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Management of common upper extremity injuries in throwing athletes: a critical review of current outcomes

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Given the rising incidence and prevalence of shoulder injuries in throwing athletes, this review aims to evaluate management options and outcomes of common shoulder injuries in overhead throwers. Laxity of the glenohumeral joint is often adaptive for overhead athletes to achieve the velocity necessary to compete in the professional ranks. Surgical repair of the stabilizers of the humeral head—specifically the labrum and rotator cuff—often causes inflammation, scarring, and overtensioning of the glenohumeral joint which lead to poor postoperative performance. Thus, nonsurgical management should be exhausted in this population before considering surgical intervention.

Since 1998, there has been a steady increase in the number of injuries per season in Major League Baseball (MLB). In 1998, less than 400 players were placed on the injured list (IL) each season, compared to today's annual rate of over 500.[10,45] This trend is not limited to the pros, as rising injury rates plague the sport at all competitive levels.

The shoulder accounts for 21%-35% of all injuries in the professional ranks.[20,45] Chalmers et al reviewed data from all professional baseball players undergoing shoulder procedures from 2012 to 2016 and found the incidence of shoulder surgery to be 1.48%, with 60% of the players being pitchers.[7]

The throwing motion places significant stress on the soft-tissue stabilizers of the glenohumeral joint, predisposing the shoulder to injury. Fleisig et al designated two points in the throwing motion where the shoulder pushes its physiologic limits: just before maximal external rotation and just after ball release.[22] When the shoulder is abducted and maximally externally rotated, the glenohumeral stabilizers need to generate 67 N-m of internal rotation torque and 310 N of anterior force to keep the humeral head stabilized in the glenoid.[22] Also, at this point, the high degree of external rotation can cause subacromial impingement of the rotator cuff. Similarly, just after the pitcher releases the ball, the shoulder musculature needs to generate 1090 N of compressive force on the joint to prevent subluxation or dislocation of the humeral head.[22] The tensile strain results in microtrauma to the soft-tissue stabilizers of the shoulder at these two instances. With repetition, the microtrauma accumulates, increasing the likelihood of shoulder injury.

While the literature has yet to evaluate the relationship, the global trend of year-round training and increased throwing volume is thought to be a reason for the ballooning injury rates. Poor postinjury and/or postoperative performance significantly impacts a player's ability and career. Furthermore, the cost of paying players on the IL and their replacements across MLB is closing in on $750 million a year.[10] For these reasons, this review aims to critically evaluate the existing literature and give an overview of the current concepts specific to overhead throwing athletes, detailing the optimal management strategies and their outcomes.

The throwing motion

There are 6 phases to the throwing motion; each is a step in a kinetic chain sequentially transferring energy from the legs and trunk through the arm to the ball.[4,22] The first phase is the windup phase in which the pitcher generates potential energy with the lead leg. During the next phase, the stride phase, the lead leg steps forward while the back leg pushes off the mound, extending the pitcher's center of mass toward the home plate. In the previous two phases, the trunk is closed to the plate, but at the beginning of the

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arm cocking phase, rotation of the pelvis opens the trunk to the plate, maximizing the angular velocity of the pelvis and upper trunk. At this time, the throwing shoulder is abducted to 90°, reaching maximal external rotation with the elbow flexed to 90°.

The arm acceleration phase begins at the instant the arm reaches maximal external rotation. The energy created by the rotation of pelvis up through the trunk is translated to the arm as the shoulder internally rotates, the elbow extends, and the wrist flexes, transferring energy through the ball. This is followed by the deceleration phase during which eccentric forces and torques imparted by the upper extremity muscles dissipate the energy from the accelerating arm. After the deceleration phase, the pitcher enters the final phase of the throwing motion in which the back foot hits the ground as the pitcher readies himself to field the ball.

While deficiencies in any phase that distracts from the entire kinetic chain can contribute to injury, the acceleration and deceleration phase are responsible for most shoulder pathology.[22] During the acceleration phase, external rotation and abduction of the humerus can impinge the rotator cuff between the greater tuberosity and the posterosuperior glenoid or the acromion.[27] Tension through the biceps tendon during this phase can pull the labrum from the glenoid rim. During the deceleration phase, the rotator cuff is stressed as it eccentrically contracts to slow the arm. Contraction of the biceps to oppose extension of the elbow also stresses the labrum via the long head tendon.[6]

Superior labral anterior-posterior tears

Superior labral anterior-posterior (SLAP) tears are considered one of the most devastating injuries to the career of an overhead throwing athlete. The repetitive overhead throwing motion creates a torsional force directed through the biceps tendon, anchored on the superior aspect of the labrum. This process is known as the "peelback" mechanism because the superior labrum is "peeled" off the bony glenoid rim and torn.[6]

SLAP tears are not always symptomatic.[1] Tearing increases the mobility of the glenohumeral joint and can lead to improvements in external rotation and athletic performance. While these adaptive and asymptomatic tears should not be treated, those that cause pain and decreased performance need to be addressed.[1,30] The three main management strategies include conservative physical therapy, arthroscopic SLAP repair with suture anchors, and biceps tenodesis. Overall, more than 60% of professional baseball players return to play (RTP) after sustaining a pathologic SLAP tear, with rates in position players exceeding those of pitchers.[21]

All athletes should begin with conservative management. Most players respond well to conservative treatment, which should focus on improving total rotation and internal rotation at 90° abduction in addition to balancing force couples and improving function along the kinetic chain and throwing mechanics.[26] This can be accomplished through trunk strengthening, scapular stabilization, and capsular stretching with maneuvers such as the sleeper's stretch. Improvements in these measurements after 2 months of nonoperative treatment are associated with successful outcomes, as are youth (younger than 26 years) and a shorter symptomatic period. Athletes that complete nonoperative treatment successfully RTP at 6 months on average, compared to 12 months in their surgical counterparts.[26]

Surgical management has less than optimal outcomes in overhead throwers. Rates of RTP after surgery are around 50%-60%.[21,49] While return to previous level of play (RTPP) is less than 50%, most players that RTP also achieve their previous level of performance.[49] A 3:1 matched case-control study of 119 professional baseball players by Chauhan et al found that throwers who underwent SLAP repairs before being drafted had a higher risk of placement on the IL and pitched fewer innings than nonoperative controls.[9] However, there was no difference in organizational advancement between the two groups. At the MLB level, players that underwent surgical management pitched fewer innings than nonoperative controls and averaged only 3 years in the league postoperatively. Thus, surgery should be avoided if possible and should only be considered after failure of conservative management.

Biceps tenodesis is growing in popularity as a surgical treatment, having shown excellent results in studies examining active populations. However, the initial studies examining elite throwers are not encouraging. One retrospective study of 17 professional baseball players that underwent biceps tenodesis found a 35% RTP rate in pitchers versus an 87% RTP rate in position players.[8] A recent systematic review of 8 articles, covering a total of 99 baseball players, by Frantz et al reported RTP rates of 69% in recreational overhead athletes, 80% for collegiate athletes, and 60% for professionals.[23] These results further demonstrate that the procedure is an excellent primary intervention for younger and recreational athletes but should continue to be a salvage procedure for failed SLAP repair in elite throwers.

Labral repair with suture anchors remains the standard for operative management of SLAP tears in overhead athletes. The outcomes remain suboptimal, so conservative management should be aggressively pursued before electing operative treatment. Biceps tenodesis has shown positive results in athletic populations but should be reserved for revision surgery because of unsatisfactory outcomes in elite throwers and concern regarding the stability of the glenohumeral joint in this population.

Posterior shoulder instability

In baseball, posterior shoulder instability can result from a head-first slide or dive where a posteriorly directed force is applied to an adducted shoulder, stressing the posterior labrum. The resulting increase in posterior translation of the humerus in the glenoid is especially concerning if the injured shoulder is the dominant throwing shoulder. In some cases, hitting can lead to posterior instability or batter's shoulder, which occurs as the adducted lead arm absorbs a posteriorly directed force during the swinging motion, resulting in posterior subluxation/dislocation with spontaneous reduction.[29]

Diagnosis is difficult because patients often present with pain rather than gross instability (75% vs. 3%).[28] On occasion, players may be able to recount a specific, traumatic event that caused the symptoms, but many times, this is nonspecific. Special maneuvers for posterior instability include the Kim test, Jerk test, circumduction test, posterior load-and-shift test, and posterior stress test.[33] The examination elicits instability in most patients, but this finding is not specific to posterior instability.[28] Magnetic resonance imaging (MRI) is often necessary to confirm the diagnosis and is most effective when used in conjunction with physical examination findings.[28,44]

Involvement of the throwing shoulder presents more hurdles to RTP. Switch hitters and left-handed hitters who throw right-handed often experience symptoms while throwing because the lead shoulder is also the dominant throwing shoulder.[2] As the throwing motion is sensitive to shoulder pathology, RTP outcomes for pitchers are poor compared to position players.[28]

Nonoperative management prioritizes rest, pain management, and the development of proper mechanics. Emphasis is placed on strengthening the hips and core as proper mechanics throughout the kinematic chain is essential to prevent injury. Once athletes have regained full range of motion, they can resume strength training and hitting. For those athletes, whose lead shoulder and throwing arm are the same, the hitting and throwing rehabilitation

need to be staggered to avoid overstressing the shoulder. In some cases, it may take up to 12 weeks to determine if nonoperative treatment is successful.[2]

The most common operative management of choice is an arthroscopic capsulolabral stabilization procedure using suture anchor fixation on the posterior labrum, typically without capsular plication. DeLong et al produced a systematic review of 53 publications covering open or arthroscopic surgical management and found that operative outcomes are excellent in the overall athletic population with 92% returning to play and 67% returning to previous performance.[12] However, the rates declined in overhead throwers, yielding a RTP rate of 84% and RTPP rate of 58%. Several studies in the literature had similar findings with RTP rates ranging from 75% to 91% and RTPP rates near 60%.[5,12,28,33,46,50] In a retrospective review of 32 baseball players undergoing arthroscopic repair of the posterior labrum, Kercher et al found that outcomes were significantly worse in pitchers, as they returned to their previous level of performance at a rate of 41% compared to 86% of position players.[28] The study also found that those at the professional level had better RTP rates than collegiate and high school athletes.

Rate of recurrent instability in overhead throwers was found to be 12%, which is slightly higher than the 8.58% rate in the overall athletic population.[12] Better RTP rates are correlated with suture anchors while anchorless sutures account for most postoperative failures.[12,33,46] Bradley et al noted that underestimation of capsular laxity is a common factor contributing to failure.[5] In a throwing population, McClincy et al discovered that intraoperative findings of an intact posterior labrum and treatment with anchorless sutures lead to significantly worse RTP rates.[33] The authors postulated that the use of suture anchors creates a more aggressive capsular shift, thus accounting for underestimation and creating better outcomes. Average time to RTP ranges between 6 and 12 months as reported in the literature, but most studies report returns closer to the 6-month mark.[28,33,50]

Posterior instability in throwers can be a result of traction to the posteroinferior glenoid in cases of a contracted posterior capsule or extension of superior labrum pathology associated with internal impingement. Because many of these changes are adaptive and advantageous to throwers, surgical management has produced suboptimal outcomes and should only be considered after attempting extensive conservative treatment.

Traumatic/anterior shoulder instability

Anterior shoulder instability most often results from trauma and is relatively rare in the baseball population and, thus, is not well studied in throwers. This injury most often occurs in the throwing shoulder because of a collision or sliding headfirst into a base. While infrequent, the throwing motion places the arm in a position of abduction and maximal external rotation, which is the position most susceptible to anterior subluxation.[15] Therefore, this injury in overhead throwers needs to be managed carefully.

Nonoperative treatment has limited use in the throwing population, as it typically involves bracing and avoiding overhead movements.[15] While this can be achieved in contact sports such as football or rugby, where this injury is common, the overhead motion of the shoulder is critical to throwers and cannot be avoided or limited. Furthermore, success after nonoperative treatment in the total athletic population is poor with a high rate of recurrent instability based on sport and age of patient.[13,14]

In comparison to other shoulder pathologies, operative treatment is considered best for anterior shoulder instability because the ligamentous stabilizers of the glenohumeral joint are tightened and stabilized. Gulotta et al examined management and outcomes of anterior capsule injury in throwing athletes.[24] Both arthroscopic and open techniques returned good results with 80% of athletes returning to preinjury level of play at a mean of 13.3 months after surgery.

Limited research has shown that glenoid defects are smaller in baseball players, making them better candidates for arthroscopic Bankart repair.[39,40] The procedure has great RTP results in the nondominant arm of all players, and in the dominant arm of position players, with 89%-100% of players meeting the criterion of returning to play in 10 or more games postoperatively.[43] Pitchers undergoing a Bankart repair on the dominant shoulder often have poorer outcomes than their peers. Rehabilitation after repair can be extensive, often lasting 7-9 months.[43]

Rotator cuff tears

The rotator cuff muscles provide dynamic stability to the glenohumeral joint and is essential to throwing. Lesniak et al found a significant correlation between the number of career innings pitched and presence of rotator cuff tears in asymptomatic pitchers.[30] The presence of these tears, however, was not related to future placement on the DL. Another study found that articular-sided partial-thickness rotator cuff tears were not correlated with shoulder pain and weakness and are unlikely to be pathologic in nature.[35] While repetitive throwing and overuse lead to rotator cuff tearing, changes are often asymptomatic.

Asymptomatic partial tears often have little to no effect on performance, but most will progress over the course of 2 seasons.[42] Trends show a decline in performance leading up to the injury, with one study noting that walks and hits per inning pitched increased and innings pitched declined significantly 2 years after damage is noticed.[42] After repair, performance metrics slowly improve, trending back toward baseline.[25,41] Players that successfully RTP can have better performance than controls, but do not often reach their personal baseline of success, with presurgical innings pitched being approximately 40 innings higher in the two seasons before surgery.[41]

After failure of physical therapy, debridement or repair is often the primary surgical intervention. Debridement, if indicated based on the tear size, is favored over repair in professional baseball players as outcomes are superior. The literature demonstrates a 50.8% RTP rate for debridement versus a 33.3% RTP rate in those professional baseball players undergoing repair.[17] The average time to RTP after surgical management is 8.3 months, with a range of 4.8-10.7 months.[47]

RTP rates for overhead throwing athletes of all skill levels undergoing surgical management are encouraging, averaging around 75% or greater.[31,37,47] However, RTPP rates are unsatisfactory, ranging from 40% to 75%, with most studies finding outcomes nearer 40%.[7,31,47] A metanalysis of 15 studies, including 347 athletes that underwent arthroscopic rotator cuff repair, by Altintas et al reported 79% RTP rate among baseball and softball players, with only 38% of the athletes returning to at least the same level of play.[3] Injuries to the rotator cuff are seldom isolated, and poor outcomes are often associated with concomitant pathologies.

In the overhead thrower, rotator cuff tears begin because of repetitive microtrauma from overuse. Asymptomatic tears can quickly progress to pathologic tears, significantly affecting athletic performance. Outcomes of surgical management are poor in the elite thrower population, so conservative management should be prioritized. If conservative management fails and the tear size and thickness are amenable to it, debridement avoids overtightening the glenohumeral joint and is a better primary option than repair. After surgical management, athletes that were above-average performers before injury can still perform above-average but

Table I
Latissimus dorsi, teres major, and subscapularis events in professional baseball players from 2015 to 2019.

Level of play	2015	2016	2017*	2018*	2019*
Minor	107	99	111	117	114
MLB	21	34	25	44	44
Total	128	133	136	161	158

Data obtained from Major League Baseball's (MLB's) Health and Injury Tracking System (HITS) database.
*Includes events labeled with the ICD-10 "Strain of other muscles, fascia and tendons at shoulder and upper arm level".

Table II
Latissimus dorsi, teres major, and subscapularis events in professional baseball players from 2015 to 2019 that caused players to miss playing time.

Level of play	2015	2016	2017*	2018*	2019*
Minor	96	82	98	99	114
MLB	17	23	21	26	44
Total	113	105	119	125	158

Data obtained from Major League Baseball's (MLB's) Health and Injury Tracking System (HITS) database.
*Includes events labeled with the ICD-10 "Strain of other muscles, fascia and tendons at shoulder and upper arm level".

often fail to reach their personal preinjury baseline level of performance.

Latissimus dorsi, teres major, subscapularis

Injury to the latissimus dorsi (LD), teres major (TM), and subscapularis (SS) is less common in overhead throwers than pathologies in the shoulder girdle and elbow. Consequently, they are often overlooked and, if missed, can lead to poor performance and impaired ability to RTP. In recent years, there has been a consistent increase in injury to these structures and lost time according to MLB's Health and Injury Tracking System (HITS) database (Tables I and II). The LD originates at the spinous processes of the T7-T12 vertebrae, lower ribs, and iliac crest and inserts in the intertubercular sulcus of the humerus. The TM originates from the inferior angle of the scapula dorsally and inserts on the medial edge of the intertubercular sulcus of the humerus. The muscles are so closely related that the tendons can become confluent before inserting on the humerus, meaning that both tendons are often injured at the same time. SS is an intrinsic stabilizer of the shoulder, originating on the anterior scapula. The insertion on the lesser tubercle of the humerus, however, allows this rotator cuff muscle to act synergistically with LD and TM. Given the insertion point, these muscles function as internal rotators of the humerus and are activated during the late cocking phase and acceleration phase of the throwing motion.[48]

Tears of LD and TM have excellent prognoses in overhead throwers. Research has shown that 80%-90% of players RTPP, most often after nonoperative treatment.[16] Nonoperative management consists of rest and pain control followed by stretching to improve range of motion and strengthening the core muscles and lower body, as weakness can alter the kinematic chain and lead to shoulder injury. Once range of motion is restored, the athlete progresses through a throwing program. Time to RTP after conservative management is relatively quick compared to other shoulder pathologies, averaging 100 days or 3 months.[19,34,38,48]

Surgical management is avoided if possible because exposure of LD/TM footprint places the axillary and radial nerves at risk for injury. However, if nonoperative management fails or there is significant tendon retraction, surgery is necessary to reattach the tendons to the intertubercular sulcus of the humerus. Athletes that undergo surgical management (typically in the setting of higher grade tears) have similar RTPP outcomes to those who elect conservative treatment but take much more time to RTP, usually between 5 and 8 months.[34,48] These outcomes reflect that, with regard to performance, there is no significant difference in postoperative performance between conservative and surgical treatments. In fact, players undergoing conservative treatment logged increases in walks and hits per inning pitched and decreases in games played.[16] Given the success rates of conservative treatment and the lengthier recovery time for operative management, it is best to pursue nonoperative treatment. However, Erickson et al concluded that grades III and IV tears should be given special consideration for surgery and proposed a reliable MRI grading system to assess the grade of tears to aid in diagnosis and management[18]

Management strategies and outcomes of SS injuries are not well documented in the literature. We believe that this warrants further investigation as the incidence of these injuries is on the rise in the professional baseball population.

Throwers that suffer injury to the LD and TM have great outcomes independent of the treatment modality. Conservative management should be prioritized on account of success and faster RTP. Injuries should be graded by MRI to isolate grade III and IV tears which need special consideration for operative management.

Pectoralis major

Strains and tears of the pectoralis major are common among overhead throwers; however, there are few articles in the literature that detail management and outcomes of such injuries in this population. Pectoralis major functions as a strong adductor, internal rotator, and flexor of the humerus, while providing dynamic stabilization for the glenohumeral joint. Thus, this muscle plays an integral role in pitching kinematics and is susceptible to strain or tear from repetitive microtrauma. However, the muscle is most often injured during weightlifting, typically during the eccentric contraction phase of a bench press. Weightlifting is a staple of any athlete's training regiment, putting all types of athletes at risk. Owing to the important function of pectoralis major in shoulder movement and stability, injury to this muscle can be especially devastating to overhead throwers.

Bone tunnel, suture anchor, and cortical button repair techniques are all used to anchor the pectoralis major tendon to the

humerus, but recent studies most commonly report the unicortical button repair technique.[51] Yu et al reported that in their systematic review, 90% of patients returned to sport after pectoralis major tendon repair at a mean time of 6.1 months.[51] Seventy-four percent of these patients were able to return to their preinjury level of sport. A retrospective cohort study by Cordasco et al found results consistent with the existing literature in patients undergoing cortical button repair with all patients returning to sport at an average of 5.5 months postoperatively.[11] Mooers et al examined patients undergoing suture anchor repair and found similarly high rates of patient satisfaction and return to sport.[36] Similarly, a case series by Liu et al found that patients undergoing both unicortical button and suture anchor repair exhibited significant functional improvements with a low complication rate.[32] The authors noted that while most athletes return to sport, only 50% reach their preinjury level of intensity.

While outcomes are excellent after repair of pectoralis major ruptures in an athletic population, the literature mainly examines strength outcomes. Prior studies focus on athletes in contact sports, such as football or martial arts, and weight training. As seen in many other shoulder injuries, overhead throwers often have significantly greater deficits in functionality because of the high demand placed on the shoulder. As an integral component of dynamic glenohumeral stability, internal rotation, and adduction, we would expect to see poorer outcomes after pectoralis major injury in the overhead throwing population than in other athletes. Future studies should focus on this subset of athletes to develop a better understanding of pectoralis major injury in throwers.

Conclusion

The performance of overhead throwers depends on the exceptional range of motion and dynamic forces on the glenohumeral joint and surrounding soft-tissue structures. Injuries to the shoulder can significantly impact a player's ability to compete and need to be managed with great care and caution. Adaptive changes to the capsule and biceps labrum complex allow for increased scapular clearance and external rotation in the abducted and external rotation position. When these changes become pathologic and require surgical management, outcomes are less favorable. Operative repair of structures that are not intrinsic stabilizers of the glenohumeral joint, such as LD, TM, and pectoralis major often has excellent nonoperative and surgical outcomes. In all circumstances, nonoperative management should be exhausted in throwing athletes, focusing on optimizing all aspects of the kinetic chain before considering surgical treatment.

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