Shoulder and Elbow Injuries in the Adolescent Throwing Athlete

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ABSTRACT

Shoulder and elbow injuries in the adolescent population can be generally divided into skeletally immature and skeletally mature. Skeletally immature injuries refer to damage to the open growth plate (physis) in the young athlete, which have distinct differences in long-term risks if not managed correctly due to the potential for growth disturbance. Skeletally mature injuries occur in athletes with closed growth plates and are less likely to limit growth potential. It is important to recognize these different types of injuries, as well as the patients most at risk for each type because treatment may vary significantly between the two groups. The main skeletally immature injuries covered by this review will include: medial epicondyle apophysitis ("Little Leaguer's elbow), medial epicondyle fractures, olecranon stress fractures, capitellar osteochondritis dissecans (OCD), and proximal humeral apophysitis ("Little Leaguer's shoulder"). The skeletally mature injuries discussed will include: valgus extension overload syndrome (VEOS), ulnar collateral ligament (UCL) tear, shoulder instability, and superior labral anterior-posterior (SLAP) tears. We will review the history and presentation of the injuries as well as different treatment strategies and return to play guidelines for both primary care sports physicians as well as orthopedic surgeons.

INTRODUCTION

Youth sports are ubiquitous across America, and on any given weekend, millions of adolescents participate in baseball and softball. An estimated 2.4 million children participate in baseball and softball through the Little League organization alone.[1] Children and families devote significant time, money, and effort into children's participation in youth sports. According to the Aspen Institute's 2019 state of play report, 71.8% of all kids between the ages of 6–12 participated in some type of sport in 2018, with families spending an estimated $693 on sports per child, with baseball specifically costing families $660 per child.[2] With high participation rates as well as increasing trends towards sport-specific specialization, there is also a non-trivial amount of pain and injury associated with overhead youth throwing sports such as baseball and softball. In 2019 it was reported that children on average play 1.8 different sports, versus 2011 when this number was 2.1, indicating that single sports specialization continues to be an ongoing problem.[2]

A recent study found that the most commonly diagnosed injury in baseball sustained in both practice and competition were strains/sprains, accounting for 39% and 44% respectively of the 52,889 total estimate of national injuries.[3] Hand/wrist (14.6%), shoulder (13.9%), and arm/elbow (11.6%) injuries accounted for a significant burden. Ultimately, 11.0% of injuries sustained in competition required surgery, compared to 2.8% of injuries sustained in practice. Demographics and injury breakdown were similar for softball injuries; however, total softball injury rates were significantly greater than baseball injury rates (RR 1.38, 95% CI 1.12–1.71).[3] Additionally, Trofa et al published data from baseball injuries presenting to US emergency rooms between 2006–2016 revealing the overall incidence to decrease by 11.7% during that time period. However, these injuries still accounted for an estimated 54,777 injuries per year.[4] The most common sites of injury were the upper extremity (36.3%) and face (26.2%), and the most common diagnoses were contusion (26.8%), fractures (23.6%), and strains/sprains (18.7%). The data revealed elbow injuries to have increased over that time period, accounting for 17.7% of total injuries. The only mechanism of injury to have increased in correlation with the increase in elbow injuries in this data set was throwing, further emphasizing the role of throwing as a source of potential injury in youth athletes.

Multiple epidemiologic studies published within the last 2 years reveal the increasing role of overuse in shoulder and elbow injuries in youth throwing sports. Previous publications estimated overuse in adolescent athletes to be the cause of 50% of all injuries in this population.[5] Saper et al's 2018 publication of injuries from 2005–2015 in high school baseball players, showed that shoulder and elbow injuries in this population were caused by overuse in 71.3% and 73.9% of cases, respectively.[6] Factors associated with increased risk for shoulder and elbow injury included: increased height, increased pitch velocity, pitching for multiple teams, and pitching through fatigue, with factors related to overuse and fatigue having the strongest contribution to risk.[7,8] This is consistent with the current body of literature surrounding burnout and overuse injuries in youth sports and

the relationship to early sports specialization and excessive sport volumes.[9] Even "healthy" young baseball players report arm or shoulder pain at alarmingly high rates; in a 2013 survey of summer league players with an average age of 15.2 years, 74% reported playing with arm pain or fatigue.[10] In the same survey of summer league youth baseball players, 46% reported being encouraged to play even though they were having pain.[10] A 2010 prospective cohort study from Lyman et al of 298 youth league pitchers conducted over two seasons revealed 26% and 32% of players reported elbow and shoulder pain respectively.[11] Risk factors for reporting elbow pain included playing baseball in multiple leagues, decreased self-satisfaction, arm fatigue during play, and throwing fewer than 300 or more than 600 pitches during the season.[11] Risk factors for reporting shoulder pain included decreased self-satisfaction, arm fatigue during pitching, throwing greater than 75 pitches in a game, and throwing fewer than 300 pitches during the season.[11] Additionally, Major League Baseball (MLB) has funded a large amount of research to form the "Pitch Smart" guidelines to help prevent youth injury with regards to innings pitched and rest times after throwing (**Table 1**).[12] Additionally, this research has shown that pitchers who exceed 100 innings in one season are up to 3.5 times more likely to sustain injury.[13]

Table 1. MLB Pitch Smart Guidelines for Youth Pitchers[12]

Age	Daily Max (Pitches in Game)	0 Days Rest	1 Days Rest	2 Days Rest	3 Days Rest	4 Days Rest	5 Days Rest
7–8	50	1–20	21–35	36–50	N/A	N/A	N/A
9–10	75	1–20	21–35	36–50	51–65	66+	N/A
11–12	85	1–20	21–35	36–50	51–65	66+	N/A
13–14	95	1–20	21–35	36–50	51–65	66+	N/A
15–16	95	1–30	31–45	46–60	61–75	76+	N/A
17–18	105	1–30	31–45	46–60	61–80	81+	N/A
19–22	120	1–30	31–45	46–60	61–80	81–105	106+

HISTORY AND PHYSICAL EXAM

Obtaining a thorough history and physical exam can accurately diagnose many of the pathologies noted above. Patient sex, age, sport and position(s) played, number of teams, seasons played, and pitch counts are all crucial for formulating a differential. Obtaining a thorough "throwing history" of when the athlete experiences pain is also crucial to making the correct diagnosis. For players who are pitchers, it is important to inquire about what types of pitches they throw ((2-seam/4-seam FB, curve, changeup, other off-speed pitches), as well as when the pain occurs, where the pain occurs, how often they pitch, and how many months of the year they pitch. (**Appendix 1.** Sample patient intake form used in our practice to obtain a throwing history)

SKELETALLY IMMATURE INJURIES

Medial epicondyle apophysitis

Also known as Little Leaguer's elbow, medial epicondyle apophysitis is an example of a traction apophysitis which occurs over the medial aspect of the elbow. The medial epicondyle apophysis is the last primary ossification center to close in the elbow, closing between the ages of 15–16 in most individuals.[14] This is significant because the ulnar collateral ligament (UCL) complex of the elbow which provides primary stabilization in the elbow during throwing originates here.[15]

Medial epicondyle apophysitis occurs due to chronic valgus forces during throwing, with the greatest prevalence occurring in players aged 11 to 12 years old.[16] Sixty-eight percent of players who develop this injury report a history of elbow pain.[16] Although it may not always be symptomatic, a 1965 radiographic study of 162 baseball players aged 9–14 by Adams et al reported all 80 pitchers included displayed some degree of traction related change to the medial epicondyle.[17]

Medial epicondyle fractures

Fractures to the epiphysis of the medial epicondyle lie on the extreme end of the spectrum of traction injuries to the area and have a characteristic acute presentation. Osbahr et al described the presentation in a 2010 case series detailing 8 skeletally immature baseball players, all of whom described an acute pop with significant medial elbow pain while throwing.[18] Median time to return to play was 7.6 months, and 3 of 8 players had greater than 5mm of displacement and underwent operative management with open reduction and internal fixation. Medial epicondyle fractures are typically diagnosed on radiographs of the elbow after this characteristic presentation, and treatment depends on the degree of displacement seen on imaging, the mechanism of injury, and the patient's overall activity level (**Figure 1**).

Olecranon apophysitis and stress fractures

The olecranon is also exposed to the stress of throwing and triceps contraction during the acceleration phase generates force directly perpendicular to the olecranon apophysis (**Figure 2**).[19] Chronic forceful contractions due to throwing lead to a similar spectrum of injury as medial epicondyle apophysitis, depending on the degree of stress overload and degree of epiphyseal closure. In adolescents with an immature apophysis, olecranon apophysitis may develop. As the apophysis closes, the risk of avulsion fracture and stress fracture increases. Concurrent ulnar collateral ligament (UCL) injury has been identified as a risk factor for olecranon stress fractures in throwers and there is a significant overlap with medial epicondyle injuries[20] – both can occur with the common pathophysiological driver of chronic overuse. Patients classically present with pain specifically over the olecranon, worsened during the follow-through phase of throwing, and associated with posterior elbow swelling and decreased range of motion.

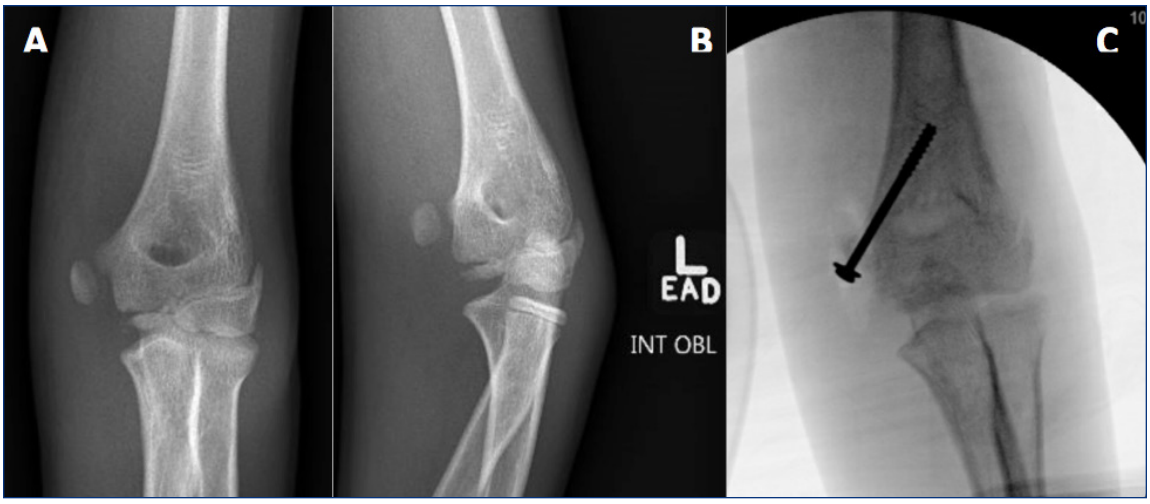
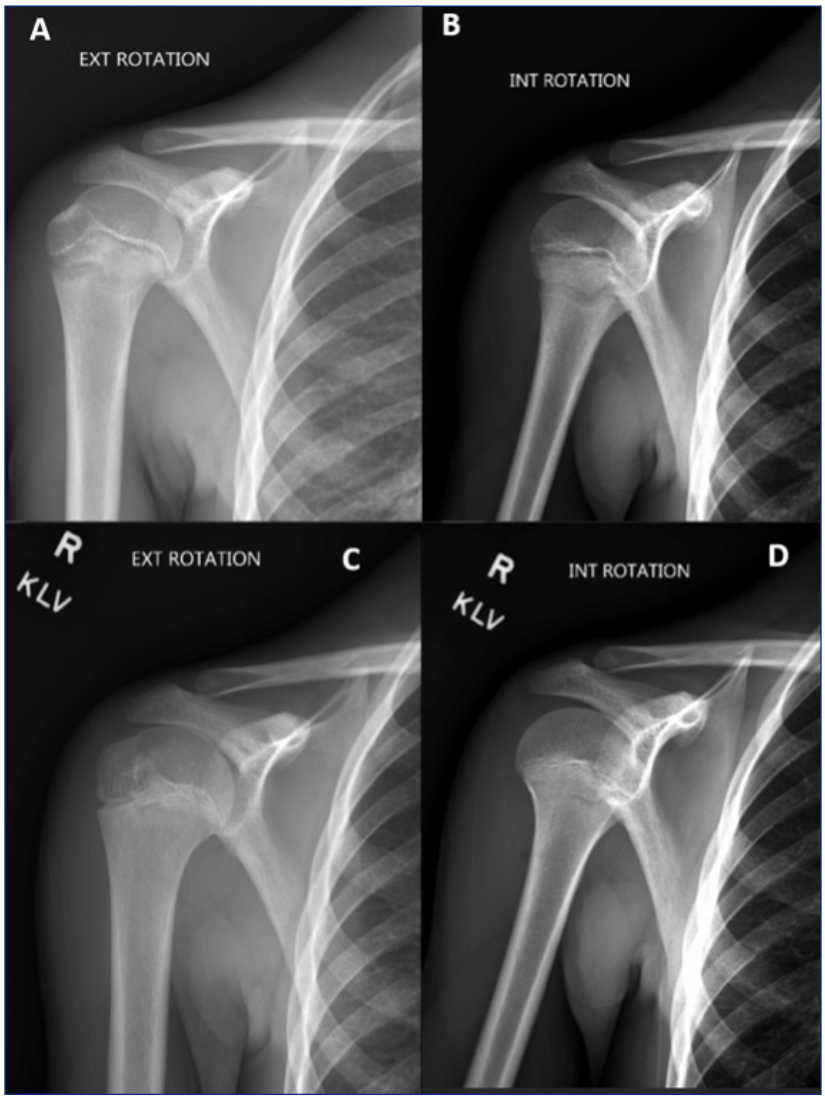


Figure 1.
[**A**] AP and [**B**] Internal oblique view of displaced medial epicondyle fracture. The internal oblique view allows for determination of the maximal amount of displacement. [**C**] Post-operative image following open reduction internal fixation of the fracture with screw and washer.

Figure 2. T2 weighted MRI in a 15-year-old catcher showing enhanced signal within the olecranon representing olecranon stress reaction (arrow).

Figure 3. [**A,B**] External and internal rotation anteroposterior views demonstrating widening of the proximal humeral physis consistent with Little Leaguer's shoulder at the time of diagnosis, and [**C,D**] following 10 weeks conservative management with throwing holiday.



Little Leaguer's shoulder: Proximal humeral epiphysiolysis

First described as "Little Leaguer's Shoulder" (LLS) by Dotter in 1953[21], LLS refers to traction apophysitis of the proximal humeral growth plate, also associated with overuse (**Figure 3**). Maximal external rotation torque occurring during the arm-cocking phase of throwing leads to shear stress on the proximal humeral epiphyseal cartilage leading to the development of LLS[22]. Patients typically describe chronic worsening pain in the throwing shoulder, occasionally even with simple lifting of the arm, which is improved by rest. Physical exam reveals tenderness over the posterior aspect of the proximal humerus in congruence with the location of the growth plate, with or without swelling.

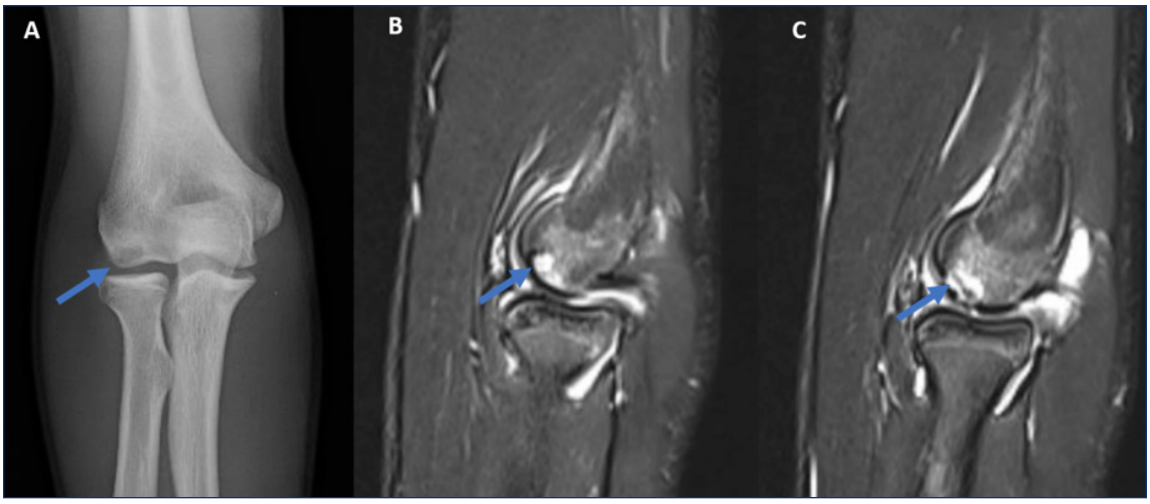


Figure 4.
[**A**] AP X-ray demonstrating lucency (row) in the capitellum consistent with capitellar OCD. [**B**,**C**] Sagittal cuts from T2 weighted MRI demonstrating increased uptake in the subchondral bone of the capitellum seen in patients with OCD lesions.

Patients may have decreased range of motion and muscle weakness due to pain. Radiographs demonstrate widening of the proximal humeral epiphysis consistent with a traction apophysitis.[23]

Capitellar Osteochondritis Dissecans

Osteochondritis dissecans (OCD) of the radiocapitellar joint is a distinct clinical entity, likely related in pathophysiology to other disorders of endochondral ossification, most notably Legg-Calve-Perthes disease. Capitellar OCD refers to the non-inflammatory degeneration of subchondral bone most commonly in the capitellum, related to excessive compressive forces and repetitive microtrauma most common in overhead and throwing athletic endeavors.[24] Patients with capitellar OCD typically present with a history of chronically worsening lateral elbow pain (relieved by rest), clicking, and flexion contractures in severe cases. Physical exam most commonly finds tenderness over the capitellum and lateral elbow with the elbow maximally flexed to best palpate the capitellum. Imaging of suspected OCD should include X-ray of the elbow and/or advanced imaging modalities such as MRI if a high clinical suspicion, as early OCD is commonly missed on plain radiographs (**Figure 4**).[25]

SKELETALLY MATURE INJURIES

Valgus extension overload syndrome

Valgus extension overload syndrome (VEOS) refers to a constellation of injuries in all three compartments of the elbow (medial, lateral, and posterior) directly related to the repetitive stress of the throwing action. The most notable finding is the development of posteromedial osteophytes, osteochondritis, and chondromalacia within the olecranon fossa.[26,27] VEOS typically presents with posteromedial elbow pain, possibly preceded by a decrease in pitch velocity and accuracy. Pain is typically worse during the follow-through phase of throwing when the elbow reaches terminal extension, and in cases with significant osteophyte burden, patients can report the sensation of locking or catching.

Physical exam typically reveals pain over the posteromedial portion of the olecranon and is sometimes associated with crepitus. Provocative maneuvers can reveal pain with terminal extension, and the elbow must also be examined for valgus instability and UCL injury. The valgus extension overload test is performed by holding a valgus force on the elbow and rapidly extending the elbow. If this produces posteromedial pain about the olecranon, this is deemed a positive test. Plain radiographs are typically diagnostic, revealing osteophytes and loose bodies.

Ulnar collateral ligament tear

The ulnar collateral ligament (UCL) complex of the elbow is the primary static stabilizer against the extreme valgus stresses occurring in the overhead throwing motion, and thus is prone to overuse injury.[28] The UCL is subject to chronic microtrauma from throwing, leading to inflammation and structural weakening, which can predispose to an acute tear. Acute UCL tear classically occurs during play with an acute popping sensation and the development of pain and ecchymosis over the medial elbow. Physical exam is generally notable for tenderness over the medial elbow and valgus instability in complete tears. Increased valgus laxity can be indicative of injury to the UCL when compared to the contralateral side. It is important to assess for medial epicondyle apophysitis or fracture, which can be ruled out with absence of pain on resisted wrist flexion and normal X-rays. MRI is the most sensitive and specific imaging modality (**Figure 5**), although ultrasound can also be useful in initial assessment.[29]

Shoulder Instability

Shoulder instability is a spectrum ranging from frank dislocation to repetitive subluxation events, and is often more associated with collision sports such as American football,

Figure 5.
T2 MRI indicating chronic UCL deficiency and thickening in the setting of an ulnar collateral ligament tear.

and rugby. However, the repetitive nature of pitching in baseball puts players at risk for shoulder instability due to microtrauma and microinstability.[30] Injuries to the labrum, both anterior-inferior (Bankart lesion), and superior (SLAP lesion), are common among baseball players, especially pitchers.[31] It can also occur in a traumatic fashion after a headfirst slide, or dive for the baseball while fielding when the arm is in the vulnerable position of abduction an external rotation.

SLAP tears (superior labral anterior posterior)

Superior labral anterior-posterior (SLAP) tears in throwing athletes are thought to be due to the extreme external rotation of the throwing movement, with a "peel-back" mechanism involving the biceps-labral junction.[32,33] SLAP tears cause a vague aching pain localized to the posterosuperior joint line. Patients typically report a loss of velocity on pitches, and pain worse in the late-cocking phase of throwing. SLAP tears can be very challenging to diagnose on exam. Multiple maneuvers have been described, including the Jobe, O'Brien, Yergason, active compression, shear and Speeds tests. However, no single test has proven reliable in diagnosing a SLAP tear and therefore a battery of tests should be performed during evaluation.[34,35]

IMAGING

Plain radiographs should be obtained as part of the standard workup. Three views (true anteroposterior, scapular Y, and axillary lateral) of the shoulder and two views (anterior-posterior and lateral) of the elbow are adequate for most shoulder and elbow injuries, respectively. An anteroposterior (AP) of the shoulder may show humeral physeal widening on internal and external rotation views, which is indicative of LLS (**Figure 3**). Comparison views of the contralateral asymptomatic shoulder can be useful to confirm the diagnosis.[23]

Elbow radiographs may reveal olecranon stress fractures, olecranon apophysitis, or medial epicondyle fractures. Displacement of medial epicondyle fractures can be determined by an internal rotation view; however, this is subject to interpreter variability (**Figure 1**).[36] Similar to the shoulder, comparison views may be indicated if the diagnosis is in question. A capitellar OCD may also be visible on radiographs, but this is not often the case and typically requires advanced imaging for diagnosis and management.[25] Computed tomography (CT) is not frequently obtained in the workup for adolescent thrower pathologies. In the case of posteromedial impingement from VEOS, a CT scan of the elbow with 3D reconstruction can be useful to identify osteophytes or fragments from the olecranon tip for surgical planning of debridement.

Magnetic resonance imaging (MRI) is indicated in certain situations. When there is high suspicion for UCL injury, an MRI of the elbow should be obtained. OCD lesions of the capitellum can be graded based on MRI findings, and treatment is directed based on the size and stability of the lesion seen on MRI. Stress fractures of the olecranon may also be identified on MRI. Compared to a conventional MRI, an MR arthrogram increases the sensitivity and accuracy of diagnosing SLAP tears, as well as Bankart lesions and other labral pathology associated with shoulder instability.[37]

TREATMENT

Nonoperative treatment with temporary cessation of aggravating activities is the mainstay of treatment for the majority of overuse injuries, especially in the skeletally immature athlete. Treatment is primarily non-operative, involving rest from throwing. Players affected by medial epicondyle apophysitis are often those who are playing the most and at the highest level in youth sports, and may need an enforced rest period of 4–6 weeks, as well as symptomatic treatment with non-steroidal anti-inflammatory drugs (NSAIDS), ice, and/or work with a physical therapist to improve biomechanics[38].

Medial epicondyle avulsion fractures, particularly those

with intraarticular incarceration, ulnar nerve entrapment, open fracture, or instability associated with a dislocation are managed operatively. However, there is significant debate regarding the degree of displacement that indicates operative intervention.[39–41] Some of this can be accounted for by the poor interobserver reliability in measurement on radiographs.[42] Classically, displacement up to 5 mm can be treated nonoperatively. Some authors advocate for stricter indications for surgery in the overhead athlete, yet no prospective randomized study has validated appropriate indications.[39]

Whether simple apophysitis or stress fracture, treatment is generally non-operative with rest from throwing, NSAIDs, ice, and physical therapy for a period of 4–6 weeks. Olecranon stress fractures should be immobilized for 4 weeks in 20° of flexion, with rehabilitative exercises starting at 6 weeks.[43] Olecranon stress fractures that fail to improve with nonoperative measures may benefit from stabilization and can result in >90% return to play rates.[44] High rates (>70%) of concomitant UCL injuries have been noted in these patients.[20]

In the case of LLS, treatment is exclusively initiated with non-operative management focused on rest of the throwing shoulder and successfully results in full return-to-play in 90–95% of players.[23,45,46] A longer time from onset of pain until rest initiation and the presence of range of motion deficits is associated with worse outcomes.[47,48] One study found that for patients with LLS, a 3-month period of eliminating throwing, coupled with physical therapy for strengthening has been shown to return 91% of patients to play.[23]

Stable capitellar OCD lesions should initially be managed conservatively in skeletally immature athletes, as these may heal during maturity of the epiphysis.[49] However, a skeletally mature athlete with an unstable symptomatic OCD lesion can benefit from early arthroscopic debridement, microfracture, and in some cases osteochondral grafting depending on size of the lesion.[50]

While skeletally mature injuries may be more resistant to non-operative management, it often is still the first line of treatment in the youth athlete. Posterior impingement caused by valgus extension overload is typically seen in older athletes, as younger patients have not yet formed osteophytes. Non-operative management, with a prescribed decrease in throwing activity and physical therapy is paramount, and symptom control achieved via ice, NSAIDS, and intra-articular glucocorticoids is used as needed. Arthroscopic or open debridement can be indicated in patients who fail non-operative management. Park et al. identified a high rate of posterior olecranon tip fractures in adolescents with VEOS and treated them successfully with arthroscopic debridement after a trial of nonoperative management.[51]

Management of UCL tears in the adolescent athlete can be controversial; however, initial management for young athletes is generally non-operative, with rest, ice, bracing, and physical therapy for 6 weeks before a gradual return to activity.[52] Elite athletes and those athletes who fail non-operative management can be considered for orthopedic referral and UCL repair or reconstruction.[53] Although the gold standard surgical management for UCL tear in competitive throwers is reconstruction, as initially described by Jobe, recent reports of successful repair have shown promising results in high school and college athletes.[53,54] The indications are limited to young patients with acute simple tears, but this technique may allow faster return to sport with no donor site morbidity.

Athletes who experience first time instability in season will often desire to return to play following non-operative management.[55] The literature has shown that frequently an athlete may return to play following approximately 3 weeks of rehabilitation; however, it is crucial to counsel these athletes regarding the risk of recurrence.[55] Recurrence can be especially high in younger athletes. Gigis et al. compared treatment of first-time dislocaters aged 15–18 that underwent conservative versus arthroscopic management.[56] Among the 27 patients managed conservatively, 19 (70.3%) experienced recurrent dislocation.[56] It is important to note that this study included patients with traumatic dislocation and their individual sport was not specified. While bracing may help limit the risk of repeat instability events, it can be severely limiting, especially in the case of throwers.[57] If non-operative management does not provide symptomatic relief and return to the same level of play, operative treatment should be performed to address the underlying pathology (either arthroscopic or open, based on the extent of the pathology present).

Likewise, SLAP tears should initially managed with focused rotator cuff and periscapular strengthening. In general, operative management is utilized for patients that fail to improve with nonoperative treatment. However, there are specific indications for more acute operative intervention for some of these injuries. SLAP tears are uncommon in adolescents, yet when they occur, nonoperative management with rotator cuff strengthening and scapular stabilization is successful in returning the majority of patients to sport. When arthroscopic repair is performed for those failing nonoperative treatment, the successful return to overhead throwing is highly variable, ranging from 22-64%, which is significantly worse than other athletes.[58]

PREVENTION

Prevention of adolescent throwing injuries may be the most important aspect of managing these patients. The majority of these injuries occur from repetitive overuse and throwing while fatigued.[8,59] Youth pitchers carry a 5% chance of sustaining a serious throwing injury with 10 years of competitive throwing. Literature suggests that pitching at high velocity, arm fatigue, pitching on multiple teams, increased pitch count per game, and participation in showcases are risks factors for injuries that require surgical intervention.[8,60,61]

Pitching more than 100 innings per year is also associated with a 3.5 times increased risk of injury. Position played has been shown to be a risk factor for injury, as pitchers have increased incidence of injuries compared to position players. It was also shown that pitchers who also played catcher were injured more frequently.[62] A nationwide survey study of youth and adolescents found that certain factors, including pitching on consecutive days, pitching on multiple teams with overlapping sessions, and pitching multiple games in one day increased odds of experiencing pitching-related arm pain.[63] Overall, overuse, pitching at high velocity or in a more competitive environment, and pitching while fatigued increase the injury risk for these young athletes. It has been shown that athletes with throwing-related pain have weakened posterior shoulder musculature, especially in their trapezius and supraspinatus, compared to increased strength in their internal rotators.[64] In professional pitchers, preseason weakness in external rotation, specifically in the supraspinatus, was associated with increased risk of throwing-related injury that ultimately necessitated operative intervention.[65] Posterior shoulder girdle muscle strengthening may be a way to help prevent throwing-related injury, especially in young athletes.[64] Working on neuromuscular control and strength of an athlete's core, scapula, and lower extremity is important in prevention of injury and postoperative rehabilitiation.[66,67] A focus on developing a balanced kinetic chain during the throwing motion to promote an effective and fluid coordination of the entire body is extremely important to offload excessive stress on the shoulder and elbow joints and prevent injury while enhancing performance.[68] The American Academy of Orthopedic Surgeons and Little League has made recommendations for the maximum amount of innings pitched in one game and one week based on age, the number of days of rest needed based on the amount of pitches thrown in the previous game, the maximum number of pitches in one game, and the appropriate age when different pitches should be learned (change-up, curveball, slider, etc.).[67] It is also important to educate players, parents, and coaches, and conduct regular screening and monitoring of those with at risk.[63,69]

CONCLUSION

Overuse injuries in the adolescent throwing athlete can be very common, and typically affect the shoulder and elbow. Providers of all types are likely to see these injuries, but primary care physicians are often the first line of defense in the prevention and diagnosis of this long list of potential issues. A thorough throwing history and physical exam are extremely important in making the correct diagnosis, with early referral to physical therapy and orthopedic surgery for proper management. By better educating players, coaches, and parents, these injuries can potentially be avoided, helping maximize playing time and minimize the time needed for operative intervention.

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