Diagnosis and Management of Little League Shoulder

A Systematic Review

E. Dimitra Bednar,* MSc, Jeffrey Kay,† MD, MSc, Muzammil Memon,† MD, Nicole Simunovic,‡ MSc, Laura Purcell,§ MSc, MD, and Olufemi R. Ayeni,†‖ MD, PhD

Investigation performed at McMaster University, Hamilton, Ontario, Canada

Background: Little League shoulder (LLS) is an overuse injury characterized by throwing-related pain that commonly presents in adolescent male athletes. Investigations into the optimal duration of rest from throwing and protocols for graduated return to sports (RTS) are lacking.

Purpose: To summarize the current literature with respect to the diagnosis, management, RTS, and return to throwing for LLS.

Design: Systematic review; Level of evidence, 4.

Methods: The databases EMBASE, MEDLINE, and PubMed were searched between inception and April 22, 2020. References of retrieved records were reviewed for potentially eligible studies. English-language studies that reported the diagnosis and/or management of LLS in children or adolescents were included. Studies of animals or cadavers, review articles, and non—peer reviewed records were excluded. Data were summarized narratively using descriptive statistics.

Results: Overall, 23 studies (21 level 4 studies, 2 level 3 studies) met the criteria for a total of 266 participants with a weighted mean age of 12.8 years (range, 7.4-17 years). Treatment recommendations evolved from prolonged rest and complete cessation of throwing to shorter periods of rest and graduated RTS. Less than half (11/23) of studies reported specific criteria to RTS; 1 case report discussed a coaching strategy to resume throwing, and 1 case report discussed a regimented throwing program. The proportion of participants returning to any sport participation was 94.0% (n = 157/167). The proportion returning to their preinjury level of sport was 92.5% (n = 123/133). Upon RTS, 18.7% (n = 35/187) of participants experienced a recurrence of symptoms. Premature closure of the epiphysis was reported in 1 participant.

Conclusion: Young athletes with LLS may return to play after a period of rest, and a high proportion return to their preinjury level of sport. Further prospective studies are warranted to develop evidence-based, graduated RTS protocols and to better capture any long-term sequelae of the condition.

Keywords: Little League shoulder; humeral epiphysiolysis; return to sport; pediatric; adolescent; throwing

Throwing-related pain accounts for 10% of all shoulder pain in pediatric patients.[28] Little League shoulder (LLS), or proximal humeral epiphysiolysis, is an overuse injury common in adolescent baseball players characterized by throwing-related pain over the proximal humerus.[8] The number of pitches thrown and the cumulative rotary torque experienced are strongly associated with the pathophysiology of LLS.[19,22,28] This repetitive microtrauma likely damages the cartilage of the physis, which is more vulnerable to torsion than it is to tension.[31] The classic radiographic finding of LLS is widening of the proximal humeral physis of the throwing arm, classified as a Salter-Harris type I injury.[28] Treatment recommendations include cessation of throwing for 3 months, physical therapy for associated changes in range of motion (ROM) or strength of the shoulder, and a graduated return to throwing when asymptomatic.[33]

The majority of young athletes are able to return to their preinjury levels of participation after adequate rest, and surgery is rarely indicated.[33] Strategies to prevent the onset or recurrence of LLS include teaching proper pitching mechanics, limiting pitch/throw counts, and taking 1 season off from throwing each year.[22,28] The USA Baseball Medical & Safety Advisory Committee recommends age-based pitching counts and days of rest to help guide young athletes, coaches, and guardians in safe throwing practices.[22,38]

Although the prognosis for Salter-Harris type I fractures is good and complications of LLS are rare, this injury is potentially significant to the skeletally immature athlete.

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The proximal humeral epiphysis is established by coalescence of the physes at the humeral head, the greater tuberosity, and the lesser tuberosity at approximately 7 years of age.[15,20] It is responsible for up to 80% of longitudinal growth of the humerus and typically closes between the ages of 16 and 20 years.[15,20] Complications associated with LLS include premature growth arrest, lateral metaphyseal fragmentation, and demineralization of the metaphysis.[28,32] If managed improperly, LLS may have sequelae with potential to limit future recreation and career prospects.

The diagnosis of LLS is currently challenged by inconsistent reports of whether positive radiographic findings are required. Several case series have documented physeal widening of the dominant proximal humeral physis in adolescent athletes without symptoms.[2,23,25,31] Investigations into the optimal duration of rest from throwing and protocols for graduated return to sports (RTS) are lacking.[28] The objective of this systematic review was to summarize and assess the diagnosis, management, outcomes, and RTS or return to throwing for LLS. We hypothesized that LLS would be diagnosed based on history and imaging, that it would be treated using rest from throwing with graduated return and a focus on coaching proper techniques, and that the majority of all patients would experience a full recovery and full return to preinjury levels of participation.

METHODS

Search Strategy

This systematic review was performed and reported according to PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines.[34] Three online databases (EMBASE, PubMed, and MEDLINE) were searched between inception and April 22, 2020. The search terms "shoulder," "Little League," "humerus," and "epiphysiolysis"/"epiphysitis"/"apophysitis" were combined using Boolean operators (Appendix Table A1). Retrieved articles also underwent a screen of their references to further capture potentially eligible studies.

Study Screening

The titles, abstracts, and full-text articles were screened by 2 reviewers (J.K. and M.M.) independently. Disagreements during title and abstract screening were included in the next stage for more in-depth review. Further disagreements were discussed between the reviewers, and a senior author (O.R.A.) was consulted for any remaining discrepancies.

Assessment of Study Eligibility and Reviewer Agreement

The research question and eligibility criteria were determined a priori. Included studies reported the diagnosis and/or management of LLS (humeral epiphysiolysis) in children and adolescents and were written in English. Therapeutic studies of any level of evidence were included. Cadaveric studies, animal studies, conference papers or poster presentations, book chapters, and review articles were excluded.

Interreviewer agreement was assessed using the κ statistic for the title, abstract, and full-text screening stages. Agreement was categorized a priori as follows: $\geq$0.61, substantial; 0.21 to 0.60, moderate; and $\leq$0.20, slight agreement.[21]

Quality Assessment

The methodological quality of the included studies was assessed using the methodological index for nonrandomized studies (MINORS) instrument.[35] Using the MINORS checklist, noncomparative studies were assigned a maximum score of 16, and comparative studies were assigned a maximum score of 24.[35] Noncomparative studies were categorized a priori as follows: 0 to 4, very low-quality evidence; 5 to 7, low quality; 8 to 12, fair quality; and $\geq$13, high quality. Comparative studies were categorized as follows: 0 to 6, very low quality; 7 to 10, low quality; 11 to 15, fair quality; and $\geq$16 high quality.

Data Abstraction and Statistical Analysis

Data were abstracted in duplicate and recorded in a spreadsheet using Microsoft Excel Version 2007 (Microsoft Corp). Data regarding year of publication, study design, level of evidence, sample size, age, sex, follow-up, clinical and radiographic diagnosis, rehabilitation protocols, rates and timing of RTS, and recurrence were recorded.

Given the nonuniform nature of qualifying studies' techniques and outcome reporting, the results were presented in a descriptive summary fashion. Descriptive statistics including means, weighted means, proportions, and ranges were calculated using Microsoft Excel Version 2007.

‖Address correspondence to Olufemi R. Ayeni, MD, PhD, McMaster University Medical Centre, 1200 Main Street West, Room 4E15, Hamilton, Ontario L8N 3Z5, Canada (email: ayenif@mcmaster.ca).
*Michael G. DeGroote School of Medicine, McMaster University, Hamilton, Ontario, Canada.
†Division of Orthopaedic Surgery, Department of Surgery, McMaster University, Hamilton, Ontario, Canada.
‡Department of Health Research Methods, Evidence, and Impact, McMaster University, Hamilton, Ontario, Canada.
§Department of Pediatrics, McMaster University, Hamilton, Ontario, Canada.
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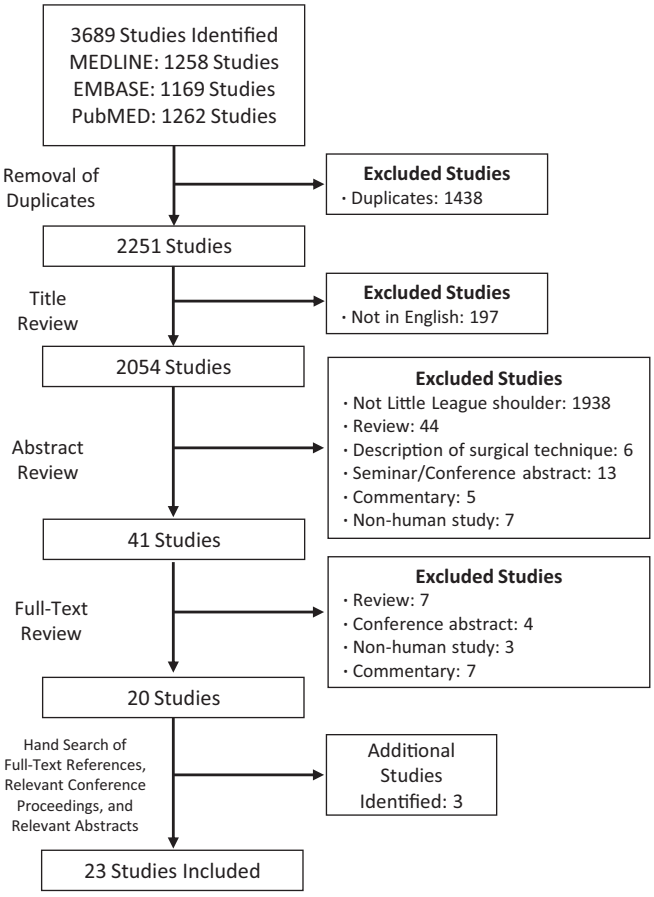

Figure 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram.

RESULTS

Search Strategy

The initial search of the online databases yielded 3689 records. Systematic record screening identified 20 full-text articles, and reference checking yielded an additional 3 records for a total of 23 full-text articles eligible for inclusion (Figure 1). The reviewers reached substantial agreement at the title ($\kappa = 0.853$; 95% confidence interval [CI], 0.812-0.894), abstract ($\kappa = 0.879$; 95% CI, 0.824-0.934), and full-text ($\kappa = 1.00$) screening stages.

Study Characteristics

Among the 23 included articles, there were 15 case reports,[¶] 6 case series,[6,7,14,15,18,27] 1 retrospective cohort study,[13] and 1 case-control study.[17] A total of 266 participants with a weighted mean age of 12.8 years (range, 7.4-17 years) were included. The proportion of girls was 0.75% (n = 2/266). The majority of participants played baseball primarily (n = 261/266), but other sports played included tennis (n = 4), badminton (n = 1), basketball (n = 1), cricket (n = 1), and American football (n = 1). Countries of publication were as follows: United States (16 studies),[#] Japan (4 studies),[13,16,17,18] Canada (1 study),[39] Germany (1 study),[10] and the United Kingdom (1 study).[5] Mean follow-up duration (defined as time from initial presentation) ranged from 6 weeks to 6 years. The included studies had an evidence level of 4 (21 studies)[**] or 3 (2 studies).[13,17] Using the MINORS tool, the methodological quality of all noncomparative studies was determined to be of low quality, with a mean score of 4.8 of 16. The best scoring criterion was a clearly stated aim (17/23 studies).[5-7,9-18,27,37,39,40] No studies reported prospective collection of data, prospective calculation of sample size, or inclusion of consecutive patients. Table 1 details individual study characteristics.

Diagnosis of LLS

The chief symptom of participants was consistent across all studies: pain localizing to the dominant proximal humerus during the act of throwing or racquet swinging. No single phase of throwing was identified to cause symptoms. Both acute and insidious onset presentations were reported. Symptom duration ranged from 2 weeks to 1 year. Details of the symptoms and clinical characteristics identified across the included studies are reported in Appendix Table A2. The reporting of participants' histories and physical examination findings were highly variable among studies.

Tenderness to palpation over the anterolateral or posterolateral aspect of the proximal humerus was the most commonly reported physical examination finding (n = 116/174; 66.6%).[††] Minor swelling over the proximal humerus was reported in 4.0% of participants (n = 7/174),[6,7] and overdevelopment of the dominant shoulder girdle musculature was reported in 2.30% (n = 4/174).[1] A firm palpable mass was noted in 1 participant's proximal humerus (0.57%).[37] Nearly half (n = 80/174; 46.0%) of the study population had pain with or altered ROM of the dominant shoulder compared with the contralateral side. Five studies reported inconsistent changes in ROM of the affected shoulder (Appendix Table A2).[6,12,15,17,40] A total of 28 participants (16.1%) had glenohumeral internal rotation deficit (GIRD).[15] Pain and/or weakness during resisted external rotation (ER) was reported in 9.77% (n = 17/174),[4,7,11,29] while pain with internal rotation (IR) was reported in 1.72% (n = 3/174).[5,7] Abduction reproduced symptoms in 8 participants.[4,5,7,36] Tests for shoulder instability and impingement were not routinely performed.

IR and ER anteroposterior plain radiographs of both shoulders were the most commonly used imaging investigation (20/23 studies).[‡‡] Two studies used computed

[¶]References 1, 3-5, 9-12, 16, 29, 30, 36, 37, 39, 40.

[#]References 1, 3, 4, 6, 7, 9, 11, 12, 14, 15, 27, 29, 30, 36, 37, 40.
[**]References 1, 3-7, 9-12, 14-16, 18, 27, 29, 30, 36, 37, 39, 40.
[††]References 1, 5-7, 9, 11, 15-18, 29, 36, 39.
[‡‡]References 1, 3-7, 9-15, 17, 18, 27, 30, 36, 37, 40.

TABLE 1
Study Characteristics[a]

Lead Author (Year)	Country of Publication	Study Design (LOE)	MINORS score (out of 16)	Sample Size	Girls, %	Age, y	Follow-up
Adams (1966)[1]	US	Case report (4)	3	5	0	14 (13-15)	NR
Albert (1990)[3]	US	Case report (4)	3	1	0	13	8 wk
Barnett (1985)[4]	US	Case report (4)	4	1	0	13	2 y
Boyd (1997)[5]	UK	Case report (4)	5	1	0	15	2 y
Cahill (1974)[6]	US	Case series (4)	4	5	NR	11-12	6 y
Carson (1998)[7]	US	Case series (4)	6	23	0	14 (11-16)	9.6 mo (1.5-54 mo)
Domes (2012)[9]	US	Case report (4)	4	1	0	15	2 y
Drescher (2004)[10]	Germany	Case report (4)	4	1	0	12	1 y
Fleming (2004)[11]	US	Case report (4)	4	1	0	12	NR
Greenberg (2018)[12]	US	Case report (4)	5	1	0	15	NR
Harada (2018)[13]	Japan	Retrospective cohort (3)	8	87	0	12.1 (7.4-17.0)	8.0 mo (1-37 mo)
Hatem (2006)[14]	US	Case series (4)	7	4	0	12.8 (12-14)	NR
Heyworth (2016)[15]	US	Case series (4)	6	95	2.1	13.1 (8-16)	NR; until resolution of symptoms (64 mo)
Hosokawa (2017)[16]	Japan	Case report (4)	4	1	0	15	2 y from diagnosis
Ito (2019)[17]	Japan	Case-control (3)	8	10	0	12.6 (11-15)	4 y from LLS episode
Kanematsu (2015)[18]	Japan	Case series (4)	8	19	0	12.7	8.5 mo (2-31 mo)
Obembe (2007)[27]	US	Case series (4)	7	4	0	Median, 13 (11-15)	3 mo
Popkin (2006)[29]	US	Case report (4)	3	1	0	12	3 mo
Reeder (2015)[30]	US	Case report (4)	3	1	0	13	NR
Song (2006)[36]	US	Case report (4)	3	1	0	13	2 mo
Tullos (1974)[37]	US	Case report (4)	4	1	0	12	6 wk
Wasylynko (2015)[39]	Canada	Case report (4)	4	1	0	17	1 y
Zipser (2018)[40]	US	Case report (4)	4	1	0	15	3 mo

[a]Data are reported as mean (range) unless otherwise indicated. LLS, Little League shoulder; LOE, level of evidence; MINORS, methodological index for non-randomized studies; NR, not reported.

tomography (CT) scans and found physeal widening.[16,39] Three studies used magnetic resonance imaging (MRI) to either confirm the diagnosis or in lieu of radiographs.[14,29,36] Combined imaging (radiograph and MRI) was used in 7 studies.[7,14,15,27,30,36,40] Widening of the proximal humeral physis of the throwing arm was reported in 264 participants (99%). Other radiographic findings included fragmentation, demineralization, or sclerosis of the metaphysis; Salter-Harris type II fracture (n = 2); and a subperiosteal cyst in the bicipital groove (n = 1).[§§] MRI diagnostic findings for LLS included bone marrow edema, physeal widening, periosteal edema, and mild periosteal elevation.[14,29]

Three studies evaluated humeral retroversion using 3-dimensional (3-D) CT, ultrasonography, and/or physical examination.[12,16,17] Humeral retroversion was greater on the dominant side compared with the nondominant side ($104^\circ \pm 8^\circ$ vs $84^\circ \pm 12^\circ$; $P < .001$) as measured using ultrasonography.[17] In a case report that used 3-D CT, humeral retroversion was 27.1° greater on the dominant side compared with the nondominant side.[16]

[§§]References 1, 4, 6, 7, 9, 30, 36, 37, 39, 40.

Management of LLS

The management of LLS differed in studies published before compared with those published after 1998. Six of the included studies were published before 1998, wherein management of LLS included complete rest from throwing until closure of physes was demonstrated on radiographs[1] or participants were asymptomatic,[1,3,5,6,37] sling immobilization,[4] and change of position from pitching indefinitely.[1,37] Of the 17 studies[7,9-18,27,29,30,36,39,40] published in or after 1998, only 1 recommended rest until physis closure,[18] and another reported changing position (n = 25/95) and sling immobilization (n = 2/95) for a proportion of participants.[15] The more current recommendations included rest from throwing, ranging in duration from 1 month to 1 year, and relied on symptom resolution before RTS.[10,11,13,14,16-18,27,29] The greatest proportion of participants abstained from throwing for 4 months (41.9%; n = 95/227),[15] but other periods recommended were 4 to 6 weeks (n = 89/227),[11,13,36] 3 months (n = 41/227),[5,7,27,40] and 2 months (n = 2/227).[16,29] Newer recommendations advised participants to avoid throwing but advised them to continue with other sporting activities and to not change position from pitching indefinitely.

Formal physical therapy was recommended in 4 studies for participants with documented restricted ROM or

TABLE 2
Management of Little League Shoulder[a]

Lead Author (Year)	Activity Modification/Cessation of Throwing	Formal Physical Therapy	Criteria for Return to Activities
Adams (1966)[1]	Complete rest until asymptomatic (n = 2) Discontinued play for remainder of season (n = 1) Refrain from pitching until physes closed (n = 4) Play different position (n = 3)	NR	Physes closed Symptom resolution
Albert (1990)[3]	Restricted from all athletic activities for 8 wk (n = 1)	NR	NR
Barnett (1985)[4]	Sling immobilization × 3 wk (n = 1) Abstain from throwing × 12 wk (n = 1)	NR	NR
Boyd (1997)[5]	Restricted to pain-free activities for 3 mo (n = 1)	Structured home rehabilitation program to strengthen shoulder musculature (n = 1)	NR
Cahill (1974)[6]	Rest without immobilization or splinting (n = 5)	NR	NR
Carson (1998)[7]	Rest from throwing for an average 3 mo (range, 1 mo to 1 y)	Worsening pain with any type of strengthening exercises (n = 7)	Symptom resolution
Domes (2012)[9]	ORIF for avulsed medial humeral epicondyle (n = 1) Splint and sling × 2 wk (n = 1) Abstinence from throwing × 12 wk (related to ORIF; n = 1)	Throwing exercises with coaching at 12 wk (n = 1)	NR
Drescher (2004)[10]	Abstinence from throwing × 12 wk (n = 1) Abstinence from fast bowling until closing of proximal humeral physis (n = 1)	NR	RTS when pain subsided Return to fast bowling after closure of proximal humeral physis
Fleming (2004)[11]	Rest × 4-6 wk (n = 1)	NR	Symptom resolution
Greenberg (2018)[12]	NR	Subsequent measurements of ROM and HRT (n = 1)	NR
Harada (2018)[13]	Prohibited from throwing × 1.2 mo (n = 68) Throwing with limitations (n = 19) Advised to perform all other baseball activities (running, batting, fielding; n = 87)	1-mo rehabilitation aimed at improving shoulder tightness (n = 87)	Physis width is narrower than it was 1 mo earlier Symptom resolution
Hatem (2006)[14]	Rest from throwing (n = 2)	Formal physical therapy program (n = 1)	Symptom resolution
Heyworth (2016)[15]	Cessation of throwing with rest × 4.2 mo (n = 94) Position changes (n = 25) Sling immobilization (n = 2) Pitch count limits (n = 1)	Formal physical therapy (n = 75) All participants diagnosed with GIRD received physical therapy including shoulder adduction stretching (n = 28)	NR
Hosokawa (2017)[16]	Rest × 2 mo (n = 1)	NR	Symptom resolution
Ito (2019)[17]	Rest from playing baseball × 2-3 mo (n = 10)	NR	Symptom resolution Physis appearing normal on radiographs
Kanematsu (2015)[18]	Rest from throwing (n = 19)	NR	Healing confirmed radiographically
Obembe (2007)[27]	Rest from overhead sports activities × 3 mo (n = 4)	NR	If pain free by 3 mo, gradually resume activity over 3 wk

(continued)

TABLE 2 (continued)

Lead Author (Year)	Activity Modification/Cessation of Throwing	Formal Physical Therapy	Criteria for Return to Activities
Popkin (2006)[29]	Rest × 2 mo (n = 1)	NR	Symptom resolution
Reeder (2015)[30]	Rest, then regimented throwing program (n = 1)	Thoracic mobilization (n = 1)	NR
Song (2006)[36]	Rest × 4-6 wk (n = 1)	NR	NR
Tullos (1974)[37]	Discontinued as a pitcher; continued as a catcher (n = 1)	NR	NR
Wasylynko (2015)[39]	Rest from throwing (n = 1)	General strengthening and active release techniques (n = 1)	NR
Zipser (2018)[40]	Cessation of throwing × 3 mo (n = 1)	NR	NR

[a]GIRD, glenohumeral internal rotation deficit; HRT, humeral retrotorsion; ORIF, open reduction internal fixation; NR, not reported; ROM, range of motion; RTS, return to sport.

GIRD.[13-15,30] One participant underwent a structured rehabilitation program from home.[5] One participant was treated by a chiropractor.[39] One article reported coaching proper pitching technique as a management strategy, in which the participant completed throwing exercises under the guidance of a throwing coach as part of his recovery.[9] One participant underwent activity modifications with pitching count limits.[15] Another participant progressed through a regimented throwing program.[30] Surgery was not prescribed for the treatment of LLS (Table 2).

RTS and Return to Throwing

The results of individual studies regarding RTS and throwing are detailed in Tables 3 and 4. Criteria to return to activities were variable and were reported in 11 of the 23 studies.[||||] Symptom resolution alone was the most common criteria to RTS.[7,11,14,16,27,29] One study required healing to be confirmed radiographically before return to activities.[18] A decrease in physeal widening of the affected humerus or a comparable width to the nondominant side was considered "healed."[18] Two studies required both symptom resolution and physis healing on radiographs before returning to activities.[13,17] One participant resumed his position as a fast bowler only after his physes closed.[10]

Outcomes on RTS and/or throwing were available in 19 of 23 studies.[¶¶] Of those participants with reported follow-up, 94% (n = 157/167) were able to return to any type of sport participation.[##] Two participants had not yet completed the prescribed duration of rest.[7] Two more participants were recently diagnosed, and their outcomes are not yet reported.[14] The proportion of participants able to return to their preinjury position or level of sport was reported in 13 studies as 92.5% (n = 123/133).[a] Five case reports documented 100% of participants (n = 5/5) had returned to pitching.[3,4,11,39,40] Three studies reported 64.7% (n = 11/17) of participants had returned to pitching.[6,14,17] The range of mean time to RTS was 2 months to 2 years and was reported in 11 of 23 articles.[3-5,9,13,14,16-18,39,40]

Key clinical outcomes in the 17 articles that reported any such outcomes included symptom resolution, ability to return to activity without symptom exacerbation, and full ROM.[b] All 261 participants with adequate follow-up had a resolution of their symptoms (100%). The mean time to resolution of symptoms was reported in 8 of 23 included studies and ranged from 2 to 7.7 months.[3,6,7,15-17,29,40]

Follow-up radiographs were used to confirm healing in 13 of 23 included studies,[1,3-7,9,13,15-18,37] while follow-up MRI was used in 1 study.[36] Of the 149 participants with data available, 126 (84.6%) had healed.[4,6,7,9,13,16-18] Alternatively, 21 of these participants had continued widening of the lesion despite symptom resolution,[7] while 9 participants had recurrence on radiographs, defined as widening of the physis compared with 1 month earlier.[13]

Recurrence of symptoms after RTS was reported in 8 studies.[5,13,15,17,18,29,39,40] Of the 187 participants with data available, 35 (18.7%) experienced pain recurrence. The proportion of participants with pain recurrence varied among studies: Harada and colleagues[13] documented that 25% of 87 participants experienced recurrent symptoms at a mean of 3.5 months after complete RTS; Heyworth et al[15] reported 7% of their 95 participants experienced recurrent symptoms at a mean of 7.6 months; Ito et al[17] reported 80% of their 10 participants experienced pain recurrence. Four studies reported no pain recurrence among their combined 22 participants.[18,29,39,40] None of the included studies reported validated outcomes scores.

Complications and Concurrent Injuries

Complications and concurrent injuries of the affected shoulder included premature closure of the proximal humeral physis (n = 1),[7] accelerated growth of the affected humerus (n = 1),[1] an increase in humeral retroversion (n = 3),[12,16,17] shoulder arthritis (n = 7),[17] a partial tear of the pectoralis major (n = 1),[17] and a nondisplaced labral tear (n = 1).[40] Other injuries included Little League elbow,

[||||]References 1, 7, 10, 11, 13, 14, 16-18, 27, 29.
[¶¶]References 1, 3-7, 9-11, 13, 14, 16-18, 27, 29, 37, 39, 40.
[##]References 1, 3-7, 9-11, 13, 14, 16-18, 27, 29, 39, 40.
[a]References 3-6, 9, 11, 13, 14, 16-18, 39, 40.
[b]References 1, 3-7, 9, 10, 13-18, 29, 39, 40.

TABLE 3
Outcomes and Complications[a]

Lead Author (Year)	Mean Time to Symptom Resolution	Clinical Outcomes Reported	Radiographic Outcomes Reported	Proportion with Recurrence of Symptoms, %	Other Complications
Adams (1966)[1]	NR	Symptom resolution (n = 2)	Normal appearance of affected physis (n = 2)	NR	Accelerated growth of affected humerus (n = 1)
Albert (1990)[3]	8 wk	Symptom resolution (n = 1) No change in physical examination findings (n = 1)	Reconstitution of the physeal plate; metaphyseal sclerosis (n = 1)	NR	NR
Barnett (1985)[4]	NR	Symptom resolution (n = 1)	Active healing at 14 wk and healed fracture at 2 y (n = 1)	NR	NR
Boyd (1997)[5]	NR	Symptom resolution (n = 1) No change in physical examination (n = 1)	Union of the fracture (n = 1) Physis remained open (n = 1) No growth asymmetry (n = 1)	100 (n = 1)	Pain with extreme hits, particularly in ER (n = 1)
Cahill (1974)[6]	6 wk	Full ROM (n = 5) Symptom resolution (n = 5)	Healing at 8.5 wk (n = 1)	NR	NR
Carson (1998)[7]	7.7 mo	Symptom resolution (n = 21)	Continued widening of proximal humeral epiphysis (n = NR)	NR	Premature closure of affected physis (n = 1)
Domes (2012)[9]	NR	Full painless ROM (n = 1) Normal strength in shoulder at 10 mo (n = 1) Symptom resolution (n = 1)	No physeal widening (n = 1) Complete resolution of periosteal reaction along lateral humeral metaphysis (n = 1)	NR	NR
Drescher (2004)[10]	NR	Symptom resolution (n = 1)	NR	NR	NR
Greenberg (2018)[12]	NR	NR	NR	NR	Increased difference between dominant and nondominant humeral retroversion (n = 1)
Harada (2018)[13]	NR	Complete return (throwing 90%-100% of maximum strength) at average 2.8 mo (n = 83) Incomplete return to baseball (n = 4) Continued shoulder pain at final observation (n = 5)	Width of physis similar to nondominant side at average of 3.0 mo (n = 43) Width of physis narrowed but not similar to other side (n = 44) Recurrence (defined as widening of physis compared with 1 mo earlier; n = 9)	25 (n = 22) at mean 3.5 mo	Fractures: clavicle (n = 1), finger (n = 2) Lumbar spondylolysis (n = 2) Finger ligament injury (n = 1)
Hatem (2006)[14]	NR	Symptom resolution (n = 2) Pain-free throwing (n = 1)	NA	NR	NR

(continued)

TABLE 3 (continued)

Lead Author (Year)	Mean Time to Symptom Resolution	Clinical Outcomes Reported	Radiographic Outcomes Reported	Proportion with Recurrence of Symptoms, %	Other Complications
Heyworth (2016)[15]	2.6 mo for resolution of symptoms 4.2 mo to return to competition	Symptom resolution (n = 64)	NR	7 (n = 7) at mean time of 7.6 mo (range, 2.4-18.6 mo)	None
Hosokawa (2017)[16]	2 mo	Symptom resolution (n = 1)	Improvement in width of physis (n = 1)	NR	NR
Ito (2019)[17]	2-3 mo	Symptom resolution permitting RTS (n =10)	Physis appeared normal (n = 10) after 3-mo rest	80 (n = 8)	Shoulder arthritis (n = 7) Partial tear of pectoralis major (n = 1) Partial UCL tear (n = 4) Elbow arthritis (n = 1) Cubital tunnel syndrome (n = 1) Olecranon stress fracture (n = 1)
Kanematsu (2015)[18]	NR	Symptom resolution (n = 19)	Healed (no difference in width of physes) confirmed for 4.7 mo (2-15 mo; n = 19)	0 (n = 0)	NR
Popkin (2006)[29]	2 mo	Symptom resolution (n = 1)	NR	0 (n = 0)	NR
Song (2006)[36]	NR	NR	Less physeal widening (MRI; n = 1)	NR	NR
Tullos (1974)[37]	NR	NR	Maturation of callus and progression of healing (n = 1)	NR	NR
Wasylynko (2015)[39]	NR	Symptom resolution (n = 1)	NR	0 (n = 0)	NR
Zipser (2018)[40]	3 mo	Symptom resolution (n = 1)	NR	0 (n = 0)	NR

[a]Three studies were not included in this table because of insufficient data: Fleming et al,[11] Obembe et al,[27] and Reeder and Smith.[30] ER, external rotation; MRI, magnetic resonance imaging; NA, not applicable; NR, not reported; ROM, range of motion; RTS, return to sport; UCL, ulnar collateral ligament.

elbow arthritis, fractures of the clavicle and fingers, cubital tunnel syndrome, and ligamentous tears in the upper extremity (Appendix Table A2).

DISCUSSION

This systematic review summarized the diagnosis, management, recovery, and RTS and throwing for adolescents with LLS. The condition was commonly diagnosed in male athletes who presented with a chief symptom of throwing-related pain in the dominant arm. Pertinent physical examination findings were tenderness at the anterolateral proximal humerus, limitations in ROM, and weakness. The most consistent investigations were radiographs of both shoulders to compare physeal widths. CT or MRI may better visualize the physis and surrounding bone quality. Although there are reports in the literature of incidental physeal widening in young athletes, 99% of the participants diagnosed with LLS in this review had both symptoms and positive radiographic findings. Current recommendations for management included rest from throwing for approximately 4 months. During this hiatus, participants were encouraged to continue with other athletic activities. Follow-up radiographs were inconsistently used in the literature to observe healing. The criteria to resume activity included a resolution of symptoms and/or healing confirmed by radiographs. All participants with available data (n = 260/266) experienced resolution of their symptoms, and 92.5% (n = 123/133) returned to their preinjury level of participation.[c] Premature closure of the epiphysis was reported in just 1 participant.[7]

[c]References 3-6, 9, 11, 13, 14, 16-18, 39, 40.

TABLE 4
Sport Participation and Return to Sport[a]

Lead Author (Year)	Preinjury Sport	Preinjury Sport Position	Preinjury Sport Participation	RTS			
				Returned to Any Sport Participation, %	Returned to Preinjury Level/ Position, %	Pitchers Able to Return to Pitching, %	Mean Time to Return
Adams (1966)[1]	Baseball (n = 5)	Pitchers (n = 5)	Little League for 1-6 y	20 (n = 1)	NR	NR	NR
Albert (1990)[3]	Baseball (n = 1)	Pitcher	NR	100 (n = 1)	100 (n = 1)	100 (n = 1)	8 wk
Barnett (1985)[4]	Baseball (n = 1)	Pitcher	Pitching year-round in competitive league and at pitching school	100 (n = 1)	100 (n = 1)	100 (n = 1)	2 y
Boyd (1997)[5]	Badminton (n = 1)	NA	Junior-level international Normally played 1-2 h/d, 3-4 times/wk Intense training camp: 6 h daily for 5 d	100 (n = 1)	100 (n = 1)	NA	3 mo
Cahill (1974)[6]	Baseball (n = 5)	Pitchers (n = 5)	NR	100 (n = 5)	40 (n = 2)	40 (n = 2)	NR
Carson (1998)[7]	Baseball (n = 23)	Pitchers (n = 19), 3rd basemen (n = 3), 2nd baseman (n = 1)	Played continuously for at least 12 mo (n = 15) Played on 2 different teams at same time (n = 6)	91 (n = 21)	NR	NR	NR
Domes (2012)[9]	Baseball and football (n = 1)	Pitcher, quarterback	Competitive high school baseball in spring/summer; competitive high school football in fall	100 (n = 1)	100 (n = 1)	NR	2 y
Drescher (2004)[10]	Cricket (n = 1)	Fast bowler	Junior class	100 (n = 1)	NR	NR	NR
Fleming (2004)[11]	Baseball (n = 1)	Pitcher	NR	100 (n = 1)	100 (n = 1)	100 (n = 1)	NR
Greenberg (2018)[12]	Baseball and basketball (n = 1)	Pitcher and third baseman	Baseball 8/12 mo; basketball and weight training other months	NR	NR	NR	NR
Harada (2018)[13]	Baseball (n = 87)	Pitcher (n = 38), nonpitcher (n = 49)	NR	100 (n = 87)	95 (n = 83)	NR	2.8 mo
Hatem (2006)[14]	Baseball (n = 4)	Pitcher (n = 2), nonpitcher or starting to pitch (n = 2)	NR	50 (n = 2)	25 (n = 1)	25 (n = 1)	9 mo (7-11 mo, n = 2)
Heyworth (2016)[15]	Baseball (n = 92), tennis (n = 3)	Pitcher (n = 79), catcher (n = 7), other (n = 6)	NR	NR	NR	NR	NR
Hosokawa (2017)[16]	Baseball (n = 1)	Outfielder	Began playing baseball at age 9 y	100 (n = 1)	100 (n = 1)	NA	2 mo
Ito (2019)[17]	Baseball (n = 10)	Pitcher (n = 2), other (n = 8)	Played baseball year-round from age 6-10 y	100 (n = 10)	100 (n = 10)	100 (n = 8)	2-3 mo
Kanematsu (2015)[18]	Baseball (n = 19)	NR	NR	100 (n = 19)	100 (n = 19)	NR	4.7 mo
Obembe (2007)[27]	Baseball (n = 3), tennis (n = 1)	Pitchers (n = 3)	NR	75 (n = 3)	NR	NR	NR
Popkin (2006)[29]	Baseball (n = 1)	Catcher (n = 1)	Youth baseball team	0 (n = 0)	NR	NA	NR

(continued)

TABLE 4 (continued)

Lead Author (Year)	Preinjury Sport	Preinjury Sport Position	Preinjury Sport Participation	RTS			
				Returned to Any Sport Participation, %	Returned to Preinjury Level/ Position, %	Pitchers Able to Return to Pitching, %	Mean Time to Return
Reeder (2015)[30]	Baseball (n = 1)	Pitcher (n = 1)	NR	NR	NR	NR	NR
Song (2006)[36]	Baseball (n = 1)	Pitcher (n = 1)	Traveling team (competitive)	NR	NR	NR	NR
Tullos (1974)[37]	Baseball (n = 1)	Pitcher and catcher (n = 1)	NR	NR	NR	NR	NR
Wasylynko (2015)[39]	Baseball (n = 1)	Pitcher (n = 1)	Junior baseball	100 (n = 1)	100 (n = 1)	100 (n = 1)	12 mo
Zipser (2018)[40]	Baseball (n = 1)	Pitcher (n = 1)	NR	100 (n = 1)	100 (n = 1)	100 (n = 1)	3 mo

[a]NA, not applicable; NR, not reported; RTS, return to sport.

Although the prognosis of LLS has always been quite good, current management plans allow athletes to resume their preinjury position and level of participation sooner and more reliably than did those in the past. The case series by Carson and Gasser[7] in 1998 established this change in management. While LLS was first described in 1953, this review found just 6 subsequent studies about LLS until 1998. Earlier studies recommended patients should not throw for the remainder of the season or until their physes closed.[1,3-6,37] In 1966, Adams[1] recommended athletes with shoulder or elbow pain discontinue pitching but play other positions, and for prophylactic measures, he recommended a restriction in the number of innings pitched and abolition of curve ball throwing and called for the establishment of medical advisory boards at national and local levels.

In 1998, Carson and Gasser[7] postulated that the Salter-Harris type 1 fracture in LLS healed clinically much faster than was radiographically apparent, and they instead permitted participants to resume throwing after their symptoms subsided, after approximately 3 months of rest. Their study was considered a success, with 91% of participants returning to sport, and since then, a gradual return to throwing in 2 to 4 months has been recommended.

Changes in humeral retroversion and concurrent GIRD were reported with limited understanding of the long-term implications. Previous studies have shown an association between rotational shoulder deficits and pathological changes to the shoulder including LLS in young pitchers.[24,26] Given the retrospective nature of all studies to date, it remains unclear whether bony or soft tissue changes are risk factors for the development of LLS or if they are sequelae from repetitive overhead activities at a young age.

There are 2 primary deficiencies within the current body of literature. First, reports of proper pitching coaching technique and of graduated RTS protocols are lacking. This systematic review found only 1 of 266 participants received postinjury coaching for throwing[9] and only 1 of 266 participants had a pitching count limit upon his RTS.[15] One case report had the participant RTS after a regimented throwing program.[30] These techniques are routinely recommended to prevent the recurrence of LLS but have not been frequently reported in the literature. Second, no prospective study with long-term follow-up has been conducted to date to determine the incidence and significance of any long-term sequelae.

This systematic review is limited primarily by the quality of evidence it summarized. Included articles were all retrospective observational studies of lower levels of evidence (3 or 4), which inherently make the results prone to bias. There was considerable heterogeneity across the included studies with respect to diagnostic and treatment modalities, which precluded the ability to combine the data and determine meaningful summary measures. Furthermore, these studies had inconsistent outcome reporting and lengths of follow-up; therefore, the comparison of results across studies is done with caution. However, the conclusions from this systematic review reflect current understandings of LLS and can be an important source of information on what is known about the natural progression of the condition and what remains to be investigated. Future prospective studies should be undertaken to develop a standardized approach in the diagnosis and management of LLS to facilitate an optimal RTS for adolescent athletes with this condition.

CONCLUSION

Current evidence to manage LLS supports a return to throwing after a period of rest. All participants with adequate follow-up in this systematic review reported symptom resolution, a high proportion returned to their preinjury participation (92.5%), and there was just 1 instance of premature physeal closure. Prospective

longitudinal studies are warranted to identify potential long-term sequelae of the condition and to determine an optimal RTS protocol.

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APPENDIX

TABLE A1
Database Search Strategy

MEDLINE: 1258 Studies		Embase: 1169 Studies		PubMed: 1262 Studies	
Strategy	Studies	Strategy	Studies	Strategy	Studies
1. little league.mp.	121	1. little league.mp.	143	1. little league	417
2. Shoulder Joint/ or Shoulder/ or shoulder.mp.	76,558	2. shoulder.mp.	100,374	2. shoulder stress fracture	440
3. humerus.mp. or Humerus/	20,843	3. humerus.mp.	28,960	3. shoulder epiphysiolysis	46
4. osteochondrosis.mp. or Osteochondrosis/	2562	4. osteochondrosis.mp.	2777	4. shoulder osteochondrosis	82
5. stress fracture.mp. or Fractures, Stress/	4542	5. stress fracture.mp.	7130	5. epiphysitis	94
6. epiphysiolysis.mp.	544	6. epiphysiolysis.mp.	2004	6. apophysitis	209
7. epiphysitis.mp.	94	7. epiphysitis.mp.	82	7. 1 or 2 or 3 or 4 or 5 or 6	1262
8. apophysitis.mp.	209	8. apophysitis.mp.	307		
9. 2 or 3	91,230	9. 2 or 3	120,261		
10. 4 or 5	7089	10. 4 or 5 or 6	11,826		
11. 9 and 10	312	11. 9 and 10	700		
12. 1 or 6 or 7 or 8 or 11	1258	12. 1 or 7 or 8 or 11	1169		

TABLE A2
Diagnostic and Clinical Characteristics of the Included Studies[a]

Lead Author (Year)	Patient Symptoms	Physical Examination Findings	Radiographic Findings	MRI Findings	Other Associated Conditions of the Shoulder	Other Associated Conditions of the Elbow
Adams (1966)[1]	Pain with throwing (n = 5)	Painless full active ROM (n = 1) Pain on simulation of hard throw (n = 2) Tender over proximal humerus (n = 2) Overdevelopment of shoulder girdle muscles (n = 4)	Physeal widening (n = 4) Fragmentation and demineralization of physis (n = 2)	NA	Demineralization of greater tuberosity (n = 1) Accelerated growth of affected humerus (n = 1)	NR
Albert (1990)[3]	Dominant shoulder pain for several months (n = 1)	No shoulder muscle atrophy or weakness (n = 1) No point tenderness (n = 1) Full, painless passive ROM (n = 1)	Physeal widening (n = 1) Metaphyseal fragmentation (n = 1)	NA	NR	NR
Barnett (1985)[4]	8-wk history of pain associated with pitching (n = 1) Pain at insertion of deltoid (n = 1)	Pain with resistance to abduction and ER (n = 1)	Physeal widening (n = 1) Metaphyseal cystic changes (n = 1)	NA	NR	NR
Boyd (1997)[5]	Dominant shoulder pain after a 5-d intense training camp (n = 1)	Tender anterior aspect of proximal humerus (n = 1) Limited IR from neutral position (n = 1) Painful resisted abduction (n = 1)	Physeal widening (n = 1)	NA	NR	NR

(continued)

Table A2 (continued)

Lead Author (Year)	Patient Symptoms	Physical Examination Findings	Radiographic Findings	MRI Findings	Other Associated Conditions of the Shoulder	Other Associated Conditions of the Elbow
Cahill (1974)[6]	Pain and inability to perform (n = 5)	Limited ROM (n = 5) Tenderness and minor swelling over anterior aspect of glenohumeral joint (n = 5)	Physeal widening (n = 5) Metaphyseal bone separation (n = 5) Metaphyseal and diaphyseal new bone formation secondary to periosteal stripping (n = 5)	NA	NR	NR
Carson (1998)[7]	Pain localized to proximal humerus during the act of throwing. 21 participants (91%) reported gradual onset; 2 reported sudden onset pain related to a specific throw	Tender to palpation over proximal humerus (n = 20) Weakness with ER (n = 6) Pain with ER (n = 8); thumb-down forward flexion (n = 6); IR (n = 2); thumb-down abduction (n = 5) Swelling (n = 2)	Physeal widening (n = 23) Lateral metaphyseal fragmentation, demineralization, or sclerosis of proximal humeral metaphysis (n = 12)	Salter-Harris type III fracture (n = 1)	NR	NR
Domes (2012)[9]	Pain in shoulder and elbow during pitching seasons (n = 1)	Derotation of shoulder (n = 1) Tender anterolateral aspect humerus (n = 1) Complete painless ROM (n = 1)	Physeal widening Mild periosteal reactions along lateral aspect of humeral metadiaphysis just distal to the physis (n = 1)	NA	NR	LLE (n = 1)
Drescher (2004)[10]	Pain for 4 wk during fast bowling (n = 1)	Painless active and passive ROM (n = 1) No swelling or tenderness (n = 1)	Significant widening of lateral aspect of epiphysis (n = 1)	NA	NR	NR
Fleming (2004)[11]	Pain for 2 wk, worse with pitching	Tender lateral aspect of proximal humerus (n = 1) Pain with ER (n = 1)	Physeal widening (n = 1)	NA	NR	NR
Greenberg (2018)[12]	Insidious onset of throwing-related pain for 4 wk (n = 1)	Total ROM in dominant shoulder, 145°; nondominant shoulder, 170° (n = 1) Passive ER in dominant shoulder, 110° Passive IR in dominant shoulder, 35° Humeral retroversion in dominant side, 67°; nondominant side, 40°	Physeal widening (n = 1)	NA	Increased humeral retroversion of dominant side (n = 1)	NR
Harada (2018)[13]	Shoulder pain: chronic onset (n = 19), acute onset (n = 68)	NR	Widening of proximal humeral physis (n = 87)	NA	NR	LLE (n = 29)

(continued)

Table A2 (continued)

Lead Author (Year)	Patient Symptoms	Physical Examination Findings	Radiographic Findings	MRI Findings	Other Associated Conditions of the Shoulder	Other Associated Conditions of the Elbow
Hatem (2006)[14]	Dominant shoulder pain (n = 4)	Weakness (n = 1)	Widening of the proximal humeral physis (n = 1) Mineralized density at the lateral aspect of the physis (n = 1)	Epiphyseal and/or metaphyseal edema (n = 4) Widened anterolateral physeal plate of the proximal humerus (n = 3) Periosteal edema (n=2)	NR	NR
Heyworth (2016)[15]	Pain with throwing/ racquet swinging (n = 95) Weakness (n = 9) Mechanical symptoms (n = 8) Instability (n = 1) Elbow pain (n = 12)	Tenderness of proximal humerus (n = 70) Decreased shoulder ROM (n = 32) GIRD (n = 28) Shoulder girdle weakness (n = 10)	Confirmation of LLS (n = 68)	Confirmation of LLS (n = 18)	GIRD (n = 28)	LLE (n = 6) Valgus extension overload syndrome (n = 1) Radiocapitellar compression (n = 1) Olecranon apophysitis (n = 1)
Hosokawa (2017)[16]	Shoulder pain during throwing (n = 1)	Tenderness at proximal physis (n = 1)	3-D CT: Widening of proximal humeral physis (n = 1)	NA	Humeral retroversion 27.1° greater on dominant side (n = 1)	Varus deformity of dominant humeral shaft (9.4°; n = 1)
Ito (2019)[17]	NR	Tender proximal physis (n = 1) ER significantly less (11° ± 12°; $P = .02$) in dominant vs nondominant shoulder IR less (2° ± 12°; $P = .80$) in dominant vs nondominant arm	Physeal widening (n = 1) as measured using ultrasonography	NA	Humeral retroversion increased on dominant vs nondominant side (104° ± 8° vs 84° ± 12°; $P < .001$)	Elbow pain (n = 7)
Kanematsu (2015)[18]	Pain localized to proximal humerus during throwing (n = 19)	Tenderness on palpation over proximal humerus (n = 11)	Physeal widening (n = 19)	NA	NR	NR
Obembe (2007)[27]	Subacute or chronic pain (n = 4)	NR	Physeal widening (n = 2) Salter-Harris type I fracture of proximal humeral physis (n = 1)	Focal widening of physis (n = 4) Metaphyseal edema (n = 4)	NR	NR
Popkin (2006)[29]	Pain during throwing (n = 1)	Tender lateral aspect of proximal humerus (n = 1) Pain and weakness with ER (n = 1)	NR	Physeal widening (n = 1) Paraphyseal edema (n = 1) Periosteal edema, elevation (n = 1)	NR	NR
Reeder (2015)[30]	Pain in lateral aspect of shoulder with insidious onset (n = 1)	NR	Physeal widening (n = 1) Salter-Harris type II fracture of proximal humeral physis (n = 1)	Salter-Harris type II fracture of proximal humeral physis (n = 1) Periosteal edema (n = 1)	NR	NR

(continued)

Table A2 (continued)

Lead Author (Year)	Patient Symptoms	Physical Examination Findings	Radiographic Findings	MRI Findings	Other Associated Conditions of the Shoulder	Other Associated Conditions of the Elbow
Song (2006)[36]	Activity-related pain in throwing shoulder (n = 1)	Tender proximal humerus (n = 1) Full active ROM (n = 1) Pain with abduction	Subperiosteal cyst near bicipital groove (n = 1)	Physeal widening (n = 1)	NR	NR
Tullos (1974)[37]	Gradual-onset pain with throwing (n = 1) Mass (n = 1)	Full active ROM (n = 1) Firm mass in proximal humerus (n = 1)	Osteochondrosis of proximal humeral epiphysis with abundant callus formation (n = 1)	NA	NR	NR
Wasylynko (2015)[39]	Insidious onset of shoulder pain occurring during follow-through and deceleration stages of pitching	Tender posterolateral aspect proximal humerus (n = 1) Full active/passive ROM (n = 1)	CT: irregularity of proximal humeral physis, metaphyseal and epiphyseal overgrowth and remodeling	NA	NR	NR
Zipser (2018)[40]	Acute pain during acceleration phase of throwing (n = 1)	ROM in throwing shoulder: 140° of ER, 5° of IR vs ROM in nondominant shoulder: 90° of ER, 70° of IR Adduction 15° less on dominant side vs nondominant side	Lateral physeal widening with adjacent edema (n = 1)	Lateral physeal widening with adjacent edema (n = 1)	Nondisplaced labral tear of throwing shoulder (n = 1)	NR

[a]3-D, 3-dimensional; CT, computed tomography; ER, external rotation; GIRD, glenohumeral internal rotation deficit; IR, internal rotation; LLS, Little League shoulder; LLE, Little League elbow; MRI, magnetic resonance imaging; NA, not applicable; NR, not reported; ROM, range of motion.