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A narrative review of little league shoulder: proximal humeral physis widening is only one piece of the puzzle, it is time to consider posterior glenoid dysplasia

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Baseball athletes across all levels of play are at an increased risk for upper extremity injury due to the supraphysiologic demands on the shoulder and elbow during overhead throwing. Little league baseball players present with a unique subset of injuries that can affect the growth plate, commonly at the shoulder or the elbow. Ascertaining a diagnosis and plan of care for little league shoulder (LLS) historically focuses on the proximal humeral physis in skeletally immature throwing athletes presenting with shoulder pain. However, while not a current standard of care, posterior glenoid dysplasia is often present in youth baseball athletes presenting with LLS, warranting a shift in the way clinicians evaluate for and treat the youth baseball athlete's pathologic shoulder. Therefore, purpose of this narrative review is 2-fold: first, to describe the current standard of care as it relates to a diagnosis of LLS, and second, to critically describe a comprehensive evaluation process for youth throwing athletes with shoulder pain that includes screening for evidence of posterior glenoid dysplasia. This paper summarizes the current state of the available evidence for anatomic considerations of LLS in the baseball athletes throwing shoulder. Additionally, we provide a framework for clinical evaluation using a multidisciplinary approach to evaluate the entire kinetic chain of the youth baseball athlete presenting with LLS and posterior glenoid dysplasia. A case study is presented to describe common presentations, clinical and objective examinations, and a plan of care from time of evaluation to return to throwing.

This narrative review will present the history of our understanding of little league shoulder (LSS) and how osseous changes to the glenoid must be considered in the management of athletes with this pathology. Researchers investigating this diagnosis have conveyed that baseball players presenting with this pathology often experience shoulder pain and proximal humeral physis stress reaction, and for some players, this is true. However, information on LLS has evolved over time and should include a multidisciplinary continuum of care that should evaluate many variables that are often not discussed which include scapular dysfunction, glenohumeral motion loss, muscle weakness, kinetic chain dysfunction, and most importantly posterior glenoid dysplasia, a component to this diagnosis that many healthcare providers might not even know exists.

Little league shoulder

Nearly one-third of youth baseball players, aged 9 to 14 years, experience throwing-related shoulder pain over the course of a season.[46,47] This staggering number is impactful for clinicians as baseball is one of the most popular sports played in the United States, with more than 5.6 million children participating in 2021.[12]

Institutional review board approval was not required for this narrative review.

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LLS is among the most common causes of throwing-related shoulder pain in skeletally immature populations.[3,4,29,66] It was described by Adams in 1966 as osteochondrosis of the proximal humeral epiphysis that develops in response to repetitive traction forces sustained during the throwing motion.[1] More recent studies define LLS as an overuse injury to the proximal humerus that results in damage to the epiphysis in response to throwing-related traction and rotational stresses.[3,4,29] With a variety of descriptors in the literature including epiphysiolysis, epiphysitis, apophysitis, stress fracture, and Salter-Harris Type I fracture, LLS has become more of a clinical diagnosis and umbrella term for throwing-related shoulder pain in physically developing athletes.[4,21,34] With this in mind, and the emphasis based on physeal changes, important contributing factors such as posterior glenoid dysplasia are not being considered when making a diagnosis of LLS.

Etiology and risk factors

Despite advancements in upper extremity research, continued emphasis has been placed on investigating injury risk at the collegiate and professional levels with few studies focusing on athletes aged less than 18 years.[34] Physeal injuries are exclusive to skeletally immature populations and therefore require further study to better understand their etiology, pathophysiology, and outcomes.[3,29,34] While the mechanisms responsible for LLS are not well understood, some researchers theorized that repetitive stress placed across the humeral physis may negatively impact the blood supply to the metaphysis resulting in decreased calcification and the appearance of widening on a radiograph.[29,39,60] Likewise, stresses associated with repetitive overhead throwing have the potential to negatively impact the glenoid[84] with specific changes occurring at the anterior and posterior rim of the glenoid.[52,55] The age of onset for LLS is typically between 11 and 16 years, with the proximal humeral physis closing at or around 18 years,[85] and glenoid ossification peaking around 16 years of age.[73,85] Baseball players are the most commonly reported cases in the literature; however, any overhead sport, such as softball, tennis, volleyball, gymnastics, cricket, or swimming, may place a youth athlete at risk.[41,63,79] Risk factors associated with this condition include increased physical size (eg, height and weight), deficits in shoulder range of motion, shoulder strength imbalances, and poor pitching or sport mechanics.[3,13,29,34,79] Considerations around player position within a sport (eg, pitcher), level of competition, and year-round participation without periods of adequate rest are also thought to increase an athlete's chances of developing LLS.[1,29] Additional data are needed to better understand the impact of physical growth patterns and osseous development, including humeral retrotorsion (HRT) and the glenoid surface appearance, on injury risk in skeletally immature populations.[3,4,29,42]

Clinical assessment and diagnosis

LLS often presents to clinic in the form of a youth or adolescent baseball pitcher with tenderness to palpation at the lateral aspect of their proximal humerus and pain with overhead throwing motions.[50,63,79] Shoulder pain can be present at rest or with daily activities in more irritable cases.[79] Athletes may delay seeking care for these symptoms, as they perceive them as manageable without medical intervention.[34,41,63] This likely impacts the clinical perception of LLS, suggesting that it may be more prevalent in youth and adolescent throwers than previously considered.

A diagnosis of LLS can be made following clinical assessment, however internal and external rotation anteroposterior (AP) plain radiographs are typically ordered for each shoulder, to confirm.[4,63] Common radiographic findings include widening of the proximal humeral physis, sclerosis, demineralization, and possible fragmentation of the metaphysis near the lateral physis with the nondominant shoulder used for comparison.[14,41,50,63,79] Any radiographic changes may be subtle or difficult to detect, especially within the first 3 weeks of an athlete's symptoms.[79] Magnetic resonance imaging is not often recommended for individuals who present clinically with LLS; however, it can be used in cases where symptoms are not resolving or when radiographic evidence is unclear.[41,63,79] T2-weighted images may show physeal widening, metaphyseal and periosteal edema, and increased signal in the subchondral bone near the affected physis.[4,14] Clinical examination and diagnostic imaging have been focused on assessing changes in the proximal humerus; however, the humerus is only one-half of the affected joint. Additional research is needed to examine how changes in the glenoid surface may impact the clinical presentation, diagnosis, and return to sport (RTS) outcomes for individuals with LLS.

Past and current treatment progression of little league shoulder

Nonoperative treatment of LLS is very common among overhead-throwing athletes and appears to be the exclusive approach to managing this condition. The realm of surgical intervention remains absent from the present literature even in instances where the temporality of symptom resolution has extended beyond typical timeframes. Over the past 6 decades, symptom resolution has consistently been used as a primary criterion to determine RTS readiness after the conservative care of LLS. However, it is important to note the evolution of prescribed recommendations and additional criteria that have been used to determine RTS since the late 1960s until now.

Prior to the year 1998, prescribed treatment predominantly centered around complete rest from throwing.[1,4] Defining a specific duration of rest was uncommon, as rest was encouraged until the resolution of symptoms occurred. More specifically, the resolution of pain during glenohumeral external rotation during the overhead throwing motion and hitting.[1,5] In baseball players, many surgeons recommended using radiographic imaging to determine whether athletes could return to pitching.[1,2] While symptom cessation was frequently used to determine RTS for nonpitching positions, complete physeal closure was the standard criterion for an athlete returning to the position of pitcher.[1,2,4] In fact, in one case, a permanent change of positions from pitching was encouraged when closure did not occur.[1] Most cases had a resolution of symptoms by 3 months but because of the physeal closure criterion, RTS times ranged from 3 months to 2 years.[4]

Since 1998, much like the treatment prescribed in the early 1980s and 1990s, treatment revolved around symptom resolution. However, unlike earlier recommendations, very few reported cases incorporated considerations of anatomical closure of the humeral physes as a prerequisite for RTS.[4] One review of 23 individual cases showed that players could be asymptomatic and have continued widening of the humeral physis.[8] Radiographic imaging seems to be more commonly used in the last 25 years to compare progress of humeral physis narrowing or comparison of physis width to the noninjured side rather than as a tool for determining RTS readiness.[30] When comparing positive vs. absent radiographic confirmation of humeral physes widening, one study found that there was no statistical significance between the 2 groups with regard to LLS reoccurrence, time to symptom resolution, or RTS time.[34] Additionally, there are more cases since 1998 that incorporate a wider range of interventions such as home-based rehabilitation, chiropractic care, or formal physical therapy.[30,32] However, these additional treatments still make up the minority of reports.

Within the last 10 years, a multimodal approach to treating LLS has started to be incorporated into the continuum of care. Therapeutic interventions, symptom progression, and return to throw programs all merge to accelerate the RTS trajectory.[30,16,32,34,78] Although these interventions are becoming more prevalent in the treatment of LLS, investigations into the efficacy and long-term effects of these more holistic approaches to treating LLS are lacking. While research geared toward treatment efficacy for LLS is absent, there is one study that investigated the factors associated with RTS following LLS.[30] The authors found that 95% of players had fully returned to baseball in just less than 3 months. Interestingly, 25% of those players had a reoccurrence of pain with a subsequent full RTS that averaged more than 6 months. In addition, less than half of all ($n = 87$) baseball players had radiographic imaging that resembled the nonthrowing side, while the rest of the subjects had a narrowing of the physis but did not approach the width of the nonthrowing side.[30] These findings support the current evolution of the RTS criteria following LLS and suggest that future studies should incorporate a broader range of treatment algorithms and must radiographically assess the glenoid for potential abnormalities to help drive RTS decision-making for LLS. Future treatment procedures must include correction of all correctable kinetic chain conditions, resolution of strength, resolution of glenohumeral motion loss, and improved ossification of the posterior glenoid rim.

Considerations of the optimal duration of rest for LLS recovery remain understudied but are likely patient-specific. The efficacy of treatment interventions for LLS should be investigated. It is reasonable to suggest that a rehabilitation plan geared to improving the entire kinetic chain may benefit players sustaining this particular injury. Specific recommendations are discussed below in the case example section of this paper. Furthermore, there is a lack of key clinical objective measures reported in players experiencing LLS. This information would be useful when healthcare professionals are screening for deficits so benchmarks could be included in the RTS decision-making process.

Anatomical and biomechanical considerations of the throwing athlete

Understanding skeletal immaturity and the consequences this immaturity may have on the shoulder during an overhead throwing motion is imperative. A skeletally immature athlete has different bony and collagen composition when compared to a skeletally mature athlete. Bony changes to the proximal humeral epiphyseal physis and the glenoid do not completely ossify until late adolescences, aged 17-18 years and 16-18 years, respectively.[85] A greater production of type III collagen is present in ligaments in tendons when compared to adult ligaments and tendons which potentially contribute to laxity in the skeletally immature person.[77] The combination of bony immaturity and laxity under significant forces during throwing can be a recipe for shoulder injury.[77]

It is well documented that the baseball throw generates large torques and rotational range of motion at the shoulder.[22] Both rotational and distraction forces during the late cocking and acceleration phases are present during the throwing motion. The rotational forces, specifically, external rotation torque, are much larger than shoulder distraction forces, and are thought to be more of a contributing factor to LLS as the repetitive microtrauma generates deformation to the proximal humeral epiphysis.[67] In conjunction with the damage to humeral epiphyseal physis, changes to humeral torsion and to the posterior glenoid are present.[67]

Researchers over the past decade have been investigating humeral torsion,[54] specifically, HRT and its relationship to shoulder and elbow injury in the throwing athlete.[58] Humeral torsion describes the twist about the long axis of the humerus,[15] and is defined as the angular difference between the orientation of the axis of the proximal humeral head and the epicondylar axis at the distal humerus.[45] At birth, both humeri are in a marked position of HRT, as represented by a large angle between the proximal humeral head and epicondylar axis at the distal humerus.[18] As development occurs from infancy to adolescence, a remodeling process occurs along the shaft of the humerus and proximal physis, resulting in less retrotorsion (smaller angle between the proximal humeral head and epicondylar axis at the distal humerus).[18,45] However, throwing that takes place in a skeletally immature athlete will delay the natural derotation (slowing down the development of humeral internal rotation) process on the throwing arm.[28] This in turn leads to a difference in side-to-side HRT measurements, which is defined as relative HRT. HRT is often measured using an indirect ultrasonographic technique,[57] and has been described and validated by previous researchers.[53] To date, one case study on a baseball player suggests HRT may contribute to the diagnosis of LLS. The patient in the study was part of a screening program for healthy baseball players at the age of 13 and was diagnosed with LLS 2 years later, in which time a repeat screening was completed, which included HRT. HRT findings in the case study[29] are consistent with previous literature, as humeral torsion is slowed down because of the biomechanical forces that are associated with throwing.[67] The authors go onto suggest that “in skeletally immature throwing athletes, the proximal humerus of the dominant arm is being exposed to opposing torsional influences: the natural physiological forces acting to decrease HRT, and the forces that act in opposition of that process.”[29] Consequently, the opposing forces may increase the degree of mechanical stress, leading to physeal damage that is often times associated with LLS. Longitudinal research is certainly needed in this area to determine if changes in HRT during adolescences have consequences to physeal injuries. In addition, to HRT considerations, bony changes to the scapula in the form of posterior glenoid dysplasia are present as a result of repeated throwing. Investigation into how glenoid dysplasia interacts with injuries such as LLS may also provide insight on how to better treat this condition.

Little league shoulder and posterior glenoid dysplasia

Sports medicine professionals have traditionally concerned themselves with the proximal humeral physis while ascertaining a diagnosis of LLS. However, examination of the glenoid is a clinical necessity in determining the appropriate plan of care for a youth baseball athlete with throwing-related shoulder pain.

The glenoid has been previously investigated in throwing populations as it relates to glenoid version and changes to glenoid morphology. Glenoid version has previously been shown to relate to the development of humeral torsion in professional baseball pitchers on the throwing limb when compared to the nonthrowing limb.[84] Glenoid version, and more specifically, glenoid retroversion, is an increase in the posterior orientation of the glenoid which has been associated with posterior instability but not necessarily associated with throwing-related pain.[10,62,64,75] Other adaptive changes to the osseous morphology of the glenoid have been identified in the literature including posterior glenoid dysplasia.[42] Posterior glenoid dysplasia is described as mild rounding of the posterior rim in comparison to the normal triangular shape of the glenoid.[42] Alterations in posterior glenoid morphology, including posterior glenoid dysplasia, have been shown to be associated with injury in both throwing and nonthrowing populations.[31,76]

Posterior glenoid dysplasia is thought to occur concurrently with changes to the proximal humeral physis between the ages of 8 and 16 years in overhead-throwing athletes.[43,61] The subcoracoid secondary ossification center, which is located along the surface of the glenoid, does not fully mature until aged approximately 8-10 years.[42] Furthermore, the inferior two-thirds of the glenoid has been shown as the last to ossify, with ossification beginning between 11 and 14 years and fusion occurring between 12 and 16 years.[42,44] In combination with repetitive overhead throwing and the secondary ossification center's late ossification age, the demands of throwing may lead to maladaptive changes in the posteroinferior glenoid rim prior to bone maturation, leading to posterior glenoid dysplasia. Edelson[19] described this dysplasia as posteroinferior glenoid hypoplasia in a nonthrowing museum specimen population in 1995. In the same study, Edelson prospectively evaluated 12 patients with nontraumatic multidirectional instability, and found 9 of the 12 displayed posteroinferior glenoid hypoplasia.[19] A classification system was generated from this work and describes different anatomic forms of the posterior glenoid rim at the base of the scapula: (1) rounded glenoid deficiency known as the lazy J and (2) triangular bony deficiency known as delta.[19,80] These anatomic variations of the glenoid have been reported in baseball players.[42]

The anterior portion of the glenoid is postulated to be stronger than the posterior glenoid due to the triangular linear cortex that assists with anterior stability.[69] Comparatively, the posterior rim of the glenoid has been described as a balcony-like structure with decreased structural support. The mechanism driving morphologic changes at the posterior rim is thought to be attributed to activity-dependent remodeling of the glenoid. These observed morphologic adaptions are due to calcific changes of the posterior-inferior glenoid from repeated traction of the posterior capsule and the posterior band of the inferior glenohumeral ligament that occurs during the overhead throwing motion.[17,35,42] The decreased support, in conjunction with repetitive stresses across the posterior glenoid rim during overhead throwing, may lead to the development of posterior glenoid dysplasia.

Currently, there is little available evidence regarding the incidence of posterior glenoid dysplasia in overhead-throwing athletes, particularly, in a youth subset. Kirimura et al[42] investigated a cohort of baseball players with a mean age of 15 years and found that 96.7% of baseball athletes with a painful shoulder presented with posterior glenoid dysplasia. Additionally, the authors found total years' experience and a younger starting throwing age increased the risk of posterior glenoid dysplasia, although these findings were not significant.[42] To the present authors' knowledge, this is the only study looking at the incidence of posterior glenoid dysplasia in a youth cohort. There remains a void in the available literature that investigates the relationship between LLS, posterior glenoid dysplasia, and overall shoulder health of overhead-throwing athletes. Additionally, the effect of posterior glenoid dysplasia, in the presence of LLS, on clinical and RTS outcomes is unknown. This lack of information leaves a critical gap in the collective evidence of the proper management of youth athletes presenting with both LLS and posterior glenoid dysplasia.

The impact of posterior glenoid dysplasia on long-term health in the throwing athlete is currently unknown. In general populations, posterior glenoid dysplasia is present and is associated with posterior and multidirectional instability.[24,31,38] Although previous studies have demonstrated that glenoid dysplasia is prevalent in a youth population,[42] children may be asymptomatic upon presentation.[74] However, it has been proposed that children presenting with asymptomatic glenoid dysplasia may become symptomatic later in life, and with an increase in exacerbating activities (ie, overhead athletic activity).[31,37,83] While it has not been directly shown to associate with the development of time-loss injury in adolescent or adult throwing athletes, posterior glenoid dysplasia may contribute to the development of posterior shoulder instability[20] injuries in the baseball athlete, such as Batter's Shoulder[7,23,48] and Dynamic Posterior Instability in the Thrower.[68,72] As such, assessing for posterior glenoid dysplasia should be incorporated into the clinical care program for young baseball players. Posterior glenoid dysplasia can be assessed with appropriate procedures using radiographic imaging.

Figure 1 Patient position for radiographic imaging for the posterior glenoid (the Conway method). The *red line* indicates the direction of the x-ray beam.

Examination of the posterior glenoid in youth throwing athletes may include plain radiographs using either the Bernageau method or the Conway method (a modified axillary view). The Bernageau method is used with the patient in a side-lying position with the palm of the hand behind the patient's head, the scapula oriented at a 95° angle, and the image taken at a 15°-20° angle of incidence caudally.[42] The Conway method uses a modified axillary view with the patient in a seated position next to the X-ray table.[11] The patient is instructed to side bend at the trunk to the ipsilateral side to an angle of 20° while the affected arm is abducted to 80°, and the head is side bent to the contralateral side to allow for the X-ray tube to be angled at 0° caudally (Fig. 1). Both the Benageau and Conway methods depict the suprascapular loop which allows clinicians to visualize the posterior glenoid (Fig. 2 *A* and *B*). This loop is defined by the curving contour of the spine of the scapula as it meets the glenoid neck. The modified axillary view allows for the patient to be in a seated position without measuring the orientation of the scapula as described by Kirimura et al.[42]

Clinical implications

The present authors recommend that the evaluation of a youth throwing athlete with suspected LLS should involve an interdisciplinary sports medicine team and should not be limited to the involved shoulder. Primarily, an examination by a fellowship-trained, board-certified orthopedist is recommended with an

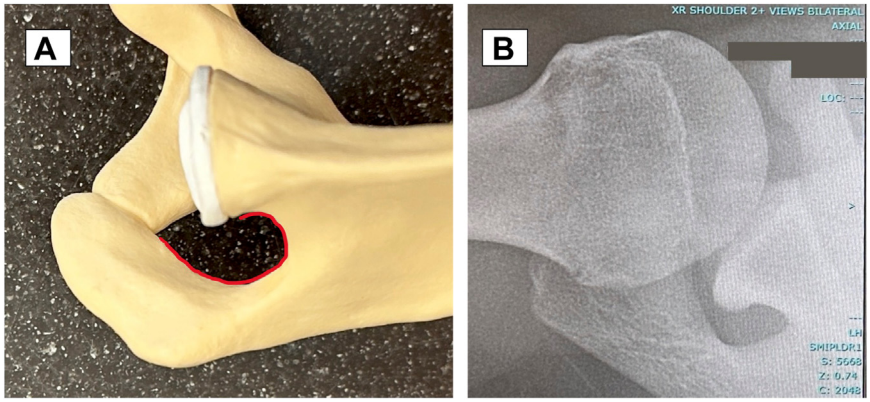

Figure 2 Suprascapular loop from a modified axillary view with skeletal model **(A)** and radiographic imaging (**B**). **(A)** A skeletal model of the right scapula that depicts a circular loop (highlighted in *red*) where the spine of the scapula meets the glenoid neck to best visualize the posterior glenoid during a modified axillary view (the Conway method). **(B)** Radiographic image of the right glenohumeral joint depicting the same curricular loop.

Table I
Initial objective measures.

Measure	Right	Left	Difference†
Glenohumeral ER	100°	100.5°	−0.5°
Glenohumeral IR	17.5°	30°	−12.5°
Glenohumeral TROM	117.5°	130.5°	−13°
HRT	20°	34°	−14°
HRT Corrected ER	−14.5°	-	-
HRT Corrected IR	+1.5°	-	-
Shoulder ER Strength	3.7 kg (8.3 lbs)	7.8 kg (17.2 lbs)	−4.0 kg (−8.9 lbs)
Shoulder IR Strength	7.7 kg (17 lbs)	13.3 kg (29.5 lbs)	−5.6 kg (−12.5 lbs)
Shoulder Scaption Strength	4.2 kg (9.1 lbs)	10.0 kg (22.2 lbs)	−5.9 kg (−13.1 lbs)
Y-Balance Anterior Reach	59.5 cm	55.0 cm	+4.5 cm

ER, external rotation; *IR*, internal rotation; *TROM*, total range of motion; *kg*, kilogram;*lbs*, pounds; *cm*, centimeters; *HRT*, humeral retrotorsion.
*Denotes pain with examination maneuvers.
†Difference was calculated as the involved arm (right) minus the uninvolved arm (left). A positive value indicates a gain for a given measure, while a negative value indicates a deficit compared to the uninvolved side.

assessment to include a comprehensive examination of the throwing extremity, as well as imagining as indicated by the clinical examination. In the case of suspected LLS, the current literature recommends bilateral AP radiographic views to properly evaluate the proximal humeral physis.[34] The authors of this paper are also recommending a modified axillary view (Fig. 1) to best view the posterior glenoid of the involved shoulder, as well as the uninvolved shoulder, to serve as a reference for any perceived changes to an immature skeleton. In conjunction with a clinical evaluation by a board-certified, fellowship-trained orthopedic physician with experience in treating overhead-throwing athletes, a musculoskeletal screen to identify key objective impairments is recommended. The objective measures included should incorporate not only the involved extremity but the contralateral extremity to serve as a reference, as well as measures that evaluate the entire kinetic chain of the throwing athlete.[70] The objective examination should include measures that have been previously associated with throwing-related injury, including but not limited to glenohumeral range of motion,[26] shoulder strength,[6,27] humeral torsion and its interpretation in regards to glenohumeral rotational range of motion,[33,81] as well as measures of balance and neuromuscular control.[25]

Following a diagnosis of LLS, the plan of care should incorporate a period of rest from aggravating activities, namely, throwing and hitting. Formal rehabilitation is also recommended with a board-certified physical therapist with a clinical specialty in sports and/or orthopedics and demonstration of experience working with overhead-throwing athletes.[34] The physical therapy plan of care should focus on improving any observed deficits noted from objective measures, as well as patient education on throwing volume and its relation to injury risk, in attempts to mitigate future injury risk.[49] At the cessation of the suggested rest period and formal physical therapy, the patient should undergo subsequent evaluation by the sports medicine team. Once the patient is cleared from physician care, the patient, the patient's caregivers, and patient's coaching staff should be educated on the implementation and execution of an individualized interval throwing program to be completed prior to full return to prior level of competition and throwing volume.[9,36] Additionally, corrections of all correctable kinetic chain conditions, resolution of strength, resolution of glenohumeral motion loss, and improved ossification of the posterior glenoid rim should be evident on radiographic imaging prior to full return to prior level of competition.

Case example

The following case example demonstrates the evaluation and course of care of one youth baseball athlete with a primary diagnosis of LLS. Prior to initial evaluation by a board-certified, fellowship-trained orthopedic surgeon (J.E.C.), the patient reported to the outpatient sports medicine physical therapy clinic for objective measurements used in conjunction with a physical examination and imaging to ascertain a diagnosis. Each of the objective measures was performed by researchers with previously reported reliability.[25,26,40,51] This case was purposefully chosen to demonstrate the progression of care when proximal humeral physis widening is present concomitantly with incomplete ossification of the posterior glenoid (posterior glenoid dysplasia).

Case example

Thirteen-year-old, right-handed male with a diagnosis of LLS with observed posterior glenoid dysplasia

Initial patient subjective

The patient is a pitcher and third baseman who presented to the outpatient sports medicine clinic for evaluation of right shoulder pain. About a year prior to this appointment, he was seen by a general orthopedist for right shoulder pain and was diagnosed with a "growth plate fracture." He was told to take 3 months off from throwing and was given a throwing program to start after his rest

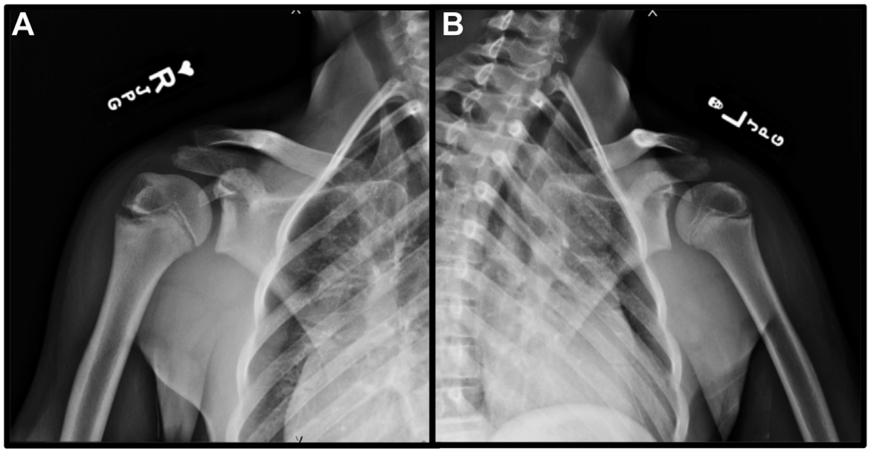

Figure 3 Initial X-rays of proximal huemral physis. **(A)** Right AP view. **(B)** Left AP view. The right proximal humeral physis is observed to be larger than that of the left.

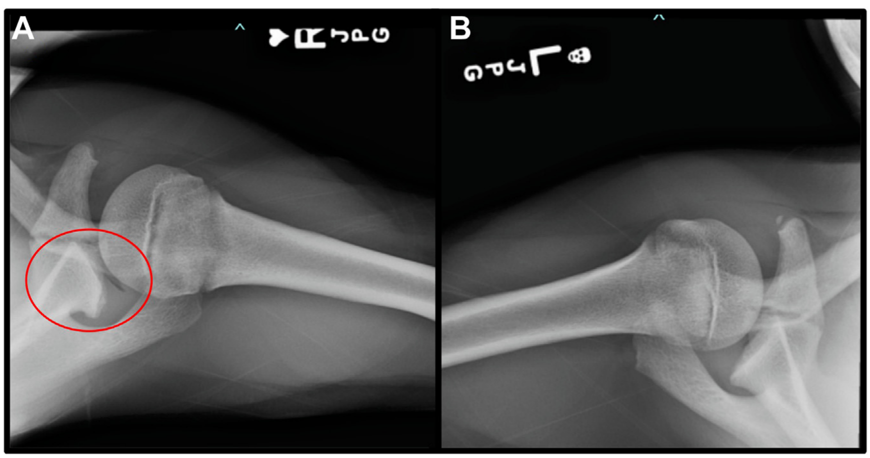

Figure 4 Initial X-rays of posterior glenoid. **(A)** Right modified axial view. **(B)** Left modified axial view. The *red circle* indicates the observed incomplete ossification of the posterior glenoid on the right shoulder.

Table II
Six-month objective measures.

Measure	Left	Right	Difference*
Glenohumeral ER	113.5°	104°	+9.5°
Glenohumeral IR	23°	34°	−11°
Glenohumeral TROM	136.5°	138°	−1.5°
HRT	15.5°	20.5°	−5°
HRT Corrected ER	−4.5°	-	-
HRT Corrected IR	+3°	-	-
Shoulder ER Strength	10.1 kg (22.3 lbs)	9.1 kg (20.2 lbs)	0.95 kg (2.1 lbs)
Shoulder IR Strength	16.8 kg (37.2 lbs)	17.5 kg (38.6 lbs)	−0.63 kg (−1.4 lbs)
Shoulder Scaption Strength	11.2 kg (24.7 lbs)	12.6 kg (27.8 lbs)	−1.4 kg (−3.1 lbs)
Y-Balance Anterior Reach	62 cm	61 cm	+1.0 cm

ER, external rotation; *IR*, internal rotation; *TROM*, total range of motion; *kg*, kilogram;*lbs*, pounds; *cm*, centimeters; *HRT*, humeral retrotorsion.

*Difference was calculated as the involved arm (right) minus the uninvolved arm (left). A positive value indicates a gain for a given measure, while a negative value indicates a deficit compared to the uninvolved side.

period. After the rest, he initiated a throwing program and was able to get back to a place where he could play third base, however, was not able to get back to competitive pitching off a mound for another couple of months. He has been going through pitching lessons with an instructor who has worked extensively on his throwing mechanics. Three weeks prior to his initial evaluation, after an outing on the mound, he started to experience soreness in his right shoulder. This soreness lasted several days, but he was able to participate in practice at third base and went on to pitch the following weekend. During his warm-up session in the bullpen on that weekend, his shoulder felt tight. He was able to pitch a pain-free first inning, but in the second inning he started to experience increased right shoulder pain with every pitch, as well as a decrease in velocity and throwing accuracy. His shoulder was significantly sorer after this outing. At his next outing, he was only able to get through one inning before being taken out due to right shoulder pain. He denies any neurovascular or mechanical complaints. He does not have any neck or elbow pain.

Initial objective measures

The patient's initial objective measures can be found in Table I. These included measures of glenohumeral external and internal range of motion (measured in supine 90° of shoulder abduction and 90° of elbow flexion while stabilizing the scapula with an inclinometer),[82] HRT (using an indirect ultrasonographic technique),[31] external and internal shoulder strength (measured via manually resisted isometric handheld dynamometry at 0° shoulder

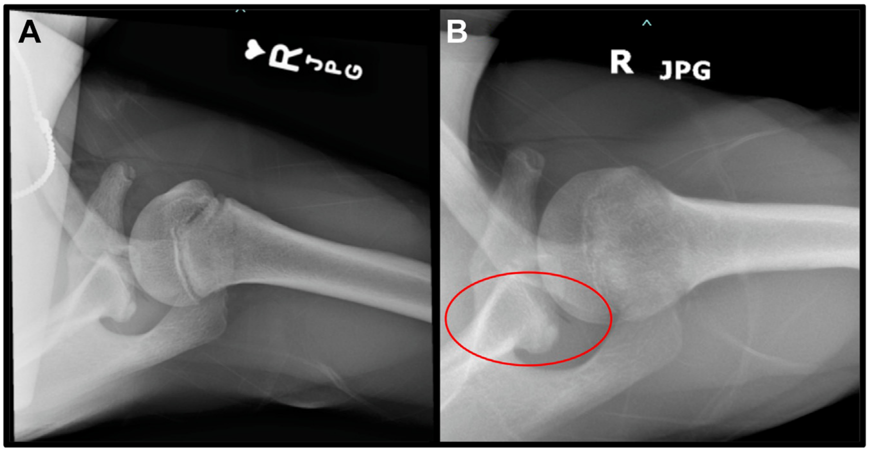

Figure 5 Follow-up X-rays of posterior glenoid. **(A)** Right shoulder axial view at 12-week follow-up. **(B)** Right shoulder axial view at 6-month follow-up.

abduction and 90° elbow flexion),[27] shoulder scaption strength (via manually resisted isometric handheld dynamometry in the position of arm abduction of 90° in the scapular plane, 30° anterior to the frontal plane [scaption]),[56,65] and postural control using the anterior reach of the y-balance test.[25] These measures were meaningfully chosen as they have been previously associated with injury risk development in youth baseball athletes.[25,33,54,59,71]

Initially, the patient had key clinical differences found in shoulder strength (external rotation, internal rotation, and Scaption), a loss of total range of motion (with torsion-corrected motion suggesting he was lacking external rotation), and neuromuscular control deficits of his stride limb. The patient's initial Kerlan-Jobe Orthopaedic Clinic (KJOC) Shoulder and Elbow score was 40 out of 100 at his initial evaluation.

Initial clinical examination

The patient's clinical examination by the orthopedic surgeon included diagnostic maneuvers to test for postural abnormalities, scapular dyskinesis/malposition, thoracic outlet compression/syndrome, shoulder impingement testing, and shoulder stability testing. Key findings within the examination included mild scapular dyskinesis, asymmetric scapular winging, mild tenderness to palpation of the proximal humeral physis, the lesser tuberosity and the posterior/inferior glenoid, and moderately painful and weak Whipple and high Whipple tests compared to the uninvolved limb. The patient was also observed to have 1+ posterior manual translation on the right compared to trace translation on the left.

Initial imaging

The patient's intitial imaging is above in Fig. 3. The dictation of the films by the radiologist and confirmed by the orthopedic surgeon documented an immature skeleton, proximal humeral physis in the right shoulder widened (Fig. 3*A*) than that of the left shoulder (Fig. 3*B*), and moderate-to-severe posterior glenoid dysplasia with incomplete ossification of the posterior glenoid rim of the right shoulder (Fig. 4) when compared to the left shoulder (Fig. 4*B*).

Plan of care

Following the objective measures, physician evaluation, and imagining, the patient initiated a comprehensive, linked kinetic chain-based rehabilitation program with a board-certified clinical specialist sports physical therapist. The linked kinetic chain-based rehabilitation program incorporates the integration of the lower extremity and trunk, while simultaneously challenging the stability and strength of the upper extremity. The patient and his family were instructed to have him refrain from hitting or throwing during this time of rest and rehabilitation. Due to the finding of incomplete ossification of the posterior glenoid rim, the initial plan was for the patient to avoid throwing for at least 4.5 months, but with the possibility that it may be delayed until 6 months depending on his examination and follow-up X-rays.

The patient was re-assessed 12 weeks later with minimal changes on X-ray imaging in regard to the posterior glenoid. Due to the lack of improvement of the ossification of the posterior glenoid, the patient was asked to refrain from throwing for another 12 weeks. The patient followed up again at the 6-month time point for re-examination.

Six-month follow-up patient subjective

The patient notes he has not been throwing but has been working on a progressive preparation for return to throwing program including double-arm and single-arm plyometrics. He reports that he is completely pain-free, and he has continued a course of intermittent formal physical therapy.

Six-month follow-up clinical objective measures

The patient's follow-up objective measures can be found in Table II. The patient demonstrated and improvement in total arc of motion (remedied by improving his shoulder external rotation as guided by HRT corrected motion calculations), and strength for all three measures and y-balance. Additionally, there was no pain noted upon examination.

At the 6-month follow-up, the patient's KJOC score improved to 100/100.

Six-month clinical examination

The patient's clinical examination by the orthopedic surgeon documented improved scapular dyskinesis with decreased winging, no tenderness to palpation of any shoulder structures, and no pain and symmetry in strength with Whipple and high Whipple tests. Laxity with posterior translation was unchanged on either side.

Six-month follow-up imaging

Follow-up X-ray of the posterior glenoid can be seen in Fig. 5. The radiologist and orthopedic surgeon again noted an immature skeleton. The posterior aspect of the glenoid showed an improvement in the ossification of the previously observed dysplasia.

Following adherence to rest from aggravating activities and participation in a formal, kinetic chain–based physical therapy program, the patient was able to return to an interval throwing and interval batting program. The patient was found to have an improvement in his posterior glenoid ossification in this time frame.

This case example followed a clinical algorithm for evaluating and treating youth baseball athletes with throwing-related LLS pain. The approach to ascertain a diagnosis and treatment plan should include an interdisciplinary sports medicine team. Objective measures of musculoskeletal health as it relates to youth baseball athletes are a necessary step to develop an effective care plan and identify key objective measures that may predispose a young thrower to recurrent pain. Plain imaging, including a standard AP X-ray to visualize the proximal humeral physis, as well as a modified axillary view to visualize the posterior glenoid, are crucial to establishing appropriate conservative care timeframes. Improvements in clinical examination, radiographic findings, and objective measures are necessary to determine the athlete's appropriateness for return to an individualized interval throwing program. As demonstrated in this case example, involvement of posterior glenoid dysplasia requires extended rest to allow for appropriate ossification and further ameliorate development of future pain and injury. This course of rehabilitation usually entails 12-24 weeks of rest from overhead throwing prior to medical release followed by the initiation of an interval throwing program. In a youth athlete presenting with throwing-related shoulder pain, evaluation of these anatomic structures is crucial. This information will drive the creation of an appropriate plan of care as well as set up rehabilitation expectations for the athlete and other key stakeholders ultimately optimizing RTS and performance outcomes.

Conclusion

LLS is among the most common causes for shoulder pain in youth baseball players.[3,4,29,66] Their immature skeletons respond differently to throwing-related stress when compared to more physically mature counterparts.[3,34] Osseous changes in the proximal humerus have been previously described in the LLS literature; however, few studies have examined changes at the glenoid.[14,41,42,50,63,79] While little is known about the impact of posterior glenoid dysplasia on long-term shoulder health and function in athletes who experience LLS, these players often require longer rest periods away from sport, nearly double that of those who present without changes to the glenoid. Serial radiologic imaging for up to 6 months must be required to ensure improved ossification of the glenoid rim prior to initiating an interval throwing program. Additional research is needed to better understand the impact of posterior glenoid dysphasia as an osseous variation of LLS in skeletally developing populations.

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References

1. Adams JE. Little league shoulder—osteochondrosis of the proximal humeral epiphysis in boy baseball pitchers. Calif Med 1966;105:22-5.
2. Albert MJ, Drvaric DM. Little league shoulder: case report. Orthop 1990;13:779-81.
3. Arnold A, Thigpen CA, Beattie PF, Kissenberth MJ, Shanley E. Overuse physeal injuries in youth athletes. Sports Health 2017;9:139-47. https://doi.org/10.1177/1941738117690847.
4. Bednar ED, Kay J, Memon M, Simunovic N, Purcell L, Ayeni OR. Diagnosis and management of little league shoulder: a systematic review. Ortho J Sports Med 2021;9. https://doi.org/10.1177/232596712110175.
5. Boyd KT, Batt ME. Stress fracture of the proximal humeral epiphysis in an elite junior badminton player. Br J Sports Med 1997;31:252-3.
6. Byram IR, Bushnell BD, Dugger K, Charron K, Harrell FE Jr, Noonan TJ. Preseason shoulder strength measurements in professional baseball pitchers: identifying players at risk for injury. Am J Sports Med 2010;38:1375-82. https://doi.org/10.1177/0363546509360404.
7. Carbone A, Limpisvasti O. Understanding batter's shoulder: diagnosis, treatment, and outcomes. Curr Rev Musculoskelet Med 2022;15:547-51. https://doi.org/10.1007/s12178-022-09795-y.
8. Carson WG, Gasser SI. Little leaguer's shoulder. Am J Sports Med 1998;26:575-80.
9. Chang ES, Bishop ME, Baker D, West RV. Interval throwing and hitting programs in baseball: biomechanics and rehabilitation. Am J Orthop 2016;45:157-62.
10. Churchill RS, Brems JJ, Kotschi H. Glenoid size, inclination, and version: an anatomic study. J Shoulder Elbow Surg 2001;10:327-32.
11. Conway JE. In: Myers NL, editor. Interview on imaging technique for posterior glenoid dysplasia; 2023.
12. Core participation in select sports. https://projectplay.org/youth-sports/facts/participation-rates. Accessed August 20, 2023.
13. Davis JT, Limpisvasti O, Fluhme D, Mohr KJ, Yocum LA, Elattrache NS, et al. The effect of pitching biomechanics on the upper extremity in youth and adolescent baseball pitchers. Am J Sports Med 2009;37:1484-91. https://doi.org/10.1177/0363546509340226.
14. Davis KW. Imaging pediatric sports injuries: upper extremity. Radiol Clin North Am 2010;48:1199-211. https://doi.org/10.1016/j.rcl.2010.07.020.
15. Debevoise NT, Hyatt GW, Townsend GB. Humeral torsion in recurrent shoulder dislocations. Clin Orthop Relat Res 1971;76:87-93.
16. Domes CM, Petering RC, Chesnutt JC, Mirarchi A. Concurrent little leaguer's elbow and shoulder in a 15-year-old baseball pitcher and football quarterback. Orthop 2012;35:e97-100. https://doi.org/10.3928/01477447-20111127-29.
17. Drakos MC, Rudzki JR, Allen AA, Potter HG, Altchek DW. Internal impingement of the shoulder in the overhead athlete. J Bone Joint Surg 2009;91:2719-28. https://doi.org/10.2106/JBJS.I.00409.
18. Edelson G. The development of humeral head retroversion. J Shoulder Elbow Surg 2000;9:316-8.
19. Edelson JG. Localized glenoid hypoplasia. An anatomic variation of possible clinical significance. Clin Orthop Relat Res 1995:189-95.
20. Eichinger JK, Galvin JW, Grassbaugh JA, Parada SA, Li X. Glenoid dysplasia: pathophysiology, diagnosis, and management. J Bone Joint Surg Am 2016;98:958-68. https://doi.org/10.2106/JBJS.15.00916.
21. Fehr S, Whealy G, Liu X-C. Investigation of ultrasound as a diagnostic imaging modality for little league shoulder. J Child Sci 2021;11:e240-4. https://doi.org/10.1055/s-0041-1735535.
22. Fleisig GS, Andrews JR, Dillman CJ, Escamilla RF. Kinetics of baseball pitching with implications about injury mechanisms. Am J Sports Med 1995;23:233-9.
23. Fury MS, Moore LK, DeSena TD, Camp CL, Dines JS. Evaluation, teatment, and outcomes of batter's shoulder. Curr Rev Musculoskelet Med 2023;16:60-5. https://doi.org/10.1007/s12178-022-09815-x.
24. Galvin JW, Morte DR, Grassbaugh JA, Parada SA, Burns SH, Eichinger JK. Arthroscopic treatment of posterior shoulder instability in patients with and without glenoid dysplasia: a comparative outcomes analysis. J Shoulder Elbow Surg 2017;26:2103-9. https://doi.org/10.1016/j.jse.2017.05.033.
25. Garrison JC, Arnold A, Macko MJ, Conway JE. Baseball players diagnosed with ulnar collateral ligament tears demonstrate decreased balance compared to healthy controls. J Orthop Sports Phys Ther 2013;43:752-8. https://doi.org/10.2519/jospt.2013.4680.
26. Garrison JC, Cole MA, Conway JE, Macko MJ, Thigpen C, Shanley E. Shoulder range of motion deficits in baseball players with an ulnar collateral ligament tear. Am J Sports Med 2012;40:2597-603. https://doi.org/10.1177/0363546512459175.
27. Garrison JC, Johnston C, Conway JE. Baseball players with ulnar collateral ligament tears demonstrate decreased rotator cuff strength compared to healthy controls. Int J Sports Phys Ther 2015;10:476-81.
28. Greenberg EM, Fernandez-Fernandez A, Lawrence JT, McClure P. The development of humeral retrotorsion and its relationship to throwing sports. Sports Health 2015;7:489-96. https://doi.org/10.1177/1941738115608830.
29. Greenberg EM, Turner C, Huse C, Ganley TJ, McClure P, Lawrence JT. Changes in humeral retrotorsion and the development of little league shoulder: a case study. Phys Ther Sport 2018;34:49-54. https://doi.org/10.1016/j.ptsp.2018.08.005.
30. Harada M, Takahara M, Maruyama M, Kondo M, Uno T, Takagi M, et al. Outcome of conservative treatment for little league shoulder in young baseball players: factors related to incomplete return to baseball and recurrence of pain. J Shoulder Elbow Surg 2018;27:1-9. https://doi.org/10.1016/j.jse.2017.08.018.

31. Harper KW, Helms CA, Haystead CM, Higgins LD. Glenoid dysplasia: incidence and association with posterior labral tears as evaluated on mri. Am J Roentgenol 2005;184:984-8. https://doi.org/10.2214/ajr.184.3.01840984.
32. Hatem SF, Recht MP, Profitt B. Mri of little leaguer's shoulder. Skelet Radiol 2006;35:103-6. https://doi.org/10.1007/s00256-005-0015-y.
33. Helmkamp JK, Bullock GS, Rao A, Shanley E, Thigpen C, Garrigues GE. The relationship between humeral torsion and arm injury in baseball players: a systematic review and meta-analysis. Sports Health 2020;12:132-8. https://doi.org/10.1177/194173811990.
34. Heyworth BE, Kramer DE, Martin DJ, Micheli LJ, Kocher MS, Bae DS. Trends in the presentation, management, and outcomes of little league shoulder. Am J Sports Med 2016;44:1431-8. https://doi.org/10.1177/0363546516632.
35. Heyworth BE, Williams RJ. Internal impingement of the shoulder. Am J Sports Med 2009;37:1024-37. https://doi.org/10.1177/0363546508324.
36. Hintz C, Colon D, Honnette D, Denning N, Porras E, Willard J, et al. Individualizing the throwing progression following injury in baseball pitchers: the past, present, and future. Curr Rev Musculoskelet Med 2022;15:561-9. https://doi.org/10.1007/s12178-022-09799-8.
37. Hurley JA, Anderson TE, Dear W, Andrish JT, Bergfeld JA, Weiker GG. Posterior shoulder instability. Surgical versus conservative results with evaluation of glenoid version. Am J Sports Med 1992;20:396-400.
38. Inui H, Sugamoto K, Miyamoto T, Yoshikawa H, Machida A, Hashimoto J, et al. Glenoid shape in atraumatic posterior instability of the shoulder. Clin Orthop Relat Res Oct 2002;403:87-92. https://doi.org/10.1097/00003086-200210000-00014.
39. Jaramillo D, Laor T, Zaleske DJ. Indirect trauma to the growth plate: results of mr imaging after epiphyseal and metaphyseal injury in rabbits. Radiology 1993;187:171-8.
40. Kennedy SM, Sheedy P, Klein B, Gist M, Hannon JP, Conway JE, et al. Differences in shoulder internal rotation strength between baseball players with ulnar collateral ligament reconstruction and healthy controls. Orthop J Sports Med 2021;10. https://doi.org/10.1177/232596712110650.
41. Kim HHR, Menashe SJ, Ngo AV, Otjen JP, Maloney E, Iyer RS, et al. Uniquely pediatric upper extremity injuries. Clin Imaging 2021;80:249-61. https://doi.org/10.1016/j.clinimag.2021.07.010.
42. Kirimura K, Nagao M, Sugiyama M. High incidence of posterior glenoid dysplasia of the shoulder in young baseball players. J Shoulder Elbow Surg 2019;28:82-7. https://doi.org/10.1016/j.jse.2018.06.021.
43. Kocher MS, Waters PM, Micheli LJ. Upper extremity injuries in the paediatric athlete. Sports Med 2000;30:117-35.
44. Kothary S, Rosenberg ZS, Poncinelli LL, Kwong S. Skeletal development of the glenoid and glenoid-coracoid interface in the pediatric population: mri features. Skeletal Radiol 2014;43:1281-8. https://doi.org/10.1007/s00256-014-1936-0.
45. Krahl VE. The torsion of the humerus: its localization, cause and duration in man. J Anat 1947;80:275-315.
46. Lyman S, Fleisig GS, Andrews JR, Osinski ED. Effect of pitch type, pitch count, and pitching mechanics on risk of elbow and shoulder pain in youth baseball pitchers. Am J Sports Med 2002;30:463-8. https://doi.org/10.1177/03635465020300040.
47. Lyman S, Fleisig GS, Waterbor JW, Funkhouser EM, Pulley L, Andrews JR, et al. Longitudinal study of elbow and shoulder pain in youth baseball pitchers. Med Sci Sports Exerc 2001;33:1803-10.
48. Marigi EM, Conte S, Reinholz AK, Steubs JA, Knudsen ML, Krych AJ, et al. Shoulder injuries in professional baseball batters: analysis of 3,414 injuries over an 8-year period. Arthrosc Sports Med Rehabil 2022;4:e1119-26. https://doi.org/10.1016/j.asmr.2022.03.012.
49. Matsel KA, Butler RJ, Malone TR, Hoch MC, Westgate PM, Uhl TL. Current concepts in arm care exercise programs and injury risk reduction in adolescent baseball players: a clinical review. Sports Health 2021;13:245-50. https://doi.org/10.1177/1941738120976384.
50. May MM, Bishop JY. Shoulder injuries in young athletes. Pediatr Radiol 2013;43:S135-40. https://doi.org/10.1007/s00247-012-2602-0.
51. Meyer CJ, Garrison JC, Conway JE. Baseball players with an ulnar collateral ligament tear display increased nondominant arm humeral torsion compared with healthy baseball players. Am J Sports Med 2017;45:144-9. https://doi.org/10.1177/0363546516664718.
52. Mochizuki Y, Natsu K, Kashiwagi K, Yasunaga Y, Ochi M. Changes of the mineralization pattern in the subchondral bone plate of the glenoid cavity in the shoulder joints of the throwing athletes. J Shoulder Elbow Surg 2005;14:616-9. https://doi.org/10.1016/j.jse.2005.02.016.
53. Myers JB, Oyama S, Clarke JP. Ultrasonographic assessment of humeral retrotorsion in baseball players: a validation study. Am J Sports Med 2012;40:1155-60. https://doi.org/10.1177/036354651243.
54. Myers JB, Oyama S, Goerger BM, Rucinski TJ, Blackburn JT, Creighton RA. Influence of humeral torsion on interpretation of posterior shoulder tightness measures in overhead athletes. Clin J Sport Med 2009;19:366-71. https://doi.org/10.1097/JSM.0b013e3181b544f6.
55. Myers JB, Oyama S, Wassinger CA, Ricci RD, Abt JP, Conley KM. Reliability, precision, accuracy, and validity of posterior shoulder tightness assessment in overhead athletes. Am J Sports Med 2007;35:1922-30. https://doi.org/10.1177/0363546507304142.
56. Myers NL, Toonstra JL, Smith JS, Padgett CA, Uhl TL. Sustained isometric shoulder contraction on muscular strength and endurance: a randomized clinical trial. Int J Sports Phys Ther 2015;10:1015-25.
57. Noonan TJ, Shanley E, Bailey LB, Wyland DJ, Kissenberth MJ, Hawkins RJ, et al. Professional pitchers with glenohumeral internal rotation deficit (gird) display greater humeral retrotorsion than pitchers without gird. Am J Sports Med 2015;43:1448-54. https://doi.org/10.1177/0363546515575020.
58. Noonan TJ, Thigpen CA, Bailey LB, Wyland DJ, Kissenberth M, Hawkins RJ, et al. Humeral torsion as a risk factor for shoulder and elbow injury in professional baseball pitchers. Am J Sports Med 2016;44:2214-9. https://doi.org/10.1177/0363546516648438.
59. Norton R, Honstad C, Joshi R, Silvis M, Chinchilli V, Dhawan A. Risk factors for elbow and shoulder injuries in adolescent baseball players: a systematic review. Am J Sports Med 2018;47:982. https://doi.org/10.1177/0363546518760573.
60. Osbahr DC, Chalmers PN, Frank JS, Williams IIIRJ, Widmann RF, Green DW. Acute, avulsion fractures of the medial epicondyle while throwing in youth baseball players: a variant of little league elbow. J Shoulder Elbow Surg 2010;19:951-7. https://doi.org/10.1016/j.jse.2010.04.038.
61. Osbahr DC, Kim HJ, Dugas JR. Little league shoulder. Curr Opin Pediatr 2010;22:35-40. https://doi.org/10.1097/MOP.0b013e328334584c.
62. Owens BD, Campbell SE, Cameron KL. Risk factors for posterior shoulder instability in young athletes. Am J Sports Med 2013;41:2645-9. https://doi.org/10.1177/0363546513501508.
63. Paz DA, Chang GH, Yetto JM Jr, Dwek JR, Chung CB. Upper extremity overuse injuries in pediatric athletes: clinical presentation, imaging findings, and treatment. Clin Imaging 2015;39:954-64. https://doi.org/10.1016/j.clinimag.2015.07.028.
64. Polster JM, Bullen J, Obuchowski NA, Bryan JA, Soloff L, Schickendantz MS. Relationship between humeral torsion and injury in professional baseball pitchers. Am J Sports Med 2013;41:2015-21. https://doi.org/10.1177/0363546513493249.
65. Pontillo M, Spinelli BA, Sennett BJ. Prediction of in-season shoulder injury from preseason testing in division i collegiate football players. Sports Health 2014;6, 1941738114523239. https://doi.org/10.1177/194173811452323.
66. Popchak A, Burnett T, Weber N, Boninger M. Factors related to injury in youth and adolescent baseball pitching, with an eye toward prevention. Am J Phys Med Rehabil 2015;94:395-409. https://doi.org/10.1097/PHM.0000000000000184.
67. Sabick MB, Kim Y-K, Torry MR, Keirns MA, Hawkins RJ. Biomechanics of the shoulder in youth baseball pitchers: implications for the development of proximal humeral epiphysiolysis and humeral retrotorsion. Am J Sports Med 2005;33:1716-22. https://doi.org/10.1177/03635465052753.
68. Schubert MF, Duralde XA. Posterior shoulder instability in the throwing athlete. Oper Tech Sports Med 2021;29:150802. https://doi.org/10.1016/j.otsm.2021.150802.
69. Schulz CU, Pfahler M, Anetzberger HM, Becker CR, Müller-Gerbl M, Refior HJ. The mineralization patterns at the subchondral bone plate of the glenoid cavity in healthy shoulders. J Shoulder Elbow Surg 2002;11:174-81. https://doi.org/10.1067/mse.2002.121635.
70. Sciascia A, Thigpen C, Namdari S, Baldwin K. Kinetic chain abnormalities in the athletic shoulder. Sports Med Arthrosc 2012;20:16-21. https://doi.org/10.1097/JSA.0b013e31823a021f.
71. Shanley E, Kissenberth MJ, Thigpen CA, Bailey LB, Hawkins RJ, Michener LA, et al. Preseason shoulder range of motion screening as a predictor of injury among youth and adolescent baseball pitchers. J Shoulder Elbow Surg 2015;24:1005-13. https://doi.org/10.1016/j.jse.2015.03.012.
72. Sheean AJ, Kibler WB, Conway J, Bradley JP. Posterior labral injury and glenohumeral instability in overhead athletes: current concepts for diagnosis and management. J Am Acad Orthop Surg 2020;28:628-37. https://doi.org/10.5435/JAAOS-D-19-00535.
73. Sidharthan S, Greditzer IVHG, Heath MR, Suryavanshi JR, Green DW, Fabricant PD. Normal glenoid ossification in pediatric and adolescent shoulders mimics bankart lesions: a magnetic resonance imaging–based study. J Arthrosc Relat Surg 2020;36:336-44. https://doi.org/10.1016/j.arthro.2019.08.011.
74. Smith SP, Bunker TD. Primary glenoid dysplasia. A review of 12 patients. J Bone Joint Surg Br 2001;83:868-72.
75. Sweitzer BA, Thigpen CA, Shanley E, Stranges G, Wienke JR, Storey T, et al. A comparison of glenoid morphology and glenohumeral range of motion between professional baseball pitchers with and without a history of slap repair. Arthroscopy 2012;28:1206-13. https://doi.org/10.1016/j.arthro.2012.02.023.
76. Uffmann WJ, ElAttrache NS, Youssefzadeh K, Carbone A, Limpisvasti O. Return to sport after arthroscopic capsular repair in elite baseball players. Orthop J Sports Med 2023;11:23259671231153142. https://doi.org/10.1177/23259671231153142.
77. Walton J, Paxinos A, Tzannes A, Callanan M, Hayes K, Murrell GA. The unstable shoulder in the adolescent athlete. Am J Sports Med 2002;30:758-67. https://doi.org/10.1177/03635465020300052.
78. Wasylynko D. Chronic pain due to little leaguer's shoulder in an adolescent baseball pitcher: a case report. J Can Chiropr Assoc 2015;59:383-9.
79. Watkins RA, De Borja C, Ramirez F. Common upper extremity injuries in pediatric athletes. Curr Rev Musculoskelet Med 2022;15:465-73. https://doi.org/10.1007/s12178-022-09784-1.

80. Weishaupt D, Zanetti M, Nyffeler RW, Gerber C, Hodler J. Posterior glenoid rim deficiency in recurrent (atraumatic) posterior shoulder instability. Skeletal Radiol 2000;29:204-10.
81. Whiteley R, Oceguera M. Gird, trrom, and humeral torsion-based classification of shoulder risk in throwing athletes are not in agreement and should not be used interchangeably. J Sci Med Sport 2016;19:816-9. https://doi.org/10.1016/j.jsams.2015.12.519.
82. Wilk KE, Reinold MM, Macrina LC, Porterfield R, Devine KM, Suarez K, et al. Glenohumeral internal rotation measurements differ depending on stabilization techniques. Sports Health 2009;1:131-6. https://doi.org/10.1177/1941738108331.
83. Wirth MA, Lyons FR, Rockwood CA Jr. Hypoplasia of the glenoid. A review of sixteen patients. J Bone Joint Surg Am 1993;75:1175-84.
84. Wyland DJ, Pill SG, Shanley E, Clark J, Hawkins RJ, Noonan TJ, et al. Bony adaptation of the proximal humerus and glenoid correlate within the throwing shoulder of professional baseball pitchers. Am J Sports Med 2012;40:1858-62. https://doi.org/10.1177/036354651245272.
85. Zaremski JL, Krabak BJ. Shoulder injuries in the skeletally immature baseball pitcher and recommendations for the prevention of injury. Phys Med Rehabil 2012;4:509-16. https://doi.org/10.1016/j.pmrj.2012.04.005.