Management of Shoulder Instability in the Overhead Athletes

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KEYWORDS

• Shoulder instability • Overhead athlete • Baseball • Shoulder

KEY POINTS

- Glenohumeral instability in overhead athletes can be debilitating with variable presentation, making it difficult to manage.
- Posterior shoulder instability (ie, "batter's shoulder") is often difficult to differentiate from pain or the sequelae of internal impingement, while anterior and multidirectional instability are usually clinically identifiable.
- Generally, treatment begins with conservative management that focuses on reinforcing proper mechanics with rehabilitation that targets strengthening shoulder stability.
- When this fails or there is an acute or severe injury, operative management is often indicated.
- Further multicenter randomized control trials analyzing surgical techniques, rehabilitation monitoring, and biomechanical analysis are needed to progress the management of shoulder instability in the overhead athlete to a proactive process.

INTRODUCTION

Shoulder instability covers a wide spectrum of glenohumeral joint pathology, ranging from subluxation to dislocation in the anterior, posterior, or multidirectional planes. Instability can be acute, most often in contact-sport athletes, whereas more chronic cases present secondary to repetitive microtrauma, such as seen in the overhead athlete. Overhead athletes participating in sports such as baseball, tennis, volleyball, and swimming perform repetitive, often forceful overhead movements that place significant stress on the static and dynamic stabilizers of the glenohumeral joint, which

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can ultimately result in injury and instability. Presentation in these athletes can be subtle and nonspecific, especially in the absence of acute trauma or obvious dislocation. Therefore, careful evaluation and a high suspicion are necessary for diagnosis. Once the diagnosis is made, nonoperative as well as surgical management may be indicated based upon the clinical and radiographic findings, which impacts the athlete's return to sport. The purpose of this review is to provide a comprehensive description of shoulder instability in the overhead athlete focusing on management.

ROLE OF SUPPORTIVE STRUCTURES

A key to understanding the pathology of shoulder instability in the overhead athlete is first appreciating the function of anatomic structures essential to stability during the throwing (or overhead athletic) shoulder motion. The stabilizing structures of the glenohumeral joint include joint congruity between the humerus and glenoid, the joint capsule (and resulting negative intracapsular pressure), glenohumeral ligaments, and the glenoid labrum. The dynamic stabilizing structures primarily include the rotator cuff muscles, which aid in stability through concavity compression. To a lesser extent, the long head of the biceps tendon, periscapular muscles, and scapulothoracic position also contribute to stabilization of the glenohumeral joint.[1,2] It is also key to consider physiologic changes that occur in the shoulder of the overhead athletes. The repetitively high forces at extremes of range of motion (ROM) may slowly lead to changes in the stabilizing anatomy. Over time, these changes may progress to dysfunction, injury, and possible instability.

Labrum

The fibrocartilaginous labrum is formed by the glenoid shape and extends the glenoid through its concavity in both width and depth to play an imperative role in articular congruity and shoulder stability. The labrum increases the glenoid concavity and resists against translational forces, withstanding up to 380 N of force during the throwing motion.[3,4] The labrum is also subjected to traction force from the long head of the biceps tendon in addition to overall joint distraction during overhead motion in athletes.[5] Given the high amount of stress, pathology of the labrum is often involved in shoulder stability.

Coracohumeral and Glenohumeral Ligaments

The coracohumeral and glenohumeral ligaments are thickenings of the joint capsule, helping to stabilize the joint via resistance to multiplanar translation in overhead athletes.[6] These structures include the coracohumeral ligament (CHL), the middle glenohumeral ligament (MGHL), superior glenohumeral ligament (SGHL), and the inferior glenohumeral ligament (IGHL), which is further divided into anterior and posterior bands.

The CHL extends from the coracoid process to the rotator cable of the rotator cuff. The CHL functions to resist external rotation and translation during inferiorly directed forces of the adducted arm.[7,8] This can be seen during the deceleration and follow through phases of the throwing motion or during a volleyball spike. Laxity or injury to the CHL may result in increased inferior translation and external rotation of the humeral head.[9,10]

The anterior band of the IGHL (AIGHL) provides stability against anterior and inferior translation forces of the humeral head when the shoulder is in 90° of abduction and external rotation.[11,12] It produces a stable envelope that prevents the humeral head from overrotation and translation during the late cocking phase of throwing, which is associated with peak throwing motion forces.[4,13,14] As a primary restraint during these phases of throwing associated with significant amount of force, the AIGHL is among the most important of the glenohumeral ligaments. The posterior band of the IGHL (PIGHL) limits posterior and inferior translation of the humeral head with the arm in an abducted and internally rotated position. Pathology related to the PIGHL in the overhead athlete may manifest as capsular tightness as seen in glenohumeral internal rotational deficit. This can result in humeral decentering and increase the risk of superior labral injuries or internal impingement. The PIGHL also serves a role in the setting of posterior instability in the overhead athlete.[13,14]

The SGHL and MGHL appear to play a lesser role than the other glenohumeral ligaments in the overhead athlete. With the shoulder in adduction and 90° of abduction with external rotation, the SGHL is taut, suggesting that it plays a role with the CHL to prevent inferior translation of the humeral head.[15] The MGHL, however, is at maximal tension in midrange abduction and provides stability against anterior translation, though there is a great variability in size.[16]

Rotator Cuff

The rotator cuff muscles provide dynamic support of the humeral head during the overhead motion by providing a compressive force to maintain a concentric glenohumeral articulation. The primary role of the rotator cuff is to compress the humeral head against the glenoid. Tears in the rotator cuff are fairly common in overhead athletes.[17] The rotator cuff plays an essential role during the deceleration phase of throwing, maintaining a compressive stabilizing force. Similar to the static stabilizers of the glenohumeral joint, the rotator cuff is subjected to repetitive forces at often the extremes of ROM, resulting in an increased risk of developing injury with possible subsequent instability.[17]

The static and dynamic stabilizing structures of the glenohumeral joint do not function independently, rather, they rely on each other for optimal function. For example, a tight posterior capsule, as often seen in patients with glenohumeral internal rotation deficit, may shift the humeral head anteriorly, subsequently exaggerating stress placed on the subscapularis muscle. Similarly, acute anterior instability, often resulting in anterior inferior labral tears with capsular injury, leaves the subscapularis to provide much of the dynamic support during glenohumeral motion.[17–19] Overhead athletes tend to rely greatly on the subscapularis during the cocking motion of the throw, serve, or stroke, which makes it one of the more common rotator cuff pathologies.[20–22] Repetitive use may also subject the rotator cuff muscles to increased laxity over time with a less dramatic clinical presentation.[23,24]

EPIDEMIOLOGY AND PATHOPHYSIOLOGY

Anterior shoulder instability (ASI) is the most common clinical instability, with an incidence of approximately 0.08 per 1000 person-years.[25,26] Posterior shoulder instability (PSI) is less common with an overall incidence of approximately 0.011 per 1000 person-years. The overall incidence of multidirectional instability (MDI) remains largely unknown due to variation in symptomatology and diagnosis, though accounting for approximately 7% of shoulder surgeries.[27,28] Patients who present with painful anterior instability have often experienced primary or recurrent dislocation.[29] In contrast, pain associated with posterior instability is less often a result of a dislocation event and more likely related to overuse rather than an identifiable injury. MDI is commonly found in sports such as swimming, where an associated increase in physiologic ROM can provide a competitive advantage. However, the overall increase in ROM can result in later pain and dysfunction.[28] Regardless of direction, shoulder instability can be difficult for the athlete and medical professional, and an understanding of the pathophysiology in each respective instability pattern helps guide clinical management.

Anterior Instability

ASI is defined by anterior dislocation or subluxation of the glenohumeral joint with associated pain. ASI commonly affects younger contact-sport athletes, more active populations, as in the case of the overhead athlete.[30] Anterior instability can occur secondary to a single acute event, often an anterior glenohumeral dislocation or secondary to repetitive microtrauma. The repetitive motions performed by overhead athletes over a long period lead to significant and recurrent overhead torque, especially at the limits of ROM.[14] The pathophysiology of anterior instability is associated with damage to or involvement of the anterior labrum, most often the anteroinferior labrum, also known as a Bankart tear. Acute or more chronic anterior instability can also manifest as superior labrum anterior posterior (SLAP) lesions caused by a peel back mechanism, anterior labroligamentous periosteal sleeve avulsion (ALPSA) lesions, and other forms of isolated labrum tears, as well as injuries to the subscapularis, and/or AIGHL (**Figs. 1** and **2**).[31] Both the subscapularis and AIGHL resist anterior translation, and chronic laxity during the overhead motion contributes to instability over time. Compressive forces, along with joint laxity and large anteriorly directed forces during the arm cocking phase of throwing motion, can all lead to anterior labral tears.[32] These structures provide the most important resistance to anterior translation and as a result of chronic or acute changes allow for an increased anterior laxity that can lead to instability.

An important consideration is the degree of osseous involvement, which occurs due to damage to the humeral head in the setting of a Hill–Sachs lesion, or on the glenoid, in the setting of a Bony Bankart lesion (**Fig. 3**). These osseous pathologies can present in 2 ways: either as an acute fracture secondary to a single shoulder dislocation event or as a chronic erosion of the glenoid or humeral head from recurrent instability.[33] Both mechanisms result in bone loss of the glenoid rim or humeral head, which further contribute to glenohumeral instability. Soft tissue stabilizers are unable to compensate for a lack of bony infrastructure as seen with glenoid bone loss. The stability of the

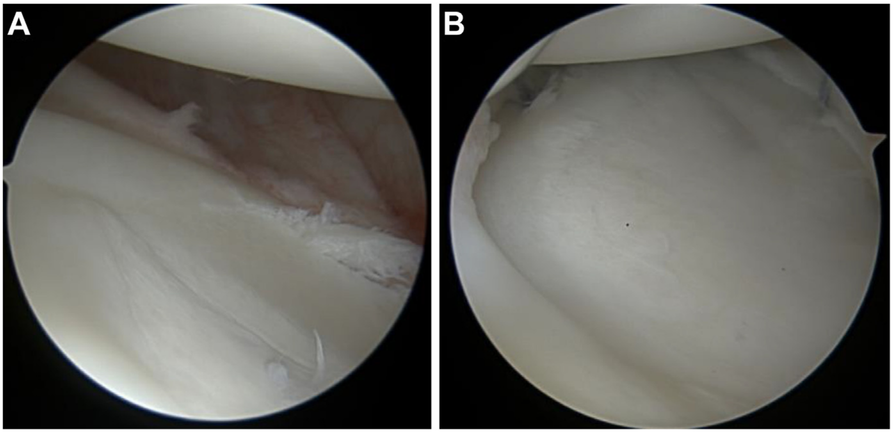

Fig. 1. Arthroscopic images of a 21 year old softball athlete with recurrent ASI secondary to a labral disruption extending anteriorly and posteriorly (*A*) in the left shoulder. Final repair (*B*) showing knotless suture anchor fixation of both anterior and posterior aspects of the labrum.

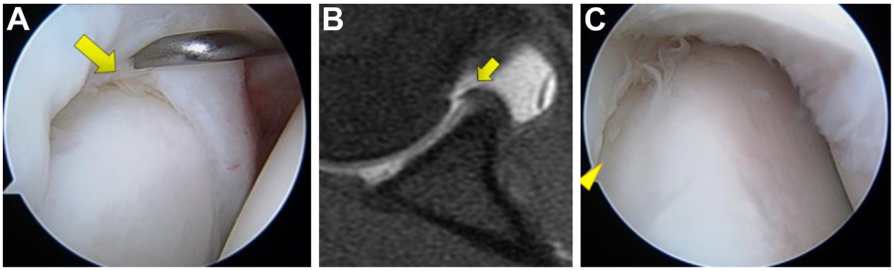

Fig. 2. SLAP lesion in a 17 year old high school baseball player shown arthroscopically (*A*) and under T2-weighted MR imaging (*B*). The peel back mechanism demonstrated arthroscopically, where the labrum rotates medially over the corner of the glenoid during abduction and external rotation of the arm (*C*). *Arrow* in (*A*) is a SLAP lesion, *Arrow* in (*B*) is the SLAP lesion under MR imaging, *Arrow head* in (*C*) is where the labrum rotates medially over the corner of the glenoid.

shoulder is significantly reduced when there is more than 20% bone loss of the glenoid, and this instability can lead to pain, weakness, reduced ROM, and long-term recurrent instability.[34]

Posterior Instability

PSI is less common in overhead athletes, but may present in more subtle manner.[27] In contrast to anterior instability, which is most likely to result in recurrent frank instability events, posterior instability may only be associated with pain and an absence of clinically noticeable instability. However, when present, PSI is especially debilitating for athletes who rely on the overhead motion for performance. Similar to anterior instability, the development of PSI can occur as an acute or more chronic entity, though it is more often multifactorial.[35]

PSI often presents in throwing or overhead athletes with increased pain or reduced velocity of overhead motion.[36,37] Risk factors include osseous abnormalities, mainly

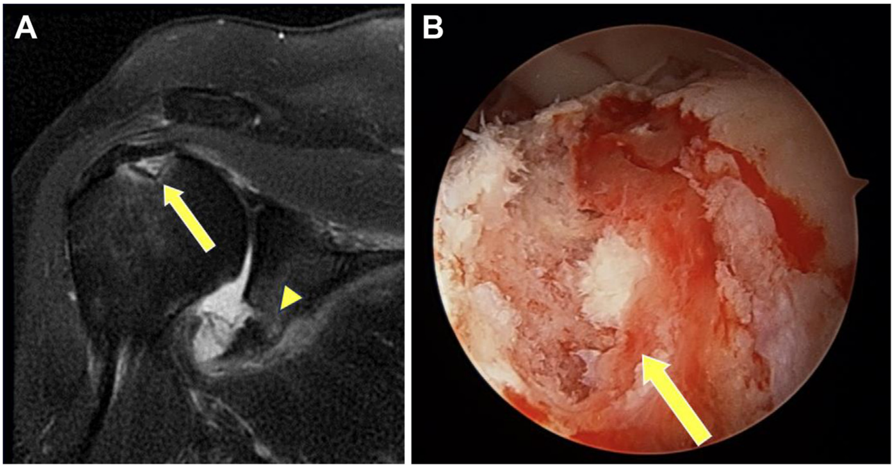

Fig. 3. (*A*) Coronal oblique T2-weighted MRI of the right shoulder in a 27 year old baseball player showing a Hill–Sachs lesion (*arrow*) and concomitant bony Bankart lesion (*arrowhead*). (*B*) Associated arthroscopic imaging showing the Hill–Sachs lesion (*arrow*).

glenoid retroversion, anterior humeral head defects, and glenoid erosion that increase athlete susceptibility to acute on chronic PSI.[38–40] Osseous findings include reverse-Bankart lesions, Kim lesions, and reverse Hill–Sachs lesions. Athletes may also develop PSI after diving onto an outstretched arm or the “batter’s shoulder,” describing the posterior subluxation of the lead shoulder following a swing on a low and outside pitch, or after missing the ball on a full swing.[39] Regardless of the etiology, PSI is often chronic and multifactorial with less distinct pathologic findings, making diagnosis a challenge.[35] In the setting of PSI, the biomechanics of the overhead motion change, such that the translational mechanics of the humeral head within the glenoid can also lead to internal impingement of the posterior articular-sided rotator cuff with concomitant posterior labral injury (**Figs. 4** and **5**).[37]

Multidirectional Instability

MDI is defined as symptomatic instability or apprehension in greater than one plane and is a common cause of symptomatic shoulder instability in the overhead athlete, especially in swimmers. The improved shoulder motion in patients with MDI may provide a competitive advantage prior to development of pain and dysfunction.[41] MDI can be a debilitating pathology for overhead athletes who rely on a stable shoulder for athletic performance. Although less studied than ASI, MDI is most often a result

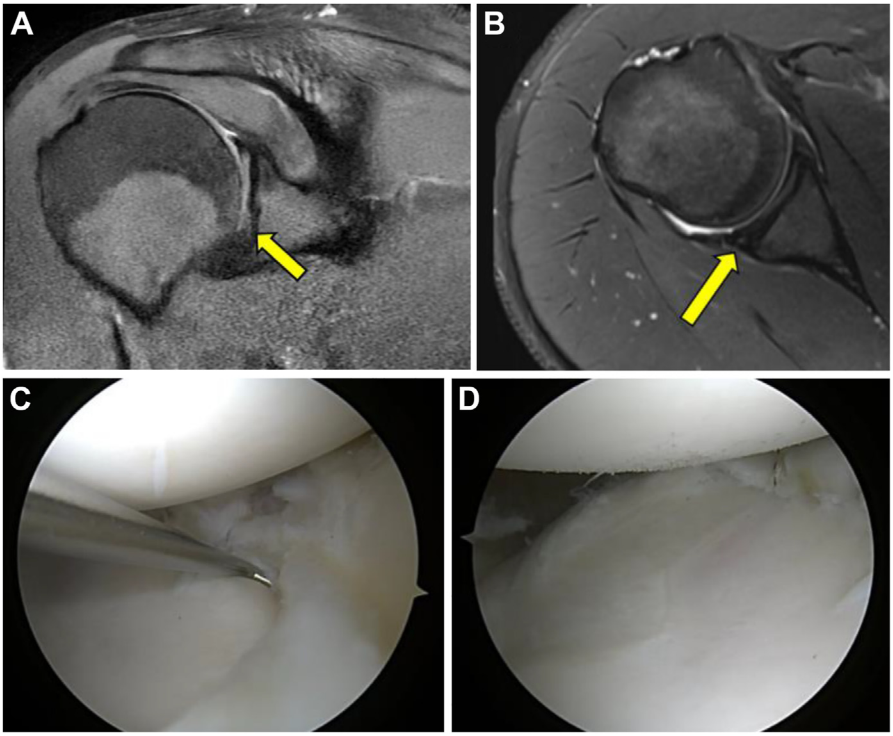

Fig. 4. A 19 year old Division I baseball player with persistent posterior glenohumeral pain during activities that failed conservative management. Identified right posterior shoulder labrum tear on T2-weighted MRI (*A*, *B*) and during diagnostic arthroscopy (*C*). The labral tear was repaired with knotless fixation (*D*). *Arrow* in (*A*) is a posterior labrum tear on sagital view, *Arrow* is (*B*) is porterior labrum tear on axial view.

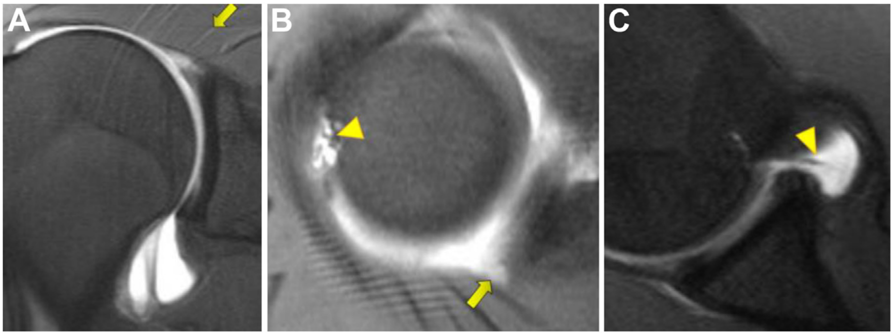

Fig. 5. Coronal (*A*), axial (*B*), and abduction-external rotation (*C*) T1 fat suppressed MR images show increased signal and fraying of the posterosuperior labrum (*arrows*) and fraying of undersurface infraspinatus fibers (*arrowheads*) in a 19 year old male baseball pitcher.

of a wide variety of factors, primarily soft tissue laxity, making it a more chronic pathology.[27,41,42] Chronic etiologies include generalized soft tissue laxity, recurrent microtrauma, redundant capsular elements, proprioceptive imbalances in the glenohumeral supportive structures, as well as congenital and anatomic abnormalities of the glenoid and humeral head. Over time, the suspected summation of these effects allows for laxity in the shoulder and eventual multiplanar subluxation or dislocation.[41]

THROWING MECHANICS

Mechanics in Brief

Overhead athletes subject their arm to a motion sequence that is akin to that of a baseball player delivering a pitch. As such, the baseball pitch is a good representation of most overhead athletes. The throwing motion includes a wind-up, stride, arm cocking, arm acceleration, arm deceleration, and follow through, with the ultimate result of efficient energy transfer from the pitcher to the ball to maximize pitch effectiveness (**Fig. 6**).[5] For this reason, understanding the overhead motion is imperative to conservative and operative management. In a throwing athlete, ball delivery involves distinct phases of motion that subject different anatomy to stress. During the stride, the rear (drive) leg remains connected with the ground and pitching rubber, while the front (stride) leg moves toward the plate. The pitcher uses the force generated by the drive leg and core musculature to hip-hinge and rotate the pelvis during the windup.[42] Once the hip-hinge is completed, the athlete will effectively shift the energy toward the plate during the stride. The arm cocking phase begins around the stride leg foot striking to the ground. Following front foot strike, the pelvis will stop rotating, transferring the

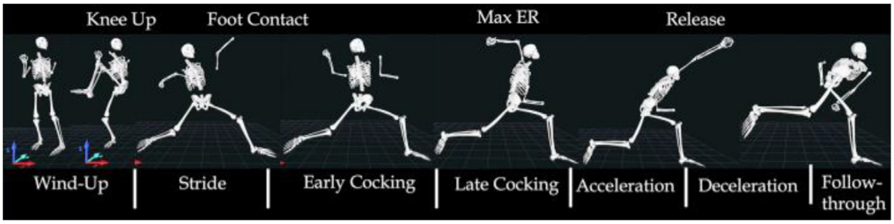

Fig. 6. Phases of pitching in video motion analysis as adapted from Trasolini and colleagues[3] (ER, external rotation).

energy through the torso to the upper extremity, accelerating the throwing arm toward the target. During arm movement toward the target, the torso rotates and tilts forward until stopping just before ball release, resulting in a kinematic transfer of energy through the shoulder as it transitions from external rotation to internal rotation, resulting in elbow extension until final ball release. The arm deceleration phase continues until maximal internal rotation and the torso rotates, tilts forward while the shoulder, arm, upper back, and chest work to decelerate the arm.[5] The follow through is highly dependent upon the athlete's throwing mechanics, but effectively ends with the thrower's upper and low extremities completing arm, torso, and lower extremity deceleration. In the shoulder, the rotator cuff serves an essential role in maintaining shoulder stability during the deceleration phase.

Throwing Analysis

Analysis of the throwing motion via pitching laboratory technology is a current and coming trend for high level athletes and can be applied beyond baseball for other overhead athletes.[5,42] It has been found helpful for evaluating and characterizing the pathobiomechanics in shoulder instability.[4,42–46] Other identifiable mechanics that may play a role in shoulder instability include increased elbow valgus torque and early trunk rotation, which have been presented as independent risk factors for many types of injury including those in the shoulder.[5,47,48] Future study will likely focus on novel attempts at biomechanical analysis. These include double calibration acromion marker cluster approaches focusing on measuring dynamic scapular orientation able to distinguish between glenohumeral and scapulothoracic contributions to shoulder biomechanics, shoulder distraction forces, ground reaction forces, drive leg components such as impulse and slope and their relation to kinematics such as rotational and angular velocities.[5] These aspects of the throwing motion may help identify the specific etiologies of instability in the overhead athletes as well as guide management, especially physical therapy and throwing progression, following conservative or operative management.

Other Sports

In swimmers, the lower extremities are not as involved in the rotation of the shoulder movement with strokes such as the backstroke, breaststroke, and butterfly. However, these techniques involve overhead extension and rotation in order to propel the swimmer forward.[49,50] Despite the relatively decreased energy needed for each stroke, the repetitive nature of swimming remains similar to the principles of throwing.[51] Like swimming, the overhead spike in volleyball and serve in tennis both rely on a similar sequence of upper extremity mechanics, with explosive overhead motion at the bounds of shoulder ROM in an abducted and externally rotated shoulder.[50] As a result, the overall overhead motion of throwers translate well to the discussion of all overhead athletes.

DISCUSSION

In-season Management

In-season management of shoulder instability is challenging for physicians and the athletic training staff. Health care professionals and coaches must prioritize athletes' safety and a safe return to play (RTP). However, in a recent survey on athlete priorities following an injury, athletes cared most about their RTP times.[51] As such, the key to in-season management is setting proper expectation based upon well-established management of overhead athlete shoulder instability. In-season management may involve conservative measures such as functional bracing, physical therapy, or time away from play, as well as more definitive measures such as surgical stabilization.

Functional bracing in overhead athletes can help to temporize an athlete's injury without a complete disruption in their participation in sports.[52] However, in-depth analysis of the effectiveness of bracing is scarce and tends to align more with clinical preference rather than quality studies. The long-term benefits, effects on RTP, or recurrence of instability in those managed with functional bracing remains unclear.

Various criteria have been established to help guide when athletes are able to RTP. One such proposal is that the athlete is to meet 4 criteria: restoration of (1) full ROM and (2) strength as well as the absence of (3) pain and (4) apprehension.[41] This may take between 1 and 3 weeks depending on athlete, demand of sport, position, and severity of instability.[41,53] The timeline to return may also be impacted by hand dominance; however, a current lack of data to suggest a clinically meaningful difference in RTP based on handedness limits this practice.[54–56] Given the fairly quick RTP time of a few weeks, a recent study on overhead athletes that returned within 10 days of injury showed that over half of them underwent off-season surgical management.[53] Overhead athletes that experience a delay in RTP beyond 1 to 3 weeks suggests that the cause is continued insufficient shoulder function or instability, even despite aggressive rehabilitation.[57] The variability in RTP times make early discussion of athlete expectations essential.

Nonoperative Management

Anterior

Nonoperative management of ASI may be successful, especially in the context of lower severity, less structural pathology, athlete and physician preference, and adherence to rehabilitation protocols.[58] Without significant lasting damage of the glenohumeral joint, including fractures, bone loss, osteochondral lesions, or damage to supportive structures, rehabilitation focuses on improving the 4 characteristics described earlier: restoration of full ROM and strength as well as testing for the absence of pain and apprehension.[41] To do this, physical therapy focusing on ROM, strength, scapular stability, as well as observation and improvement of biomechanical factors during exercises and the overhead motion should be implemented.[59,60] For example, 40% of professional baseball players SLAP tears are able to return to preinjury levels of competition via rehabilitation alone.[61,62] However, due to the heterogeneity of nonoperative treatment regimens, analysis of various protocols is limited. In a previous study of long-term outcomes with a mean follow-up of 12 years, a matched cohort between overhead athletes and nonoverhead athletes with ASI suggest that overhead athletes are more likely to experience a greater number of instability events.[63] When characterizing these instability events, they may occur during the rehabilitation process, afterward, or even both, with overhead athletes tending to subluxate more than dislocate, despite having no difference in patient-reported and other clinical outcomes.[63] Overhead athletes experienced an RTP rate of 71% in this study compared to 81% for the nonoverhead athletes. Despite successful conservative management for overhead athletes, there is a lack of a standardized protocol for athletes, making it difficult to definitively suggest a specific rehabilitation protocol.[41] In general, rehabilitation focusing on strength, ROM, scapular stability, and mechanics throughout a sport-specific motion appears to be the best approach.[41]

Posterior

PSI, though relatively uncommon in overhead athletes and thus not well studied, can be managed with multiple protocols. One such protocol suggests a staged approach trial prior to operative management, with progression from pain-free ROM to strengthening and scapulothoracic stabilization, followed by sports specific rehabilitation such as throwing programs.[38,64] Long-term outcomes after nonoperative management of PSI in both overhead athletes and nonoverhead athletes reported a rate of recurrence of 8%, with 54% of patients having continued pain.[37] This suggests that there is a role beyond simply delaying surgery for patients with PSI. An additional study that included both nonoverhead athletes and overhead athletes with PSI showed that patient-reported outcomes were improved following rehabilitation programs, such as the staged approach described above, with all athletes able to RTP.[65] However, these studies do not analyze overhead athletes individually or in subgroup analysis, suggesting further need for more focused studies on this athlete population.

Multidirectional instability

MDI is often multifactorial in nature, making the treatment of these athletes challenging. MDI is associated with increased laxity at baseline. As such, there is a wide array of presentations, making MDI dependent upon a more individualized approach. This individualized approach should consider the demands of the athlete's sport, duration and implications of seasons, and the goals of the respective athletes.[41,66] Therefore, initial treatment of symptomatic MDI should focus on rehabilitation of the specific presented directional instability. Given the likely laxity of the shoulder capsule, labrum, and other ligamentous supports, targeting the muscular support of the shoulder is advisable, specifically the rotator cuff and deltoid to facilitate greater active control of the glenohumeral joint.[67,68]

Surgical Management

A wide variety of operative techniques may be used successfully, with over 14 viable treatments of instability described in the literature.[69] The surgical technique used is often based upon patient or surgeon preference rather than high-quality research.[70–72] While this variability in treatment can be beneficial, allowing for an individualized approach, guidance and trends on surgical technique are necessary to improve expected and repeatable results for athletes. Further considerations of surgical management include larger labral tears in continuity, such as extensive SLAP tears (ie, Type V, VIII, and IX) and/or involvement of the biceps labral insertion with "peel back" phenomenon.[62]

Anterior

There are a number of surgical options for athletes with ASI, including arthroscopic and open techniques, such as capsulolabral or Bankart repair, capsular plication, osseous augmentation, and open labral repair.[73–75] Recurrence rates following arthroscopic capsulolabral repair in overhead athletes range from 0% to 4% with RTP at preinjury level reported from 45% to 82%.[59,76,77] A study evaluating outcomes in baseball players showed an average RTP time of 8.4 months, with only 63% of athletes returning to their preinjury level of play, while interpretation may be limited by the heterogeneity of indications and techniques used in this cohort.[78] Despite research that demonstrates an increased likelihood of overhead athletes to undergo surgical management, their RTP, recurrent instability, and revision rates are not significantly different from nonoverhead athletes.[41,63] Even in the context of heterogenous results, labral repair remains steadfast as the treatment of choice for persistent anterior glenohumeral instability.

In the case of SLAP tears, with and without biceps involvement, treatment algorithms have been proposed for overhead athletes.[62] When surgery is indicated, arthroscopic repair via knotted or increasingly knotless fixation of the torn labrum and/or biceps tenodesis are generally pursued depending on the type of tear, age, provocative physical examination findings, and level or position of the athlete.[62,79,80] Risks and benefits of SLAP tear stabilization, including the possibility of ROM loss and/or residual anterior shoulder pain, must be carefully considered in the overhead throwing athlete that often function at the extremes of shoulder motion.

In the setting of a concomitant Hill–Sachs lesion, capsulolabral repair may be accompanied by the remplissage procedure.[81–83] A significant concern associated with remplissage in overhead athletes is resulting stiffness, which is thought to be related to an increased capsular restraint and reduced secondary shoulder ROM, particularly external rotation in an adducted position.[41] For example, overhead athletes showed poor outcomes with regards to RTP at their preinjury levels when undergoing remplissage.[82] As such, without more extensive analysis on remplissage in overhead athletes, further adoption is currently not recommended and only selectively indicated in overhead athletes.[41,59]

Another consideration in overhead athletes with ASI is bony involvement and specifically, attritional bone loss. While the thresholds are still debated, athletes with glenoid bone loss in excess of approximately 13.5% to 20% may be preferentially considered for reconstructive procedures such as a Latarjet or anterior glenoid bone block reconstruction with allograft or autograft (**Figs. 7** and **8**).[34,84] However, a trial of soft tissue only repair, even in the setting of subcritical bone loss, may be an early option in an attempt to preserve motion and optimize RTP by avoiding the constraints associated with the Latarjet procedure. Importantly, overhead athletes who undergo arthroscopic Latarjet procedures are less likely to successfully RTP than those that do not.[59] The decreased RTP potential is also consistent with open Latarjet procedures, with an RTP rate to preinjury level of approximately 75%.[85] Much like the case of remplissage, this is likely due to reduction in ROM limiting the shoulder's ability to remain stable or even reach preinjury level of biomechanics.

A final consideration in ASI in overhead athletes is rotator cuff involvement. Previous literature suggests that operative fixation of the rotator cuff will more than likely conclude overhead athletes' careers.[86,87] Therefore, current management focuses on debridement for amenable tears, including the involvement of up to 70% of medial-lateral tendon width, rather than repair for athletes who wish to RTP.

In summary, there is a wide variety of techniques available for the surgical management of ASI, which focus on surgeon and athlete preference, with the exception of rotator cuff involvement, remplissage, and Latarjet, as outcomes following these procedures tend to impact the ability to RTP among noncollision, overhead athletes.

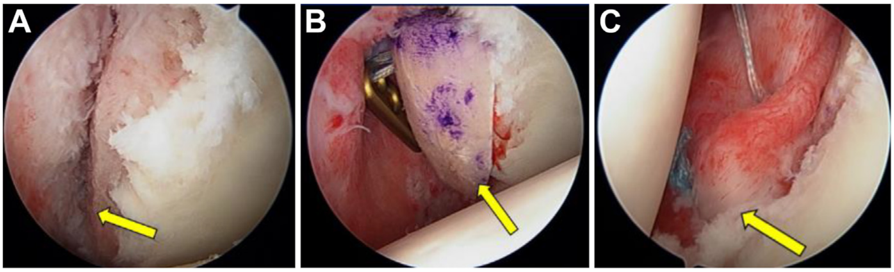

Fig. 7. Anteroinferior bony Bankart lesion (*A*) with repair using iliac crest autograft (*B*, *C*) in an overhead athlete with acute ASI. *Arrow* in (*A*) is pointing to an anteroinferior bony bankart lesion, *Arrow* in (*B*) is pointing to an illiac crest autograft, and *arrow* in (*C*) is pointing to the illiac crest autograft during fixation within the shoulder.

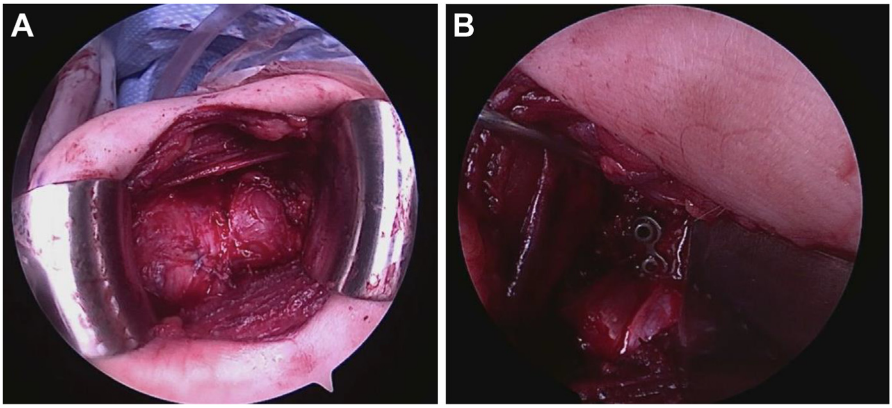

Fig. 8. A 15 year old overhead athlete with recurrent instability following ALPSA lesion repair with continued significant ASI and subsequent bony loss in the form of an irreparable bony Bankart lesion in the right shoulder (*A*). The irreparable bony Bankart lesion was treated with an open Latarjet coracoid transfer using 2 cannulated screws with a rim plate (*B*).

Proper patient selection or surgical technique requires consideration of the condition of stabilizing structures, surgeon preference, and an athlete's expectations.

Posterior

As with ASI, overhead athletes with PSI who are unable to progress following conservative management may be treated with posterior capsulolabral repair with anchor fixation.[88] Well established in the case of PSI is the concern of overtensioning and plication of the posterior shoulder labrum and capsule, as the overhead athletes relies specifically on the extremes of overhead ROM.[89,90] This is due to the possibility that excessive capsular reduction or tension may decrease the necessary ROM for proper throwing mechanics.[38,91] As such, isolated posterior labral repair is recommended with minimal capsulorrhaphy (if necessary) to retention plastic deformation of the IGHL complex. If present, an associated so-called Bennett lesion, or throwers exostosis at the attachment PIGHL, may be decompressed to facilitate better interface for healing. Early immobilization in the "gunslinger" neutral position is beneficial, and scapular and rotator cuff activation occurs early through isometric exercises. Although balancing the impact of posterior stabilization with ROM goals comes with surgical experience, athletes should target internal and external ROM goals and posterior shoulder flexibility during staged rehabilitation.[92–94] A return to throwing program may be initiated in the fourth month of rehabilitation after appropriate criteria for advancement have been achieved.[92] Similarly, a return to batting progression is introduced during the sports-specific phase of rehabilitation, starting with dry swings and hitting from a tee to soft toss and ultimately, simulated hitting.[95] Despite these best practices, athletes vary widely in their return preinjury level of activity following arthroscopic posterior capsulolabral repair (37%–83%), with a revision rate around 9%.[91,96–98] Further characterization of these injuries is important to solidify expectations following posterior stabilization.

Multidirectional instability

MDI follows the same principles, surgical techniques, and surgical selection as PSI and ASI; failed extensive rehabilitation is often treated surgically. Patients diagnosed with MDI should undergo 6 to 12 months of dedicated physical therapy prior to being considered for surgical management, particularly in the absence of trauma and/or labral tears. Historically, surgical options favored open techniques focusing on labral repair with capsular shift,[99,100] although arthroscopic options have shown increasingly equivalent outcomes. This technique is the standard for MDI management as it has a fairly low instability recurrence rate of approximately 4% to 8% at final follow-up.[28,41] Open labral repair with capsular shift may provide stabilization of the shoulder at the cost of performance, as the technique is prone to overtensioning with the resultant loss of abduction and external rotation necessary for overhead athletes. Conversely, arthroscopic pan-capsular plication with a circumferential anchor-based fixation can result in improved capsulolabral bumper and reduction of overall capsular volume with a "pinch tuck" technique. Furthermore, adjunctive lateral rotator interval closure may be considered for individuals with significant multidirectional laxity. However, long-term outcomes have been limited, with a similar concern for overtensioning with subsequently reduced ROM at the expense of increased stability.[101]

Further Recommendations

The treatment of shoulder instability, in most instances, should begin with a trial of nonoperative management. A focus on shoulder ROM, strength, and biomechanics is essential to optimize dynamic shoulder stability throughout overhead motion. When conservative management fails, critical or combined subcritical bone loss is present, or acute, first-time shoulder dislocation occurs, surgical repair may be preferentially considered. Given the risk of impairing native ROM essential to the overhead athlete, the minimal operative technique to restore stability is advisable, with avoidance of reducing capsular volume when feasible. This is in stark contrast to the non-overhead athlete, where capsular volume reduction is often included in a comprehensive surgical approach to reduce the recurrence of instability.

PHYSICAL THERAPY AND RETURN TO THROWING PROGRAM

Physical Therapy

Physical therapy following shoulder instability is integral and may take a variety of forms dependent on the type of instability present. Given the biomechanical changes seen in these overhead athletes overtime, attention to the specific needs of the sport are necessary during initial, more standardized rehabilitation. In a recent systematic review, postoperative sling use was recommended, along with elbow, wrist, and hand ROM exercises.[102] Further, full passive foreword flexion was achieved around 3 weeks, with active ROM by around 5 weeks, and normal motion by 10 weeks postoperatively. Various protocols provided recommendations on a return to sport-specific exercises around 17 weeks following surgery, though there remains variability between Latarjet and Bankart repair protocols with regard to exercise and motion goal recommendations.[102,103] As the general timeline of rehabilitation following surgery continues to solidify, research comparing types of surgery and accompanying rehabilitation is essential to optimize athlete outcomes.

Throwing and Rehabilitation Programs

Effective rehabilitation and throwing programs, such as USA Pitch Smart, are essential in the RTP process.[104] These programs are not limited to focus on the upper extremity, as core control and leg strength are foundational to the throwing motion, and ensuring proper mechanics during the return to throwing is imperative to a successful return to

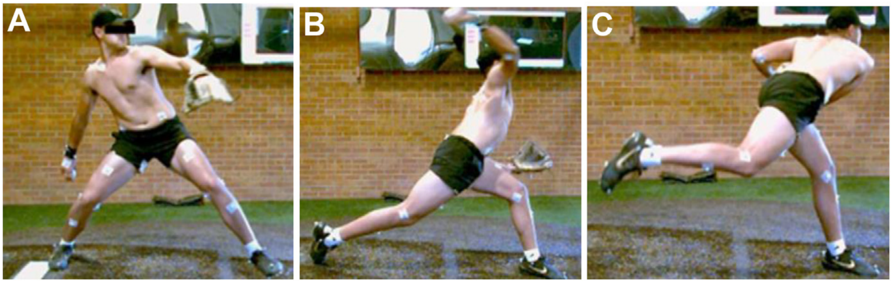

Fig. 9. Visual motion technology with attached video-motion sensors showing a pitcher in the stride (*A*), late cocking phase (*B*), and follow through (*C*) phases.

sport.[105] In the context of the volume of throwing in baseball, additional considerations include pitch or throwing counts, appropriate rest, and proper conditioning to decrease injury risk associated with shoulder instability and overall health.[5,54]

To optimize performance recovery, early interval throwing programs have thus far relied on throwing distance and velocity to estimate training load and to guide progression of sporting activities.[106,107] New technology, including pitching laboratories and field-accessible throwing analysis make estimating strain on the athlete increasingly accurate (**Fig. 9**).[107–109] With the development of accurate monitoring of throwing mechanics and stress, a more individualized and flexible throwing programs may be used. Future developments in this technology may even be predictive, such that current objective and subjective mechanics can advise adaptation to avoid or correct pathomechanics prior to injury. Examples include research on variables derived from ground reaction force curves that may predict variation in pitching mechanics before the athlete can identify these changes (see **Fig. 6**; **Fig. 10**). Adapting to these improvements in rehabilitation is key to continue the shift from a reactive to a more proactive approach for the management of shoulder instability in the overhead athlete.

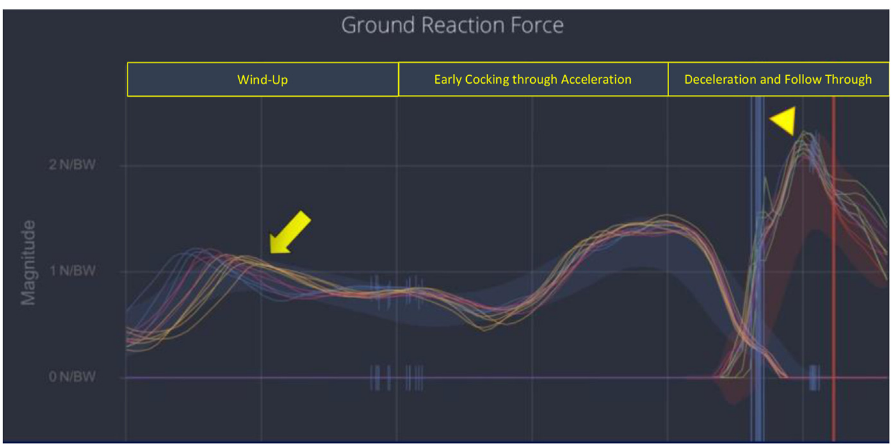

Fig. 10. Demonstrative ground reaction force curve of the drive leg (*arrow*) and stride leg (*arrowhead*) during the pitching motion. Forces measured in Newton per body weight over-time. Labeled phases of the pitching motion correlate with those noted in **Fig. 6**.

SUMMARY

Shoulder instability in overhead athletes can be debilitating with variable presentation, making it difficult to manage. In general, treatment begins with conservative management with a focus on reinforcing proper mechanics with rehabilitation that targets strengthening shoulder stability. When this fails or there is an acute or severe injury, operative management may be indicated. During labral repair and capsulorrhaphy, it is important to understand that some level of laxity relates to performance in an overhead athlete, such that overstabilization may impede ability and affect performance. The incorporation of video-motion analysis of overhead athletes may serve as a way to proactively detect pathomechanics and either improve postoperative rehabilitation or avoid injury before onset. Further multicenter randomized control trials focusing on surgical techniques, improvements in rehabilitation monitoring, and biomechanical analysis are needed to progress the management of shoulder instability in the overhead athlete from reactive to proactive.

CLINICS CARE POINTS

- In-season management is variable and should consider bracing, physical therapy, time away from sport, and surgical fixation based on the presentation and athlete preference.
- Despite heterogenous long-term outcomes, labral repair remains standard in the treatment of shoulder instability for overhead athletes.
- During labral repair and capsulorrhaphy, some level of laxity relates to performance in an overhead athlete. Overstabilization may impede ability and affect performance.
- Operative fixation of the rotator cuff will more than likely conclude overhead athletes' careers.
- Physical therapy is variable by sport and type of instability. Protocols should be based upon expected progression in the context of the athlete's sport.

DISCLOSURE

The authors have no relevant disclosures.

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