[34,36,77]

Arthrography has been shown to identify 88% of labral tears while concurrently enabling injection of local anesthetic.[22] Relief of pain after the local anesthetic in a patient with normal radiographic analysis is very suggestive of intraarticular abnormalities. The role of MRI has been expanding and can be used to rule out other articular lesions, particularly loose bodies and avascular necrosis. Many institutions use intraarticular gadolinium to obtain an MRI arthrogram; there is a reported sensitivity of 90% and an accuracy of 91%.[14] In some reports, MRI alone has not proved accurate or sensitive.[18] There is considerable variability in MR appearance of the labrum in asymptomatic patients.[12] However, early data from our institution indicate that high-resolution MRI can accurately detect labral and chondral abnormalities (Fig. 7) (R. Buly et al., unpublished data, 1999). In some cases, the diagnosis is not made until the time of arthroscopy (Fig. 8).[21,51,77]

Appropriate treatment should begin with partial weightbearing for 4 weeks. Local anesthetic injection may be both diagnostic and therapeutic.[10] Those patients who do not respond to nonoperative treatment may be offered surgery, typically arthroscopic excision of the torn portion of the labrum. The long-term outcome of arthroscopic debridement of the acetabular labrum is promising in patients without osteoarthritis or dysplasia. In a recent study, 71% of patients had good results after a mean of 34 months.[21] There are also preliminary data that indicate that arthroscopic repair is possible for labral detachment.[8] The major concern regarding arthroscopic complications is injury to nearby neurovascular structures. Fortunately, to date, most of these injuries have been transient and have eventually resolved.[25] These injuries are most likely due to the traction necessary for arthroscopic visualization rather than from surgical laceration. The most commonly described portals have been shown to be at a reasonably safe distance from major nerves and vessels.[9]

Hip Fractures. Fractures of the proximal femur are unusual injuries in athletes. Frost and Bauer [23] reported a

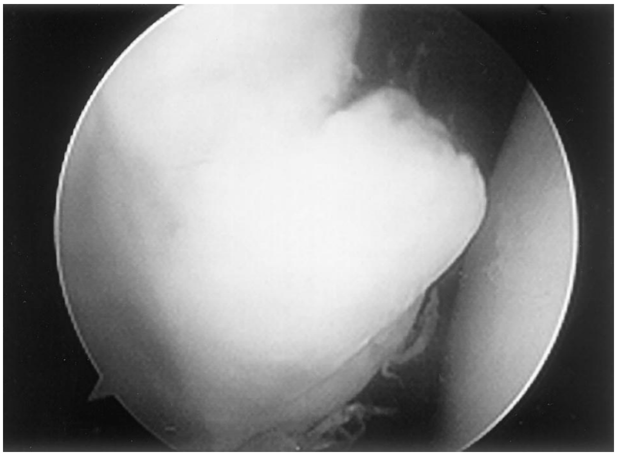

Figure 8. Arthroscopic view of an acetabular labral tear.

number of these fractures occurring from participation in cross-country and alpine skiing; these injuries have been termed "skier's hip." Displaced, intracapsular fractures are a surgical emergency requiring rapid reduction and internal fixation to minimize the risk of osteonecrosis. Radiographs are usually adequate for diagnosis. Sports-related injuries in adults are treated the same way. Children and adolescents should be treated with appropriately sized instrumentation with efforts to protect the growth plate.

Insidious Onset

Groin Pain and Hernias. Groin pain accounts for only 5% of patient visits to clinics, yet it is responsible for a much larger proportion of time lost from competition.[29,66] The "sports hernia" or "hockey hernia" has become a common injury in athletes who participate in sports that require repetitive twisting and turning at speed, that is, ice hockey, soccer, tennis, and field hockey. A study of National Hockey League (NHL) players showed a significantly increased incidence of groin injuries from 1991 to 1997.[20] At one point in the fall of 1999, the NHL had more than 20 players on its injured list as a result of groin injuries. The increasing frequency of this diagnosis may be partly attributed to heightened awareness of trainers and physicians. There is also the notion that the increasingly rigorous, off-season conditioning programs concentrate on strengthening the lower extremities but neglect the abdominal musculature, causing a pelvic imbalance. Subtle contractures of the hip flexor or adductor muscles, or both, may develop. One radiographic study noted decreased ability of hip extension in hockey players when pelvic tilt was controlled.[80]

Athletic pubalgia may be a more appropriate term for these injuries since, in many cases, an actual hernia is not seen.[53,72] Several theories exist in the literature regarding the causes of the sports hernia; most theories implicate an overuse syndrome. Hip abduction, adduction, and flexion-extension with the resultant pelvic motion produce a shearing force across the pubic symphysis, leading to stress on the inguinal wall musculature perpendicular to the fibers of the fascia and muscle. Pull from the adductor musculature against a fixed lower extremity can cause significant shear forces across the hemipelvis. Subsequent attenuation or tearing of the transversalis fascia or conjoined tendon has been suggested as the source of pain (Fig. 9).[32] Other studies have reported abnormalities at the insertion of the rectus abdominis muscle[53,78] or avulsions of part of the internal oblique muscle fibers at the pubic tubercle.[78] As a result of their operative findings, Lacroix et al.[44] believed that the abnormality existed in the external oblique muscle and aponeurosis. One anatomic study suggested that entrapment of the genital branches of the ilioinguinal or genitofemoral nerves may be the source of pain.[3] The broad variety of abnormalities reported is a clear indication of the need for further research in this area.

Insidious onset of unilateral groin pain is the most commonly reported symptom with injuries of this type. Many patients, however, describe a sudden tearing sensation. The pain usually occurs during exercise, although it can occur at lower activity levels or with coughing and sneezing if the patient undergoes extended training. Physical examination may reveal local tenderness over the conjoined tendon, pubic tubercle, and midinguinal region, or a tender, dilated superficial inguinal ring. In one report, however, more patients had pain with resisted adduction (88%) than had pubic tenderness (22%).[53] Pain with a resisted sit-up is also a common finding.[53] A Valsalva

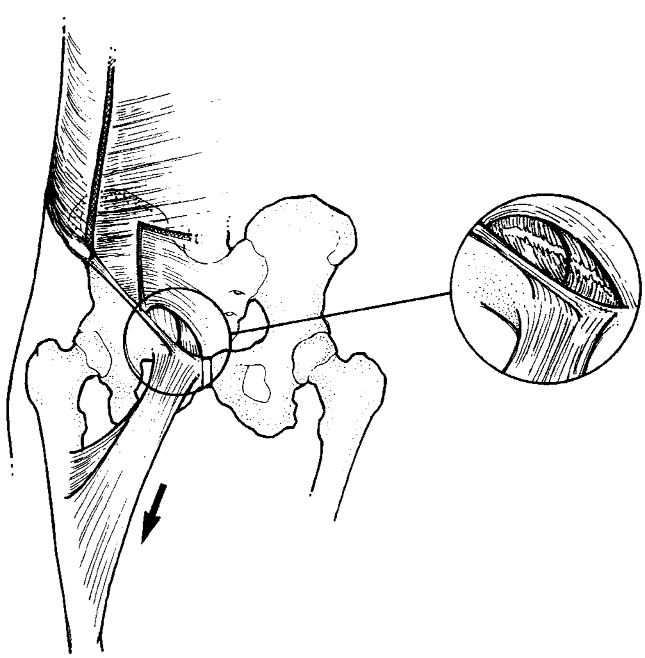

Figure 9. This simplified diagram shows a proposed theory of the mechanism of the sports hernia or "athletic pubalgia." An imbalance exists between the strong adductor muscles (arrow) and the relatively weak lower abdomen. This may lead to attenuation, avulsion, or tearing of structures in the pelvic floor (as shown in the inset).

maneuver may produce pain even without an apparent bulge. Multiple abnormalities may exist concurrently, complicating the physical examination. Plain radiographs and a bone scan can be used to exclude coexisting abnormalities with overlapping symptoms, namely osteitis pubis, adductor tenoperiosteal lesions, symphyseal instability, osteoarthritis, and tumor. Herniography as treatment has regained support in the recent literature.[33,76] An MR image may be useful for detecting abnormalities within the muscles or pubic symphysis.[19] Ultrasonography would theoretically be well suited for diagnosis of this injury, but its accuracy had been debatable and it is operator-dependent.[61] Several reports have suggested that no abnormalities were seen on preoperative imaging.[44,78]

Nonoperative treatment is occasionally effective for groin injuries, but may result in a protracted clinical course. Surgery can be considered if nonoperative treatment fails after 6 to 8 weeks, the history and physical are typical, and particularly if the patient is a high-level athlete.[53] Herniorrhaphy has had reported success with either a conventional or laparoscopic approach.[4,37,78] Frequently, the abdominal wall is reinforced with mesh during these repairs.[47,54] Postoperatively, most athletes return to sports within 6 to 12 weeks after specific rehabilitation targeted at abdominal strengthening, adductor muscle flexibility, and a graduated return to activity.[41,78] Hackney[32] reported that 13 of 15 patients (87%) returned to full sporting activity, and the other 2 had improvement in symptoms. Simonet et al.[72] reported on 10 elite-level hockey players with chronic groin pain and subsequent surgical repair; all of these patients returned to sport. In the largest series to date, Meyers et al.[53] reported a high success rate (97% of 157 patients returned to their previous level of performance) with rectus abdominus muscle reattachment. Forty-four percent of their patients had bilateral procedures. Approximately one-fourth of the patients with unilateral procedures had a concurrent recession of the ipsilateral adductor longus muscle. In light of the potential underlying pelvic imbalance, treatment of a contracted or overdeveloped adductor muscle should not be neglected. Adductor muscle pain should be noted preoperatively and, if present, adductor muscle release or recession combined with herniorrhaphy may be required. However, in one study of 16 patients, adductor tenotomy alone was used for chronic groin pain, with only a 63% rate of return to preinjury activity.[2]

Osteitis Pubis. This entity is believed to be the result of repetitive trauma and is most commonly seen in runners, soccer players, swimmers, and hockey players. Tension from the adductor muscles or rectus abdominus muscles has been implicated. Thus, this injury may appear as a component of or overlap with the sports hernia. Patients will typically complain of pain with kicking, running, jumping, or twisting. Clicking may indicate instability, but this is not a consistent finding. Pain may radiate into the suprapubic area or into the groin. Radiographs may show resorption or sclerosis of bone adjacent to the pubic symphysis (Fig. 10). Instability or symphysis step-off or even sacroiliac joint changes may be seen. Scintigraphy is also diagnostic. Infection, inguinal hernia, and adductor muscle strain are typically included in the differential diagnosis. Treatment usually involves rest and nonsteroidal antiinflammatory medications. Moist heat may relieve pain and spasm. If the athlete does not progress with these measures, one could consider a corticosteroid injection.[35] Once the patient is pain-free, stretching and hip range of motion exercises may be started. The course may be protracted over 3 months and there is occasional recurrence. Adductor tenotomy has also been used for treatment of this condition with moderate success.[2]

Bursitis. Bursitis most commonly occurs at the greater trochanter but an "internal" variety can occur at the iliopsoas tendon. (The latter is discussed in the "Snapping Hip" section.) Women with a wide pelvis or prominent trochanter, or runners who adduct beyond midline are said to be at risk. Also, running on banked surfaces may cause an uneven pelvis and abnormal stress at the trochanter. Patients have focal tenderness or warmth.

Treatment is similar for the various locations of bursitis. Rest, stretching of the involved tendons, and nonsteroidal antiinflammatory medications are the mainstays of conservative treatment. Occasional steroid injection may be useful. The injection of a local anesthetic can also be diagnostic. Refractory cases may require excision of the bursa or lengthening of the involved tendons, which can usually be done without significant functional deficit.[39]

Snapping Hip Syndrome. Commonly seen in distance runners, "snapping hip syndrome" is a term used to describe two different entities. The more common external variety occurs as the iliotibial band snaps over the greater trochanter with hip flexion and extension. Hip adduction and knee extension will tighten the iliotibial band and accentuate the snapping sensation. When this condition is painful or causes trochanteric bursitis, treatment involves rest, iliotibial band stretching, nonsteroidal antiinflammatory medications, and, occasionally, steroid injections. For refractory cases, multiple surgical procedures such as

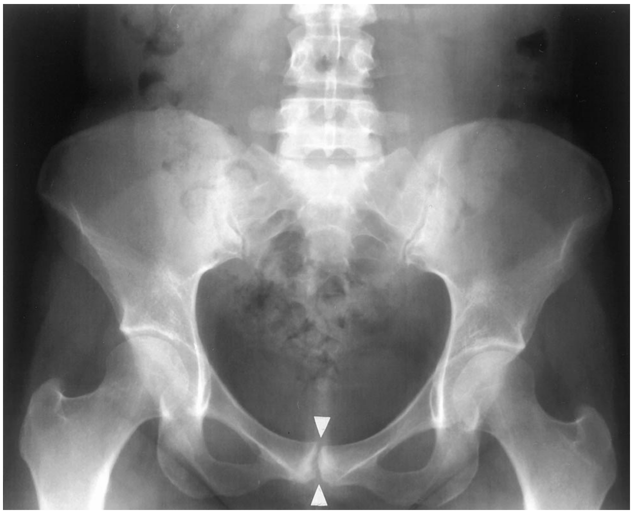

Figure 10. An AP pelvic radiograph of a patient with osteitis pubis in the healing phase. Note the sclerosis (arrowheads) adjacent to the pubic symphysis.

excision of all or part of the iliotibial band, Z-plasty, or fixation of the iliotibial band to the greater trochanter are described.

The internal variety of bursitis is caused by the iliopsoas tendon catching on the pelvic brim (iliopectineal eminence) or the femoral head. This occurs as the hip is extended and the tendon travels from a relative anterolateral position to a more posteromedial position. This can also be associated with chronic bursitis and is treated similarly, primarily with activity modification and stretching. Ultrasonography during hip motion may demonstrate the tendon subluxation.[38] Bursography can also demonstrate this phenomenon but is rarely necessary. Again, persistent cases may be treated with surgical tendon lengthening.[39]

Stress Fractures. These fractures usually occur in serious endurance athletes or military recruits and are more common in women athletes, especially runners. Stress injuries involving the hip and pelvis are not uncommon and may be part of a triad with eating disorders and irregular menses. There is significant variability in the reported percentage of stress fractures that occur in the hip region (1.25% to 18%).[45,50] Despite these relatively low percentages, an index of suspicion must be maintained because of the potential consequences of missed or delayed diagnosis.[40] These injuries are often the result of training errors. Increases in training distance should not exceed 10% per week. Some authors believe that injury occurs as a result of muscle forces, which magnify the loading that occurs simply from weightbearing on the affected part.[75] Athletes will often have pain with axial loading or with standing or hopping on the involved leg. Typically, the athlete develops an insidious onset of pain to the point of inability to run. Imaging usually involves scintography or MRI, as radiographs are often negative; CT may demonstrate sclerosis and subtle displacement. Femoral neck stress fractures are often classified as tension side (superior) versus compression side (inferior), with the contention that the tension fractures are unstable and have a poor prognosis.[24]

Treatment of stress fractures may consist initially of rest for stable, compression-side fractures. Nonimpact activities can begin once the patient has become pain-free. Jogging should be avoided for 4 to 6 weeks to allow for fracture healing. Close observation is mandatory because of the possibility of an unappreciated tension-side fracture (Fig. 11). Displacement can lead to disastrous consequences, with a complication rate of up to 50%. These complications include osteonecrosis, refractures, and pseudarthroses.[40] Most authors agree that tension-side or transverse fractures should be treated with surgical fixation. Compression fractures that do not respond to rest may also require surgical fixation. Elite athletes have consistently had decreased performance levels after these fractures. Femoral shaft stress fractures are also not uncommon. Initial symptoms often include anterior thigh pain that increases with activity in an endurance athlete.[50]

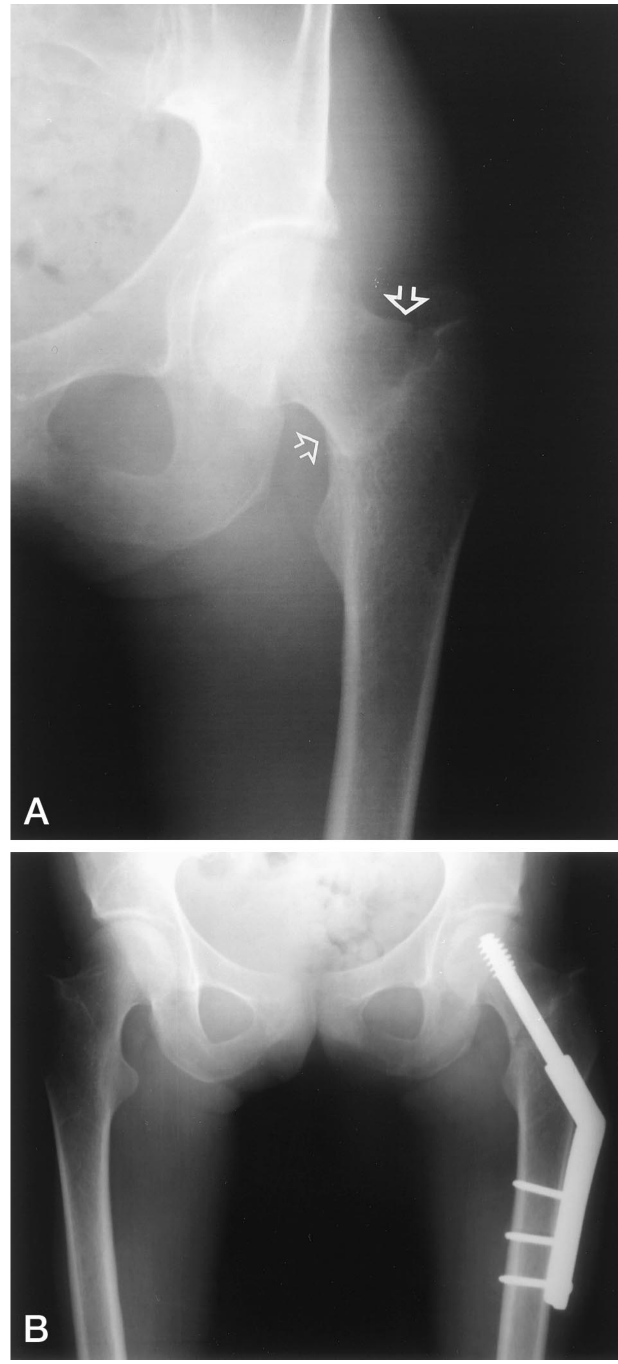

Figure 11. A, AP view of the left hip in a 25-year-old female distance runner with a stress fracture that went on to displace (arrows). B, this unstable fracture was treated with a dynamic hip screw with sideplate.

Osteoarthritis. The seemingly age-old debate as to whether sports participation predisposes a person to osteoarthritis or actually protects against it has not been clearly solved. The generally held belief is that regular, moderate activity is beneficial, and excessive loading, particularly with an underlying injury or abnormality, accelerates the degenerative process. Despite the enormous impact of osteoarthritis on our society, there are relatively little scientific data available on this issue. In a canine model, long-term exercise did not lead to degenerative joint disease.[60] Repetitive microtrauma to the articular cartilage and subchondral bone has been proposed as a mechanism. Elite athletes have been shown to have more radiographic changes of osteoarthritis than do matched controls.[49] In an analysis of patients who underwent total hip arthroplasty, patients with high exposure to sports, particularly when combined with jobs that require much physical endurance, had a greatly increased relative risk of osteoarthritis.[81]

Fortunately, for most active patients who have mild osteoarthritis, the condition can be controlled with nonoperative treatment. Range of motion exercises are an important component of early management. In addition, the introduction of cyclooxygenase-2 enzyme (COX-2)-specific nonsteroidal antiinflammatory medications may allow long-term medication use in some patients without adverse gastrointestinal effects. Preliminary evidence suggests that glucosamine and chondroitin sulfate may be effective for pain relief of osteoarthritis in the knee.[46] Larger, long-term studies are needed to determine the safety and efficacy of these supplements. The role of arthroscopy in the treatment of osteoarthritis is evolving. Arthroscopic debridement and loose body removal are being performed with increasing frequency.

Other Sources of Groin or Pelvic Pain. Referred pain from lower lumbar and sacral nerves frequently causes gluteal or posterior thigh symptoms. Facet joint and erector spinae muscle abnormalities may also be referred in this distribution. The upper lumbar nerves (L1–3) travel anteriorly and may be the source of groin or thigh pain. The femoral nerve stretch test causes anterior pain. A side stretch may also elicit pain. In adults, physical examination and thorough neurologic assessment may be sufficient to identify spinal abnormalities. It has been reported that sports involvement does not increase the risk of lumbar disc disease, but may, in fact, be protective.[59]

Cyclists can develop a pudendal neuropathy that can cause groin pain and numbness.[82] Activity and equipment modification can resolve the problem. The probable cause of pudendal neuropathy is compression of the dorsal branch of the pudendal nerve between the symphysis pubis and the bicycle seat, resulting in a temporary ischemic insult to the nerve. The genital branch of the genitofemoral nerve may also be involved, particularly when scrotal anesthesia is present. Treatment and prevention of bicycle-related pudendal or genitofemoral neuropathy involves repositioning the bicycle seat so that it does not tilt upward. Sometimes the problem can be resolved by changing to a different seat, modifying the seat, or using padded bicycle pants.

Obturator nerve entrapment is described in skaters due to adductor muscle development. Meralgia paraesthetica is a condition in which the lateral femoral cutaneous nerve is compressed by belts, pads, blunt trauma, or prolonged hip flexion. Pain and paresthesia over the anterolateral thigh with absence of motor findings fit the characteristic presentation. Sensory loss on the anterolateral thigh and a positive Tinel's sign over the nerve are diagnostic. Treatment involves simple removal of the offending compressing agent with occasional stretching and antiinflammatory medications. Occasionally, the local use of injected antiinflammatory agents can be helpful. Surgical decompression is described and successful, but is rarely necessary.

Compression of the sciatic nerve occurs near either the piriform or hamstring muscles (Fig. 2). In both cases, radiculopathy must be ruled out. Patients with piriform muscle syndrome have pain with sitting or with internal rotation of the hip. Patients with hamstring muscle syndrome have symptoms in a lower distribution and mainly with hamstring muscle stretch. Both syndromes can be treated conservatively most often but, if needed, decompression is successful.

Slipped capital femoral epiphysis is a fairly common disorder in adolescence that may be precipitated during sports participation. This is most commonly seen in African Americans or obese children and is associated with hormonal imbalances such as hypothyroidism. Patients will often have hip or groin pain, or symptoms may be referred to the knee joint. Internal rotation is limited because the femoral neck is usually externally rotated and is positioned anterior to the femoral head. Radiographs are graded on percent slippage of the epiphysis relative to the superior aspect of the femoral neck. Most authors now advocate a single anteroposterior percutaneous screw for fixation of acute and chronic slips.

SUMMARY

Injuries to structures about the hip joint occur despite the fact that these structures are well adapted to withstand forces of up to several times body weight. Information is slowly increasing regarding intraarticular hip abnormalities as well as the many complex soft tissue injuries about the pelvis. This increasing body of knowledge spans the expertise of several medical specialties and reinforces the need for a multidisciplinary approach to these athletic injuries. The osseous and soft tissue conditions briefly summarized in this article represent those most commonly considered in the differential diagnosis of hip pain in athletes.

REFERENCES

1. Afra R, Boardman DL, Kabo JM, et al: Avulsion fracture of the lesser trochanter as a result of a preliminary malignant tumor of bone. A report of four cases. *J Bone Joint Surg 81A:* 1299–1304, 1999
2. Åkermark C, Johansson C: Tenotomy of the adductor longus tendon in the treatment of chronic groin pain in athletes. *Am J Sports Med 20:* 640–643, 1992
3. Akita K, Niga S, Yamato Y, et al: Anatomic basis of chronic groin pain with special reference to sports hernia. *Surg Radiol Anat 21:* 1–5, 1999
4. Azurin DJ, Go LS, Schuricht A, et al: Endoscopic preperitoneal herniorrhaphy in professional athletes with groin pain. *J Laparoendosc Adv Surg Tech A 7:* 7–12, 1997
5. Bergmann G, Graichen F, Rohlmann A: Hip joint loading during walking and running, measured in two patients. *J Biomech 26:* 969–990, 1993
6. Bouchardy L, Garcia J: Magnetic resonance imaging in the diagnosis of myositis ossificans circumscripta [in French]. *J Radiol 75:* 101–110, 1994
7. Brand RA, Pedersen DR, Davy DT, et al: Comparison of hip force calculations and measurements in the same patient. *J Arthroplasty 9:* 45–51, 1994

8. Buly R, Padgett D, Sherman P, et al: The diagnosis of labral and chondral injuries of the hip by high resolution magnetic resonance imaging (MRI) scanning: Correlation with surgical findings. *Orthop Trans 22:* 133, 1998–1999
9. Byrd JWT: Labral lesions: An elusive source of hip pain. Case reports and literature review [current concepts]. *Arthroscopy 12:* 603–612, 1996
10. Byrd JWT, Pappas JN, Pedley MJ: Hip arthroscopy: An anatomic study of portal placement and relationship to the extra-articular structures. *Arthroscopy 11:* 418–423, 1995
11. 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 19:* 322–324, 1991
12. Cotten A, Boutry N, Demondion X, et al: Acetabular labrum: MRI in asymptomatic volunteers. *J Comput Assist Tomogr 22:* 1–7, 1998
13. Crowninshield RD, Johnston RC, Andrews JG, et al: A biomechanical investigation of the human hip. *J Biomech 11:* 75–85, 1978
14. Czerny C, Hofmann S, Newhold A, et al: Lesions of the acetabular labrum: Accuracy of MR imaging and MR arthrography in detection and staging. *Radiology 200:* 225–230, 1996
15. DeLee JC, Farney WC: Incidence of injury in Texas high school football. *Am J Sports Med 20:* 575–580, 1992
16. DiCesare PE, Nimni ME, Peng L, et al: Effects of indomethacin on demineralized bone-induced heterotopic ossification in the rat. *J Orthop Res 9:* 855–861, 1991
17. Dorrell JH, Catterall A: The torn acetabular labrum. *J Bone Joint Surg 68B:* 400–403, 1986
18. Edwards DJ, Lomas D, Villar RN: Diagnosis of the painful hip by magnetic resonance imaging and arthroscopy. *J Bone Joint Surg 77B:* 374–376, 1995
19. Ekberg O, Sjoberg S, Westlin N: Sports-related groin pain: Evaluation with MR imaging. *Eur Radiol 6:* 52–55, 1996
20. Emery CA, Meeuwisse WH, Powell JW: Groin and abdominal strain injuries in the National Hockey League. *Clin J Sport Med 9:* 151–156, 1999
21. Farjo LA, Glick JM, Sampson TG: Hip arthroscopy for acetabular labral tears. *Arthroscopy 15:* 132–137, 1999
22. Fitzgerald RH Jr: Acetabular labrum tears: Diagnosis and treatment. *Clin Orthop 311:* 60–68, 1995
23. Frost A, Bauer M: Skier's hip—A new clinical entity? Proximal femur fractures sustained in cross-country skiing. *J Orthop Trauma 5:* 47–50, 1991
24. Fullerton LR, Snowdy HA: Femoral neck stress fractures. *Am J Sports Med 16:* 365–377, 1988
25. Funke EL, Munzinger U: Complications in hip arthroscopy. *Arthroscopy 12:* 156–159, 1996
26. Fuss FK, Bacher A: New aspects of the morphology and function of the human hip joint ligaments. *Am J Anat 192:* 1–13, 1991
27. Garrett WE Jr: Muscle strain injuries. *Am J Sports Med 24 (Suppl):* S2–S8, 1996
28. Garrett WE Jr, Nikolaou PK, Ribbeck BM, et al: The effect of muscle architecture on the biomechanical failure properties of skeletal muscle under passive extension. *Am J Sports Med 16:* 7–12, 1988
29. Gilmore J: Groin pain in the soccer athlete: Fact, fiction, and treatment. *Clin Sports Med 17:* 787–793, 1998
30. Gomez E, DeLee JC, Farney WC: Incidence of injury in Texas girls' high school basketball. *Am J Sports Med 24:* 684–687, 1996
31. Green JP: Proximal avulsion of the iliacus with paralysis of the femoral nerve: Report of a case. *J Bone Joint Surg 54B:* 154–156, 1972
32. Hackney RG: The sports hernia: A cause of chronic groin pain. *Br J Sports Med 27:* 58–62, 1993
33. Hamlin JA, Kahn AM: Herniography: A review of 333 herniograms. *Am Surg 64:* 965–969, 1998
34. Hase T, Ueo T: Acetabular labral tear: Arthroscopic diagnosis and treatment. *Arthroscopy 15:* 138–141, 1999
35. Holt MA, Keene JS, Graf BK, et al: Treatment of osteitis pubis in athletes. Results of corticosteroid injections. *Am J Sports Med 23:* 601–606, 1995
36. Ikeda T, Awaya G, Suzuki S, et al: Torn acetabular labrum in young patients. Arthroscopic diagnosis and management. *J Bone Joint Surg 70B:* 13–16, 1988
37. Ingoldby CJ: Laparoscopic and conventional repair of groin disruption in sportsmen. *Br J Surg 84:* 213–215, 1997
38. Jacobson T, Allen WC: Surgical correction of the snapping iliopsoas tendon. *Am J Sports Med 18:* 470–474, 1990
39. Janzen DL, Partridge E, Logan PM, et al: The snapping hip: Clinical and imaging findings in transient subluxation of the iliopsoas tendon. *Can Assoc Radiol J 47:* 202–208, 1996
40. Johansson C, Ekenman I, Törnkvist H, et al: Stress fractures of the femoral neck in athletes. The consequence of a delay in diagnosis. *Am J Sports Med 18:* 524–528, 1990
41. Kemp S, Batt M: The "sports hernia": A common cause of groin pain. *Physician Sportsmed 26(1):* 36–44, 1998
42. Khoury JG, Brandser EA, Found EM Jr, et al: Non-traumatic lesser trochanter avulsion: A report of three cases. *Iowa Orthop J 18:* 150–154, 1998
43. Kujala UM, Orava S, Karpakka J, et al: Ischial tuberosity apophysitis and avulsion among athletes. *Int J Sports Med 18:* 149–155, 1997
44. Lacroix VJ, Kinnear DG, Mulder DS, et al: Lower abdominal pain syndrome in National Hockey League players: A report of 11 cases. *Clin J Sport Med 8:* 5–9, 1998
45. Latshaw RF, Kantner TR, Kalenak A, et al: A pelvic stress fracture in a female jogger. *Am J Sports Med 9:* 54–56, 1981
46. Leffler CT, Philippi AF, Leffler SG, et al: Glucosamine, chondroitin, and manganese ascorbate for degenerative joint disease of the knee or low back: A randomized, double-blind, placebo-controlled pilot study. *Mil Med 164:* 85–91, 1999
47. Leibl BJ, Schmedt CG, Kraft K, et al: Recurrence after endoscopic transperitoneal hernia repair (TAPP): Causes, reparative techniques, and results of the reoperation. *J Am Coll Surg 190:* 651–655, 2000
48. Leinonen V, Kankaanpaa M, Airaksinen O, et al: Back and hip extensor activities during trunk flexion/extension: Effects of low back pain and rehabilitation. *Arch Phys Med Rehabil 81:* 32–37, 2000
49. Marti B, Knobloch M, Tschopp A, et al: Is excessive running predictive of degenerative hip disease? Controlled study of former elite athletes. *BMJ 299:* 91–93, 1989
50. McBryde AM Jr: Stress fractures in runners. *Clin Sports Med 4:* 737–752, 1985
51. McCarthy JC, Busconi B: The role of hip arthroscopy in the diagnosis and treatment of hip disease. *Orthopedics 18:* 753–756, 1995
52. Metzmaker JN, Pappas AM: Avulsion fractures of the pelvis. *Am J Sports Med 13:* 349–358, 1985
53. Meyers WC, Foley DP, Garrett WE, et al: Management of severe lower abdominal or inguinal pain in high-performance athletes. *Am J Sports Med 28:* 2–8, 2000
54. Miguel PR, Reusch M, daRosa AL, et al: Laparoscopic hernia repair-complications. *J Soc Laparoendosc Surg 2:* 35–40, 1998
55. Mishra DK, Fridén J, Schmitz MC, et al: Anti-inflammatory medication after muscle injury: A treatment resulting in short-term improvement but subsequent loss of muscle function. *J Bone Joint Surg 77A:* 1510–1519, 1995
56. Moed BR, Resnick RB, Fakhouri AJ, et al: Effect of two nonsteroidal antiinflammatory drugs on heterotopic bone formation in a rabbit model. *J Arthroplasty 9:* 81–87, 1994
57. Montgomery WH III, Pink M, Perry J: Electromyographic analysis of hip and knee musculature during running. *Am J Sports Med 22:* 272–278, 1994
58. Mozes M, Papa MZ, Zweig A, et al: Iliopsoas injury in soccer players. *Br J Sports Med 19:* 168–170, 1985
59. Mundt DJ, Kelsey JL, Golden AL, et al: An epidemiologic study of sports and weight lifting as possible risk factors for herniated lumbar and cervical discs. *Am J Sports Med 21:* 854–860, 1993
60. Newton PM, Mow VC, Gardner TR, et al: The effect of lifelong exercise on canine articular cartilage. *Am J Sports Med 25:* 282–287, 1997
61. 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 32:* 134–139, 1998
62. Palmer WE, Kuong SJ, Elmadbouh HM: MR imaging of myotendinous strain. *AJR Am J Roentgenol 173:* 703–709, 1999
63. Pink M, Perry J, Houglum PA, et al: Lower extremity range of motion in the recreational sport runner. *Am J Sports Med 22:* 541–549, 1994
64. Pomeranz SJ, Heidt RS Jr: MR imaging in the prognostication of hamstring injury. *Radiology 189:* 897–900, 1993
65. Quarrier NF, Wightman AB: A ballet dancer with chronic hip pain due to a lesser trochanter bony avulsion: The challenge of a differential diagnosis. *J Orthop Sports Phys Ther 28:* 168–173, 1998
66. Renstrom P: Swedish research in sports traumatology. *Clin Orthop 191:* 144–158, 1984
67. Ryan JB, Wheeler JH, Hopkinson WJ, et al: Quadriceps contusions. West Point update. *Am J Sports Med 19:* 299–304, 1991
68. Sallay PI, Friedman RL, Coogan PG, et al: Hamstring muscle injuries among water skiers. Functional outcome and prevention. *Am J Sports Med 24:* 130–136, 1996
69. Salminen JJ, Maki P, Oksanen A, et al: Spinal mobility and trunk muscle strength in 15-year-old schoolchildren with and without low-back pain. *Spine 17:* 405–411, 1992
70. Schneider R, Kaye JJ, Ghelman B: Adductor avulsive injuries near the symphysis pubis. *Radiology 120:* 567–569, 1976
71. Scudese VA: Traumatic anterior hip redislocation. A case report. *Clin Orthop 88:* 60–63, 1972
72. Simonet WT, Saylor HL III, Sim L: Abdominal wall muscle tears in hockey players. *Int J Sports Med 16:* 126–128, 1995
73. Sparto PJ, Parnianpour M, Reinsel TE, et al: The effect of fatigue on multijoint kinematics, coordination, and postural stability during a repetitive lifting test. *J Orthop Sports Phys Ther 25:* 3–12, 1997

74. Spinner RJ, Atkinson JL, Wenger DE, et al: Tardy sciatic nerve palsy following apophyseal avulsion fracture of the ischial tuberosity. Case report. *J Neurosurg 89:* 819–821, 1998
75. Stanitski CL, McMaster JH, Scranton PE: On the nature of stress fractures. *Am J Sports Med 6:* 391–396, 1978
76. Sutcliffe JR, Taylor OM, Ambrose NS, et al: The use, value and safety of herniography. *Clin Radiol 54:* 468–472, 1999
77. Suzuki S, Awaya G, Okada Y, et al: Arthroscopic diagnosis of ruptured acetabular labrum. *Acta Orthop Scand 57:* 513–515, 1986
78. Taylor DC, Meyers WC, Moylan JA, et al: Abdominal musculature abnormalities as a cause of groin pain in athletes. Inguinal hernias and pubalgia. *Am J Sports Med 19:* 239–242, 1991
79. Tidball JG, Salem G, Zernicke R: Site and mechanical conditions for failure of skeletal muscle in experimental strain injuries. *J Appl Physiol 74:* 1280–1286, 1993
80. Tyler T, Zook L, Brittis D, et al: A new pelvic tilt detection device: Roentgenographic validation and application to assessment of hip motion in professional ice hockey players. *J Orthop Sports Phys Ther 24:* 303–308, 1996
81. Vingård E, Alfredsson L, Goldie I, et al: Sports and osteoarthritis of the hip. An epidemiologic study. *Am J Sports Med 21:* 195–200, 1993
82. Weiss BD: Clinical syndromes associated with bicycle seats. *Clin Sports Med 13:* 175–186, 1994
83. Wertheimer LG, Lopes SD: Arterial supply of the femoral head: A combined angiographic and histological study. *J Bone Joint Surg 53A:* 545–556, 1971
84. Wootton JR, Cross MJ, Holt KW: Avulsion of the ischial apophysis. The case for open reduction and internal fixation. *J Bone Joint Surg 72B:* 625–627, 1990