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Hip Injuries in Overhead Athletes

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Hip injuries in the overhead athlete have attracted little attention in the past; however, hip and groin injuries make up 5.5% of all professional baseball injuries and continue to increase in prevalence. Hip and groin injuries are exacerbated by the repetitive extremes of motion required for throwing, serving, and spiking a ball as well as the rapid acceleration and deceleration involved in overhead athletics. The diagnosis and management of these injuries in overhead athletes can be challenging, and often involves multiple pain sources. These athletes commonly experience adductor strains and athletic pubalgia/core muscle injuries which often occur concurrently with underlying bony pathology such as femoroacetabular impingement, which leads to limitations in hip range-of-motion. Hip and groin injuries in the overhead athlete can be debilitating and recurring; therefore, accurate and prompt diagnosis and management of these injuries are critical.
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Introduction

Hip injuries in the overhead athlete have become increasingly recognized and clinical research efforts have focused on diagnosis, treatment, rehabilitation as well as prevention strategies. It is well known that the overhead athlete is at risk for shoulder and elbow injuries;[1,2] however, the biomechanics involved during overhead sports can also place them at risk for hip injuries. The incidence of hip and groin injuries is increasing in this population with up to 5.5% of all major and minor league baseball injuries from 2011-2014.[3] These injuries can present as contusions, muscle strains, hip instability, osteitis pubis, athletic pubalgia, labral tears, and chondral defects with the latter 2 associated with femoroacetabular impingement (FAI).[1,2,4-6]

The importance of hip biomechanics in the kinetic chain during overhead activities has been a very relevant topic amongst sports medicine specialists.[7-9] To accomplish the overhead motion of throwing a baseball, spiking a volleyball, and serving a tennis ball, athletes must utilize the entire kinetic chain to harness a complex transfer of energy. In these athletes, hip mobility is integral to achieving trunk rotation as well as transferring power from the lower extremities through the core and trunk to the upper extremity.[7] Decreased range of motion in the hip, such as with FAI, puts the overhead athlete at risk for both intra- and extra-articular injuries.[9,10] Both injury types may lead to decreased performance and disruption of the normal kinetic chain posing additional risk to the upper extremity, most notably the shoulder and elbow.[7,10-13] This highlights the importance of identifying hip pathology early in the overhead athlete as it can manifest into issues with throwing, swinging, hitting, and practically any overhead or upper extremity motion which drives its power from the kinetic chain.[7]

The ability to diagnose and treat hip injuries in overhead athletes has greatly improved due an increased awareness of athletic hip conditions, advances in diagnostic imaging, and cutting edge research tools focused on improving our understanding of hip biomechanics which directly impacts both nonoperative and operative treatment strategies. Fortunately, these injuries have good outcomes with high rates of return

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to play regardless if they are managed operatively or nonoperatively.[4-6,14-18] Some overhead athletes may fall victim to significant disability, including recurrence of their injury pattern, which is why proper diagnosis and treatment is paramount in addition to trying to avoid injury all together through prevention strategies and programs.[19] This review will discuss hip biomechanics, common hip and groin injuries in overhead athletes, the clinical and radiographic approach to diagnosis, treatment options, and outcomes of these injuries.

Hip Biomechanics in Overhead Athletes

The functional demands of overhead sports on athletes may put them at risk for hip injuries. Sports requiring high axial torsional forces through the hips can predispose these athletes to intra-articular and extra-articular hip injuries.[16] Throughout different phases of overhead activities, extra-articular muscles can be compromised and the hip joint can be susceptible to impingement and put the labrum and articular cartilage at risk for injury.

In the overhead thrower, forward momentum begins with a wind-up phase, where the athlete moves their lead leg through open-chain flexion, adduction-internal rotation to flexion abduction-external rotation in the direction of the target (Fig. 1A and B). During this phase, the athlete is at risk for anterior-superior labral impingement in the presence of FAI. During the wind-up and early-cocking phase, hip abduction strength in the trail leg is required to stabilize the pelvis and lengthen the forward stride. During the forward stride, the lead and trail hips abduct and externally rotate, creating the risk of posterior-superior impingement (Fig. 2). Proper lead leg position when the foot is planted allows for optimal rotation of the hips, pelvis, and trunk. Greater stride distances create more hip abduction and increases the risk of lateral rim impingement. During the acceleration phase the pelvis rotates forward and the lead hip internally rotates, adducts, and flexes predisposing the lead hip to anterior-superior impingement (Fig. 3). The back hip continues to externally rotate, abduct, and extend, putting this hip at risk of anterior rotational instability and posterior impingement as the femoral head-neck junction engages the posterior rim of the acetabulum.[3,9,20]

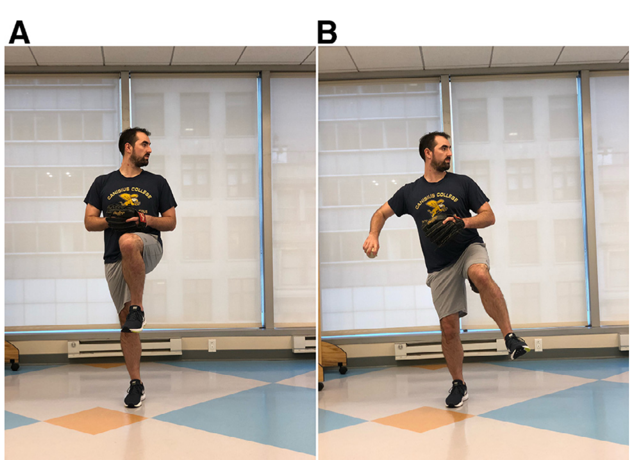

Figure 1 Wind up phase for the baseball thrower, including (A) open chain flexion and (B) rotation in the direction of the target. (Color version of figure is available online.)

Figure 2 Forward stride phase. The lead and trail hips abduct and externally rotate. (Color version of figure is available online.)

Tennis players also utilize their kinetic chain for power during serves, overhead shots, and groundstrokes.[7,8,21] Studies have demonstrated that the tennis serve is the most powerful and strenuous overhead stroke, which includes 5 phases: (1) wind-up, involving knee flexion, and trunk rotation; (2) early and (3) late cocking involving lateral pelvic tilt, hyperextension and lateral flexion of the spine, and abduction of the shoulder; (4) acceleration involving forceful trunk rotation and shoulder internal rotation and; (5) follow-through, involving landing on the lead leg which flexes, adducts and internally rotates at the hip.[21-23] For perspective, the lower extremity and trunk produce about half of the total kinetic energy during a tennis serve.[11] During a tennis forehand stroke, athletes require a great degree of external rotation increasing the risk of these injuries. The final phase is the follow-through, where body weight is transferred to the lead leg as the hip flexes, internally rotates, and adducts. This is another combination of biomechanical forces and rotations that places the lead hip at risk for anterior-superior impingement.

Similarly, volleyball requires high axial loads with jump serves and spikes as well as quick changes in direction.

Figure 3 Acceleration phase. The thrower's pelvis rotates, while the lead hip internally rotates adducts and flexes. (Color version of figure is available online.)

The volleyball spike and serve can be broken up into 4 phases: (1) approach; (2) arm cocking; (3) arm acceleration and; (4) follow-through.[24] Key events include the takeoff, where hips move from flexion to extension during the jump, maximum upper extremity external rotation, ball contact, and then landing where hips move from extension to flexion and absorb a high axial load on ground impact. During arm cocking and acceleration, the pelvis rotates opposite to the dominant arm to maintain hips that are square to the net.

Extra-articular Hip Pathologies

Adductor Strains

Adductor strains are the most common groin injury in athletes and account for 40.8% of hip and groin injuries in professional baseball players.[20] These injuries may involve the adductor longus, magnus and brevis as well as pectineus, gracilis, and obturator externus. Of these, the adductor longus is the most frequently injured muscle.[25] Strains within the adductor compartment tend to occur when an athlete is quickly changing direction which results in an eccentric contraction of the adductors with the hip in hyperabduction and hyperextension.[25] Tennis players are also at risk of developing these injuries due to sudden lateral movements involving acceleration and deceleration. Adductor strains have been shown to account for 25% of all acute tennis injuries within the elite junior tennis player population.[26]

Figure 4 Palpation of the adductor muscle. Athletes with adductor strains may have pain with palpation. (Color version of figure is available online.)

Adductor strains should be suspected in baseball and tennis players who present with acute-onset medial thigh or groin pain that is exacerbated by sudden movements and changes in direction. These injuries are usually diagnosed by patient history and physical examination, which may include focal areas of swelling or ecchymosis. These athletes may be tender to palpation at the origin of the muscle or within the muscle belly itself. Pain with resisted adduction and passive stretch into abduction should also heighten your clinical suspicion for an adductor strain. Palpation of the adductors should be performed with the patient supine and in a figure-four position (Fig. 4). Resisted adduction can also be performed with the patient supine and knees and hips brought into flexion (Fig. 5). Typically, positive findings include reproduction of pain near the origin of the muscle when adducting the legs against resistance.[27]

Clinical examination of the hip/leg should be sufficient for making an adductor strain diagnosis; however, if uncertainty remains or the player is a high-level athlete magnetic resonance imaging (MRI) is warranted. MRI has the ability to determine the final diagnosis which includes distinguishing between partial versus complete tendon disruptions.[28] Of note, the most common site of injury is the musculotendinous junction of the adductor longus.[28,29]

There is a high incidence of recurrent symptoms following adductor strains, which is likely due to an incomplete rehabilitation. Nonsurgical management consists of rest, ice, nonsteroidal anti-inflammatory medication, as well as physical therapy consisting of active eccentric resistance exercises and mobility maneuvers. Proper assessment following rehabilitation is important for determining return to play and hopefully minimizes the chances of reinjury. This includes an evaluation of adductor strength, hip range of motion, and core muscle strength as deficiencies in any of these areas pose an increased risk of reinjury.[28,29] Athletes can return to play when they have regained 70% of their strength and

Figure 5 Individuals with adductor muscle strains may have pain with resisted adduction. (Color version of figure is available online.)

pain-free full range of motion.[25] After a treatment program involving strengthening of the adductors and pelvic-stabilizing muscles, 67% of athletes returned to sports without pain within 12 weeks and 79% returned to sport overall.[30]

Surgery is rarely indicated and limited to cases of recalcitrant pain and disability despite nonsurgical management. Surgical techniques involve open or percutaneous adductor longus tenotomy and selective partial adductor longus release.[29-32] Open adductor longus tenotomy is effective in improving symptoms, however 1 study found that only 63% of athletes were able to return to preinjury level of competition following this intervention.[32] Percutaneous adductor longus tenotomy has demonstrated similar results with 54%-68% of athletes returning to preinjury level.[29] Selective partial adductor longus release in professional athletes with chronic adductor-related groin pain has shown promise, with significant improvement in visual analogue score (VAS) and 42 of 43 (97.7%) athletes returning to their preinjury level of sport in an average of 9.2 weeks.[30] This technique involves making a transverse incision 2-4 cm distal to the origin of the adductor longus tendon and releasing the superficial fibers that are under the greatest tension.[30] Adverse effects of tenotomy include adductor strength deficits and persistence of pain. Complications reported include bruising, scrotal hematoma, superficial would infection, and recurrent symptoms.[29-32]

Athletic Pubalgia

Athletic pubalgia, also known as sports hernia or core muscle injury, is an injury to the soft tissues of the lower abdominal or posterior inguinal wall.[27] The cause of this injury has gained widespread attention and is associated with repetitive trunk hyperextension and thigh hyper-abduction which leads to shearing at the pubic symphysis and stress on the inguinal musculature. This shearing is exacerbated by a muscular imbalance between strong proximal thigh muscles and weaker abdominal muscles.[27] It is often associated with weakness or deficiency of the posterior inguinal wall. This is relatively common in male overhead athletes due to trunk extension and rotation involved in overhead throwing, serving, hitting, and spiking. Baseball pitchers and batters are subject to an increased risk of core muscle injury, with athletic pubalgia making up 1.8% of all extra-articular hip and groin injuries in professional baseball players.[3] Athletic pubalgia is usually insidious in onset and has been shown to be the primary diagnosis in up to 50% of athletes suffering from chronic groin pain.[33]

For many years this has been a difficult diagnosis to make given the anatomy within this region leading to a broad differential diagnosis including intra-abdominal disorders, inguinal hernia, urogenital disorders, lumbar spine disease, intra-articular hip pathology, and muscular strains among others to consider.[34,35] The natural history of these disorders includes a prolonged course and work-up before a correct diagnosis is determined. The clinical presentation may include an increasing insidious pain in the lower abdominal and proximal adductor musculature during sports. The pain is often unilateral involving the deep groin or abdominal pain radiating toward the perineum and proximal thigh that is aggravated by sudden forceful movements such as sprints, sit-ups, coughing, or sneezing and is improved with rest.[36] Athletes often complain that they are not performing up to their usual potential. Tennis players will report that the pain is the worst during service motion and is classically on the opposite side from their serving arm.[37] In volleyball, spiking the ball may recreate the pain and in baseball activities that exacerbate the symptoms include batting and pitching.

On physical examination, athletes often have tenderness to palpation along the pubic tubercle, obliques, or rectus abdominis insertion. Their pain may also be reproduced by palpation over the conjoined tendon or mid-inguinal region as well as a tender, dilated superficial inguinal ring with tenderness of the posterior wall of the inguinal canal (Fig. 6).[35] These athletes may also have focal pain at the adductor longus origin which can make this a difficult diagnosis to dis-

Figure 6 Palpation of the rectus muscles may elicit pain in patients presenting with athletic pubalgia. (Color version of figure is available online.)

Figure 7 Athletes with athletic pubalgia will likely have pain with resisted sit-ups. (Color version of figure is available online.)

cern from adductor strains. Additionally, resisted hip adduction will cause pain in 88% of patients with athletic pubalgia.[36] Resisted sit-ups can help differentiate between athletic pubalgia and other diagnoses (Fig. 7). This test is positive if the patient experiences pain at the inferolateral edge of the distal rectus abdominis.[27]

Radiography and advanced imaging is useful for ruling out other diagnoses and can help aid in proper diagnosis of athletic pubalgia. Plain radiographs of the hips, pelvis, and lumbosacral spine can be useful in ruling out pathology that can cause similar symptoms such as FAI, osteoarthritis of the hip, sacroiliac joint arthropathy, osteitis pubis, and degenerative disk disease. Advanced imaging with MRI can be useful in differentiating athletic pubalgia from osteitis pubis and stress fractures that are not appreciated on plain radiographs. In cases of athletic pubalgia, MRI typically demonstrates abnormalities in the musculofascial layers of the abdominal wall that have been shown to correlate with surgical findings of athletic pubalgia.[38] There also may be increased signal within the pubic bones, pubic symphysis, or within one or more groin muscles such as the rectus abdominus, pectineus, or adductors.[38] Dynamic ultrasound has shown some promising use in diagnosing athletic pubalgia, but it is very user dependent. Using a high-frequency transducer, a distinct protrusion of the transversalis fascia while the patient performs a Valsalva maneuver has been correlated to surgical findings of athletic pubalgia.[39]

Nonoperative management is the most common form of treatment but rarely successful in reducing symptoms of athletic pubalgia.[34-36] Initial treatment involves anti-inflammatory medication, activity modification, and physical therapy to strengthen the core muscles and correct the muscular imbalance of hip and pelvic stabilizers.[34] A study involving Australian Rules football players demonstrated an 89% return to sport following conservative management of sports hernias which consisted of 3 months of rest and physical therapy. Unfortunately, 59% of these athletes continued to have symptoms of chronic groin pain.[40]

Surgical treatment can be considered after 8-12 weeks of failed conservative management and alternative diagnoses have been excluded; however, seasonal timing in elite athletes will also play a role in the timing of surgery. There is little consensus on 1 preferred surgical technique with treatment options including open or laparoscopic reinforcement of the posterior inguinal wall with or without mesh, minimal repair of transversalis fascia, or broad pelvic repair. These procedures can be done with or without adductor tenotomy if patients have comorbid adductor pathology that did not improve with initial conservative management.[35] Return to play rates of these procedures have been reported as high as 98%, with athletes returning to play at an average of 6 weeks postoperatively for laparoscopic repair and 16 weeks postoperatively for open repair.[36,41]

Intra-articular Hip Pathology

FAI

FAI is the leading cause of dynamic intra-articular hip pain in athletes, occurring due to abnormal engagement of the proximal femoral head-neck junction, and the acetabular rim at terminal ranges of motion.[42] FAI is the most common intra-articular diagnosis for hip/groin pain in Major and Minor League Baseball players, causing 47.6% of all intra-articular hip injuries and labral tears causing another 33.3%.[3] In elite youth tennis, the prevalence of intra-articular hip injuries was 1.3 per 100 players.[43]

Two different lesions have been described in FAI: cam-type impingement from an aspherical femoral head with loss of head-neck offset and pincer-type impingement from overcoverage of the acetabulum. FAI is most frequently a combination of both lesions.[44] FAI limits internal rotation and causes acetabular rim abutment which leads to labral damage during flexion, adduction, and internal rotation of the hip.[42] Literature has suggested an association between FAI and high-intensity athletic activities occurring throughout the critical growth phase of adolescence, putting this athletic population at increased risk for developing symptomatic FAI.[45]

Patients present with groin or hip pain that is related to activity and exacerbated by deep hip flexion and internal rotation, hip stiffness, and sometimes decreased range of motion. Baseball pitchers will often report recreation of symptoms during wind-up and follow-through phase on the lead leg. Athletes may also have mechanical symptoms such as locking or catching from associated labral pathology.[46] Location of pain with FAI patients varies and is often multifocal, with 88% of patients having groin pain, 67% having lateral hip pain, 35% having anterior thigh pain, 29% having buttock pain, and 27% having knee pain.[46]

On physical examination, hip range of motion should be carefully noted as patients with FAI generally have restricted internal rotation at 90° of hip flexion. Range of motion at the hip should always be compared to the contralateral hip. The anterior impingement test is reliable for FAI and involves the patient being positioned supine, with the hip dynamically

Figure 8 A positive anterior impingement test will elicit pain in the deep anterior groin. (Color version of figure is available online.)

Figure 10 A positive Stinchfield test is indicative for intra-articular etiology. (Color version of figure is available online.)

flexed to 90°, adducted, and internally rotated (Fig. 8). A positive test will elicit deep anterior groin pain that replicates the patient's presenting symptoms.[27,46] Meanwhile, the posterior impingement test is performed with the patient supine and the affected limb is extended and externally rotated (Fig. 9). A positive result is buttock pain that occurs when the femoral head contacts the posterior acetabular rim.[47] The Stinchfield and McCarthy hip extension test can assess for intra-articular pathology such as labral tears. The Stinchfield test is conducted by having the patient perform a straight leg raise to 45° while resisting downward pressure (Fig. 10). Pain with this maneuver indicates an intra-articular etiology as the psoas puts pressure on the anterolateral labrum. The McCarthy test brings the affected hip from flexion into extension as the examiner rolls the leg through internal and external rotation arcs. A positive test is if pain is reproduced when the hip is extended.[48]

Diagnostic imaging for suspected FAI should begin with plain radiographs to assess bony morphology. If there is concern about an injury to the labrum and articular cartilage, an MRI is warranted (Fig. 11). Finally, for operative candidates, 3-D CT scans are useful to evaluate the bony anatomy and characterize the severity of impingement which will help guide the operative plan (Fig. 12). In some instances, a diagnostic intra-articular hip injection is useful for differentiating intra-articular versus extra-articular hip pathology.

Nonoperative treatment for FAI focuses on increasing the mobility and strength of the surrounding links of the kinetic chain to make up for limited hip motion. The focus of rehabilitation is to strengthen core and lumbar muscles, aiming to increase lumbar lordosis which will in turn improve acetabular anteversion while standing.[20] Oral and intra-articular

Figure 9 Patients will report buttock pain with a positive posterior impingement test. (Color version of figure is available online.)

Figure 11 MRI showing a labral tear (arrow) in the setting of femoroacetabular impingement (FAI). (Color version of figure is available online.)

Figure 12 A 3-D CT scan can allow surgeons to prepare for hip arthroscopy for femoroacetabular impingement (FAI). These scans allow clinicians to visualize the patient's unique bony morphology. (Color version of figure is available online.)

anti-inflammatory medications can be used to alleviate pain and enable the patient to better participate in physical therapy. There is currently no peer-reviewed evidence on return to play rates with nonoperative treatment of FAI.

If conservative management fails and athletes are unable to return to their previous level of sport, operative management should be considered. Open, mini-open, and arthroscopic techniques for treatment of FAI reliably relieve hip pain with correction of the underlying deformity and treatment of associated labral pathology. Following recent technological and surgical advances as well as increased understanding of FAI, most cases are now performed arthroscopically for cam and pincer-type impingement as well as exploration and repair or debridement of associated labral pathology.[49] Arthroscopic treatment of FAI has fewer complications as well as quicker and more reliable return to sport for athletes.[15] An open technique may be considered for cases requiring labral reconstruction, articular cartilage transplantation, global rim resection, and posterior extension of a cam-type lesion.[42,44,47]

Athletes have demonstrated excellent outcomes following arthroscopic treatment for FAI and associated labral pathology. One study on baseball and lacrosse players showed a 97% return to sport rate as well as significantly higher Harris hip scores postoperatively.[9] Another study of intercollegiate and professional baseball players with a 4-year follow-up showed a 90% return to play at their previous level of competition after a mean of 4.3 months following hip arthroscopy for FAI.[50]

FAI can also contribute to compensatory extra-articular injuries due to a loss of functional hip range of motion. This motion is then compensated upstream in the kinetic chain, leading to increased motion through the lumbar spine, sacroiliac joints, pubic symphysis, and core. This puts increased stress and force on these elements of the kinetic chain, making them more prone to injury. For example, MLB pitchers had significantly more hip and groin injuries if they had a UCL reconstruction (27.6%) than if they had not (17.9%).[13]

Hip Instability

Injury patterns in the shoulder of overhead athletes are well understood and can be used to better understand instability of the hip. Just as throwing athletes can develop laxity of the anterior shoulder capsule from repetitive extremes of motion, they can also develop rotational instability of the hip from repetitive forceful hip rotation. This is often due to the external rotation of the hip beyond physiological limits, which can lead to progressive laxity of the iliofemoral ligament. Less commonly, forceful internal rotation can lead to laxity of the ischiofemoral ligament.[9] Overhead sports, such as baseball, that involve repetitive hip rotation with axial loading leads to an increased risk of instability. Tennis players, particularly during forehand strokes, are also at risk for instability. The hip is prone to abnormal loading of the anterior-superior labrum with acquired laxity and this pathologic microinstability can lead to labral and chondral damage.[51]

Athletes with hip instability may present with feeling like their leg "gives out" during activity. They also may report that actions requiring pelvic rotation such as swinging a bat, golf club, or throwing will reproduce the sense of instability. They also can have pain when rising from a chair or getting into or out of a car. On physical examination,[51] there will often be an audible and painful pop when the hip is brought from flexion into extension with axial distraction. Most patients with capsular laxity will have increased passive range of motion, in the case of throwing and tennis athletes it will most likely be increased external rotation with a diminished endpoint. For the dial test, the patient lies supine in neutral extension while the examiner internally rotates the affected limb and then releases it, allowing the limb to externally rotate. The dial test is positive if the limb passively rotates greater than 45° from vertical. However, active range of motion is often normal. The patient should also be evaluated for generalized ligamentous laxity. Patients will often have a positive posterior impingement test, with discomfort or apprehension when the hip is brought into extension and external rotation.

On plain radiographs, patients with instability may have a lower lateral center-edge angle. Abnormalities in femoral head-neck offset could imply impingement which can lead to hip instability. Traction views on fluoroscopy or plain radiographs can also be used to identify subluxation. On magnetic resonance arthrogram, the ligaments, labrum, capsule, and associated soft tissues can be assessed. There may also be a large intra-articular volume and excessive axial distraction seen.[52]

Nonsurgical management includes activity modification and physical therapy to strengthen the musculature and improve dynamic stability. Surgical intervention is indicated for instability that is refractory to conservative treatment. Anesthetic injections can also be used to improve symptoms.[51]

Arthroscopic intervention for instability aims to correct the capsular pathology by reducing the volume of the capsule by capsular plication.[52] Possible complications of this procedure include adhesions and capsulitis. In patients with associated labral pathology, arthroscopic debridement, or repair of the labrum has had good results in conjunction with capsular plication.[51]

Conclusion

Overhead sports are commonly associated with upper extremity injuries; however, hip injuries in these athletes are becoming increasingly acknowledged and studied. Many of the actions involved during baseball, tennis, and volleyball place high demands on the hip joint and rely on functional hip range of motion and strength to produce the power needed to execute overhead motions. Hip and groin injuries have become relatively common in this athlete population, and an understanding of the underlying hip biomechanics and their interaction with the kinetic chain enhances the ability to prevent, diagnose, and treat these injuries. Through a systematic approach to hip and groin pain, these injuries in overhead athletes can be accurately diagnosed and successfully treated both nonoperatively and operatively with a high rate of return to sport at or above the patient's previous level of competition.

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