A review of shoulder injuries in young athletes

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Contributions: (I) Conception and design: D Solomon, P Cagle; (II) Administrative support: None; (III) Provision of study materials or patients: None; (IV) Collection and assembly of data: All authors; (V) Data analysis and interpretation: None; (VI) Manuscript writing: All authors (VII) Final approval of manuscript: All authors.

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Abstract: Participation in youth sports is widespread throughout the United States. Shoulder injuries can be burdensome for a young athlete, particularly in overhead sports. This article is a review of the current literature regarding shoulder injuries in athletes, with a focus on the youth.

Keywords: Little Leaguer's Shoulder (LLS); glenohumeral internal rotation deficit (GIRD); pitch counts; quadrilateral space syndrome (QSS); pediatric shoulder injuries

Received: 14 December 2017; Accepted: 08 February 2018; Published: 02 March 2018.
doi: 10.21037/aoj.2018.02.04
View this article at: http://dx.doi.org/10.21037/aoj.2018.02.04

Introduction

Participation in youth sports is widespread throughout the United States, and training is increasingly taking place at younger ages and for a greater duration throughout the year (1). It has been estimated that there are two million sports injuries annually in high school athletes, and among throwing athletes, up to 30% of injuries may involve the shoulder and elbow (2). Shoulder injuries in the pediatric population are often the result of overuse. Issues regarding pitch counts, type of pitches thrown, and constant training have become important topics when discussing injury prevention. This article is a review of the current literature surrounding sports induced shoulder pain, with a particular focus on the adolescent population.

Little Leaguer's Shoulder (LLS)

Proximal humeral epiphysiolysis, more commonly known as LLS, is a painful condition with increasing incidence (3). The condition is an overuse injury that primarily affects throwing athletes between the ages of 11–16 (4). While this injury is most commonly seen in baseball players, the injury has also been found in tennis players, swimmers, gymnasts, volleyball players, and cricket players (5,6).

LLS is caused by repetitive microtrauma to the skeletally immature proximal humerus. Unfossilized cartilage and rapid linear growth with open physes make this area susceptible (7). The mechanics of adolescent athletes may predispose them to this injury, as athletes in this age group have been found to initiate trunk rotation early during the throwing phase. Trunk rotation during the cocking phase of throwing leads to arm hyper-angulation (8). This places an eccentric load on the adductors and internal rotators of the shoulder. During the release, the physis is subsequently challenged with a distracting force. These repetitive distracting and torsional forces cause disruption in the metaphyseal-physis blood supply, which can lead to widening of the physis. This physeal widening may be considered a Salter-Harris type I fracture of the proximal humeral physis (5).

Patients will typically present with new onset lateral shoulder pain, often after increasing their pitch count or the types of pitches thrown (9). In addition, the patient may experience decreased pitch control and velocity (9). There is some evidence that recent weight gain or out of season pitching can increase risk for LLS (10).

Physical examination findings commonly include tenderness to palpation over the proximal humerus, shoulder weakness in external rotation, and pain with shoulder range of motion (11). In a recent case series by Heyworth et al., out of 95 patients with LLS, 74% displayed...
tenderness of the proximal humerus, 34% had decreased range of shoulder motion, and 30% showed glenohumeral internal rotation deficit (GIRD) (3).

Although a diagnosis of LLS is usually made based on history and physical exam findings, imaging can be helpful. Bilateral radiographs should be obtained in order to compare the affected and unaffected sides. These radiographs are also beneficial to rule out a more serious physeal injury (9). Radiographic imaging may show physeal widening and sclerotic bony and cystic changes, as well as calcification (Figure 1) (3,12). However, caution should be used in diagnosing LLS based solely on radiographs, as it has been shown that even asymptomatic athletes may reveal the typical radiographic changes associated with LLS (13). MRI is infrequently obtained, but findings will demonstrate a widened physis and increased T2 signal intensity within the physis and metaphysis (10,14). Hatem et al. demonstrated through a small case series that MRI can be diagnostic, referencing a patient with LLS in which the presumed diagnosis was thought to be a rotator cuff tear (15).

Treatment typically is non-operative, and usually consists of rest and activity modification (4). All throwing activities should be stopped for approximately three months (9). Non-steroidal anti-inflammatory drugs (NSAIDs) may be used to decrease inflammation and pain, and many patients often benefit from physical therapy (3,4). A recent study by Heyworth et al., demonstrated that on average, patients recovered within 2.6 months, with about an additional month or two before resuming competitive sport (3). In case series by Carson et al., 21 of 23 patients (91%) treated with rest for approximately three months had full return to baseball and were asymptomatic (11).

Although prognosis for recovery from LLS is excellent, the primary goal should be aimed at prevention. This is a multifactorial process, and includes coaching proper mechanics, physical conditioning, and limits on pitch counts and year-round participation (4). There are several published guidelines available for specific recommendations on throwing programs and return to play (16,17).

GIRD

Glenohumeral joint kinematics can change in an adaptive manner to chronic overhead activity. This is seen in multiple sports, but especially in baseball, volleyball, handball, and basketball (18-20). All tissues of the shoulder—bone, capsule, and muscle—may be involved (21). During normal human development the humeral head rotates from a retroverted position at birth to an anteverted position as an adult. However, when individuals begin overhead throwing at an early age, extrinsic forces on the humerus cause the humeral head to remain in relative retroversion compared to that of the non-dominant arm. This, combined with tightness of the posteroinferior capsule from chronic reactive scarring, and with scapular dyskinesis with its associated muscular adaptations, creates the constellation of mechanical changes seen in GIRD (21-23).

GIRD has been linked to shoulder pathology that ranges from anterior and superolateral shoulder pain to dead arm syndrome with shoulder instability (23,24). This association has recently been implicated in controversy, as a decrease in shoulder external rotation has also been found to be a predictor of injury (25-27). GIRD has been shown to affect players of all age groups with some evidence for progression as level of competition increases (28-30). In a study of the effect of GIRD in high school baseball players, Lee et al. demonstrated an incidence of GIRD of 21.4% in 56 individuals, which was associated with reduced isokinetic shoulder strength, higher frequency of shoulder pain, and decreased quality of life (31).

A diagnosis of GIRD is based on physical examination of shoulder motion. One method to examine patients involves positioning the patient supine. The arm is abducted to 90 degrees and internal and external rotation are measured up until the point of scapular shift on the thoracic wall (23). Definition of what constitutes GIRD has evolved over the course of the past two decades and is approximately defined at 20 degrees of internal rotational deficit compared to the
contralateral arm (21). Moreover, though gain of external rotation in GIRD is more often than not sufficient to allow the total arc of motion to remain equal and circumvent injury, deficits in total arc of motion (TAM or TROM) of greater than 5 degrees compared side-to-side has been implicated in injury (21,24). Hibberd et al. demonstrated that GIRD in youth and adolescent baseball players occurs primarily as a result of humeral retroversion rather than soft tissue tightness in an ultrasound study of 287 individuals of age 6 to 18 years (30). This suggests that early development of GIRD may differ from the pathological GIRD seen in adults that significantly involves soft tissue injury.

Studies show that the magnitude of GIRD and TROM deficits can change acutely following repetitive throwing exposure (21,32). This illustrates soft tissue involvement shifts its arcs of motion, demonstrating that dynamic stabilizers of the shoulder play an important role in prevention of injury as they safeguard the GIRD-affected shoulder from extremes of motion. Fatigue can thus predispose significantly to soft tissue injuries such as thrower's superior labral tear from anterior to posterior (SLAP) lesions and impingement (33). As such, training programs should not neglect rest and strengthening as part of the therapy regimen (22).

Prevention and treatment of GIRD-related shoulder pathology conventionally begins with stretching exercises but a systematic review of randomized controlled trials on the effectiveness of stretching programs on posterior shoulder tightness and GIRD demonstrated that the sleeper stretch alone is no more effective than no intervention, while increasing evidence supports the use of the passive cross-body stretch in improving GIRD (34). The same study included analyses of combined stretching interventions that showed limited evidence in support of combined active stretching programs (cross-body stretch, sleeper stretch, and overhead stretches) in improving shoulder range of motion. Recent evidence has demonstrated a role for adjunct manual therapy and massage techniques in improving ROM of GIRD-affected shoulders (35-37). Although available data has demonstrated positive effects using passive exercises for treatment of GIRD, there is limited evidence correlating these exercises with ultimate injury prevention.

**Effect of various pitch types**

Literature demonstrates that pitch types (fastball, curveball, change-up, slider) generally have similar kinematics with only minor differences in forearm and wrist action, and even fewer in the elbow and shoulder (38-42). Fleisig et al. performed a kinematic study involving 21 collegiate baseball pitchers demonstrating the change-up pitch is the least stressful, while the curveball and fastball have similar elbow and shoulder kinetics, with the curveball exhibiting increased forearm supination and radial to ulnar wrist motion (42,43). The authors concluded that no obvious source of injury could be identified from kinematic comparisons between pitches alone. However, a larger prospective cohort study of young baseball players of average age of 12 years demonstrated a statistically significant association of curveball with shoulder pain and slider with elbow pain, suggesting possible age group differences in their vulnerability to breaking pitches (44). Though benefits may be drawn from learning proper pitch mechanics and minimizing breaking pitches, it is likely that adhering to pitch count recommendations far outweighs these benefits in injury prevention (45).

Limited research exists on the biomechanical demands of the softball fast-pitch, as the windmill pitch is regarded as a less stressful motion as compared to the baseball pitch (46). Biomechanically, softball pitches are fundamentally different than that of baseball pitches. Rather than the asymmetrical shoulder range of motion seen in baseball players after training, Softball pitchers have symmetrical findings bilaterally, and have greater strength in the dominant supraspinatus and scapular muscles (middle and lower trapezius) (47). Corben et al. recruited nineteen softball pitchers of an average age of 15.2, and demonstrated greatest degree of asymmetrical fatigue in elbow extension, forearm supination, and shoulder adduction in the throwing arm (47). Elbow flexion was also found to have a higher degree of fatigue, which corroborate with prior EMG findings that showed the biceps brachii muscle activity being twice as high in a windmill pitch as that during the baseball pitch (48). These findings correlate with the relatively high incidence of anterior shoulder pain and overuse rotator cuff injury seen in softball pitchers (48), which should guide injury prevention methods in softball pitchers. Moreover, no such enforcement of pitch count limits currently exists in softball, which can limit efforts in injury prevention.

**Monitoring of pitch counts**

Pitching injuries have become a focus for concern among junior and adolescent baseball players, with epidemiologic studies demonstrating elbow pain in up to 58% and shoulder pain up to 35% in youth and adolescent baseball
The musculoskeletal adaptations in baseball pitching include GIRD, gain of external rotation, and increased posterior shoulder tightness. Musculoskeletal adaptations include stronger internal rotators, external rotators, latissimus dorsi, middle trapezius, and lower trapezius muscles of the dominant versus the non-dominant arm, with no significant difference in the rhomboid and supraspinatus muscles. While these observed adaptations differ drastically between the dominant and non-dominant upper extremities of adolescent baseball players, these adaptations alone do not appear to directly predict injury.

Enforcement of pitch counts should be foremost in injury prevention. In a case-control study by Olsen et al. in 2006, in which 95 adolescent pitchers who had shoulder or elbow surgery were compared to 45 controls, it was found that the injured group pitched significantly more games per year, innings per game, and had higher pitch counts during and before games. Interestingly, no differences were found regarding exercise programs, stretching practices, relieving frequency, pitch type frequency. Erickson et al. demonstrated that exceeding pitch count recommendations in Little League baseball can increase the chance of requiring ulnar collateral ligament reconstruction surgery in later career. Of a total of 62 Little League World Series pitchers that progressed to professional play, 4 exceeded pitch counts, and of these, 50% required ulnar collateral ligament reconstruction, versus only 1.7% in those who did not exceed pitch counts. In a survey study of 95 Little League coaches, knowledge of pitching recommendations for young pitchers was found to be poor, with only 35% to 62% of the pitching guideline questions were answered correctly. Furthermore, only 73% of coaches state that they follow pitching guidelines, and 29% allowed their pitchers to throw breaking pitches. Pitch count violations tend to increase with age, while the degree of pitch recommendation enforcement from coaches concurrently decreases. These findings support the correlation of shoulder and elbow overuse in youth and adolescent baseball and injury.

**Shoulder injuries in volleyball**

Volleyball is a popular international sport with a relatively healthy injury profile for the shoulder, which only accounted for 17 of 193 body part injuries out of 10,621 hours played in one epidemiological study of junior world-class volleyball. Majority of injuries resulted from the ankle, followed by the knee, the hand, and the lower back. Shoulder pain, however, appears to be a prevalent concern among young volleyball players. GIRD-associated shoulder pathology has also been implicated in volleyball in a similar fashion as in baseball, but is less well studied and does not consistently correlate to shoulder problems.

Within the smaller cohort of volleyball-associated shoulder injuries, the rotator cuff appears to play a larger role in pathology. Harput et al. demonstrated a statistically significant decrease in the acromiohumeral distance in the dominant shoulder of adolescent volleyball attackers compared to the non-dominant shoulder suggesting increased potential for rotator cuff impingement. Infraspinatus syndrome presenting as weakness of the infraspinatus muscle secondary to injury to the suprascapular nerve also appears to be prevalent in volleyball, and one kinematic study suggests that greater shoulder abduction and horizontal adduction at the moment of ball strike may contribute to traction-related injury to the suprascapular nerve. Electromyography (EMG) and nerve conduction tests corroborate these findings in professional beach volleyball players, with prevalence of infraspinatus atrophy reported to be as high as 34%.

Injury prevention for the volleyball shoulder should primarily focus on minimizing excessive force on the rotator cuff and glenohumeral joint. For instance, Seminati et al. showed that an alternative technique to volleyball spike may be less traumatic to the rotator cuff as compared to the traditional spike technique by decreasing shoulder adduction in favor of forward elevation. A randomized controlled trial performed on university volleyball, swimming, and tennis players demonstrated that sleeper stretching improves dominant shoulder internal rotation and horizontal adduction at 8 weeks' follow-up. Gouttebarge et al. performed a systematic development of an injury prevention intervention for volleyball using evidence-based multidisciplinary meetings to identify key exercises to comprise a therapy program. The 15-minute program comprehensively focused on full-body on-court exercises and stretches for injury prevention in the ankles, knees, hands, wrists, and shoulders. Though deemed too demanding as a pre-game warm-up routine, such programs can be integrated into training schedules and create grounds for improving injury prevention awareness.

**Quadrilateral space syndrome (QSS)**

QSS is an uncommon process that can manifest
in several ways, and it was recently proposed by Brown et al. that this syndrome has two separate entities, vascular QSS (vQSS), affecting the posterior circumflex humeral artery (PCHA), and neurogenic QSS (nQSS), affecting the axillary nerve. QSS is most often seen in overhead athletes, including swimmers as well as baseball, tennis, and volleyball players (69). However, the symptoms can present in any patient who conducts repetitive overhead movement, such as window cleaners or yoga participants (70).

The quadrilateral space is an anatomic area bounded by the long head of the triceps medially, the medial edge of the surgical neck of the humerus laterally, the teres major and latissimus dorsi inferiorly, and the teres minor or glenohumeral joint capsule superiorly. Overhead athletes typically have a history of repetitive abduction and external rotation movements of the arm, which can lead to compression or mechanical injury to the contents of the quadrilateral space. It has been estimated that nerve symptoms are more common than vascular symptoms, with a ratio of 1:5:1 (70). Overall, there is a predilection for males over females, with a ratio of 7:1 respectively (70). This is likely due to the increased prevalence of overhead activities in male dominated sports, such as baseball (70).

Compression of the PCHA (vQSS) can cause localized thrombosis and aneurysm formation, sometimes leading to emboli that can lead to symptoms distally in the extremity. The ischemia caused by these thrombi can manifest with pain, absent pulses, coolness, and pallor of the affected hand or digit (70). Differential diagnosis in the adolescent population may include thoracic outlet syndrome, hypothenar hammer syndrome, and autoimmune conditions such as vasculitis or scleroderma. Diagnostic imaging can be of significant value, with the use of digital subtraction angiography (DSA), CT angiography, and MR angiography being able to identify a thrombus or aneurysm of the PCHA. DSA may be particularly beneficial; in addition to diagnostic value, it can be used therapeutically for thrombolysis (70). Surgical treatment may be necessary, and often involves ligation of the PCHA in order to prevent distal embolization (70).

Neurogenic QSS has a different presentation than vQSS. The irritation of the axillary nerve is commonly attributed to fibrous bands that develop from repetitive trauma to the soft tissue within the quadrilateral space (71). Paralabral cysts have also been reported as a cause of QSS (72). Symptoms are typically varied, but often include pain over the posterior shoulder, neuropathic pain that may manifest with pain, absent pulses, coolness, and pallor of the affected hand or digit (70). Differential diagnosis in the adolescent population may include thoracic outlet syndrome, hypothenar hammer syndrome, and autoimmune conditions such as vasculitis or scleroderma. Diagnostic imaging can be of significant value, with the use of digital subtraction angiography (DSA), CT angiography, and MR angiography being able to identify a thrombus or aneurysm of the PCHA. DSA may be particularly beneficial; in addition to diagnostic value, it can be used therapeutically for thrombolysis (70). Surgical treatment may be necessary, and often involves ligation of the PCHA in order to prevent distal embolization (70).

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Dislocation

Shoulder dislocation events are relatively rare in non-contact overhead sports in the young athlete (77). The extent of bony injury also tends to be less in non-contact overhead sports as compared to contact sports (78). However, if a first-time dislocation does occur, primary reduction of the shoulder should be performed in a controlled manner. Consideration should be given to the physically fit young athlete in the closed reduction of the shoulder injury; due to increased muscle mass, it is advisable to have a low threshold for premedication with sedation, intravenous and/or intra-articular analgesia prior to reduction to minimize additional injuries to the bone or soft tissue (79).

Traditionally, immobilization for 6 weeks in a sling in internal rotation with gradual out of sling exercises, followed by at least 4 weeks of physical therapy has been
the treatment of choice for first-time dislocators (80). In cases without extensive tissue injury and with diligent rehabilitation, athletes can in some instances return to play as early as 3 weeks after injury (81). Recently however, there has been an increased trend in arthroscopic stabilization of first-time shoulder dislocators, especially in younger skeletally-mature patients and athletes at the end of the sporting season, as a result of the findings from a number of non-blinded randomized trials demonstrating its efficacy in preventing future instability events (79,80,82,83). This may be of additional pertinence to the overhead athlete for whom the mechanics of their overhead activity may predispose them to further instability events. Contrarily, the limited data that exists on that of skeletally immature patients who underwent operative versus non-operative therapy for first-time shoulder dislocation demonstrate a tendency for operative patients to do worse (84,85). Overall, current literature supports consideration for surgical intervention in first-time dislocation in the skeletally mature young overhead athlete, and in recurrent dislocation in the skeletally immature patient.

**Hypermobility (JH)**

JH, which is diagnosed when a joint has an exaggerated range of motion, may present in several ways and is involved in a variety of conditions. Joint hypermobility syndrome (JHS) is when the joint has increased range of motion in conjunction with musculoskeletal pain (86,87). This entity can exist in conditions such as generalized JHS, benign JHS, and Ehlers-Danlos syndrome (hypermobile type) (86,88,89). Children with JHS may complain of cramps in their leg muscles, especially at night (88). It may also be associated with generalized pain, fibromyalgia, musculoskeletal injuries, and anxiety (86). Conversely, El-Metwally et al. demonstrated that in Finnish adolescents, hypermobility was not predictive of future musculoskeletal pain, either traumatic or atraumatic in nature. However, follow up in this study was only 1 year, which limits its prognostic value considerably (90).

A common measurement of hypermobility is the Beighton score, a well-known criterion that measures mobility of several joints, including the hands, elbows, knees, and trunk (88). Smits-Engelsman et al. have validated this criterion in children, and noted that a higher Beighton score corresponds to increased range of motion even in joints that are not measured as part of the criteria. In their cohort of Dutch elementary school students, 35% scored 6/9 or greater on the Beighton score, which is considered hypermobile (87). It has also been described that swimmers, ballet dancers, gymnasts, and musicians have a higher prevalence of JHS (86). Hypermobility itself is not a pathology; it is only diagnosed as a syndrome when the patient is in pain due to their laxity.

Generalized JHS may specifically affect the shoulder, and this may lead to increased incidence of musculoskeletal symptoms in the head and neck area (86). In one recent study of a Danish cohort, generalized joint hypermobility was found to be prevalent in 30% of the population, while generalized joint hypermobility of the shoulder was only 5% (86). In addition, there is a high prevalence of generalized hyperlaxity in patients who have shoulder multidirectional instability (91).

JHS may be a hereditary condition (86). Em et al. showed that the enzyme prolidase, involved in collagen formation and degradation, is significantly lower in patients with benign JHS (89). Regardless of etiology, this is a disease that is best treated conservatively, and there is evidence that exercises and physical therapy can help reduce painful symptoms associated with joint hypermobility (92).

**Conclusions**

There are a variety of shoulder injuries that can affect the young athlete, and because of the open physes in the pediatric population, overuse injuries are of critical concern. It is therefore important to educate parents, coaches, and athletes about the danger of overusing the shoulder. In addition to the conditions described in this article, children and adolescents, like adults, can suffer rotator cuff tears, labral tears, and instability episodes from athletic play. The management of such injuries is beyond the scope of this focused article, yet these conditions are nonetheless important diagnostic considerations in a young athlete with shoulder pain. Although most pediatric shoulder injuries can be treated non-operatively with therapy and rest, some, such as QSS, may require surgery. During examination of all pediatric musculoskeletal complaints, global issues such as hypermobility must also be assessed. A multidisciplinary approach with emphasis on proper training is vital to the prevention and treatment of these injuries.

**Acknowledgements**

We would like to give thanks to Dr. Sheena Ranade for providing clinical imaging for this manuscript. We also
give thanks to Carolyn Kushner, for her assistance in the submission process of this work.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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doi: 10.21037/aoj.2018.02.04

Cite this article as: Solomon D, Cong GT, Cagle P. A review of shoulder injuries in young athletes. Ann Joint 2018;3:12.