[Orthopaedic Surgery]

Ulnar Collateral Ligament and Elbow Adaptations in High School Baseball Pitchers

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Background: Baseball pitchers have adaptive changes in the soft tissues of the throwing elbow.

Hypothesis: High school baseball pitchers would show adaptive changes in the ulnar collateral ligament (UCL), such as calcifications and hypoechoic foci, thickening, and increased ulnohumeral joint laxity, on dynamic ultrasound (DUS).

Study Design: Cross-sectional study.

Level of Evidence: Level 3.

Methods: Twenty-two asymptomatic high school pitchers, designated as their primary position by their coach, underwent DUS and physical examination of the throwing and nonthrowing elbows prior to the start of the season. UCL substance consistency and thickness, ulnohumeral joint space widening, and soft tissue elbow structures were evaluated.

Results: The mean age of the cohort was 16.9 years. Calcifications of the UCL were similar, being present in 7 of 22 (32%) throwing elbows versus 8 of 22 (36%) nonthrowing elbows ($P = 0.11$). UCL hypoechoic foci also were similar between elbows: 2 of 22 (9%) throwing elbows versus 0 of 22 nonthrowing elbows ($P = 0.11$). UCL thickness was also found to be similar in both elbows (throwing arm, 6.54 mm vs nonthrowing, 6.71 mm; $P = 0.48$). Ulnohumeral joint laxity unloaded (throwing arm, 3.13 mm vs nonthrowing, 3.17 mm; $P = 0.835$) and loaded (throwing arm, 3.87 mm vs nonthrowing arm, 4.11 mm; $P = 0.30$) was similar between elbows. Throwing elbows showed posteromedial olecranon spurring in 36%, effusions in 27%, and synovitis in 9%.

Conclusion: High school pitchers show limited adaptive changes in the elbow, including UCL calcifications, hypoechoic foci, posteromedial olecranon spurring, and effusions. However, these changes are similar to those seen in the nonthrowing elbow, and these younger athletes lack findings seen in professional and collegiate pitchers such as UCL thickening and increased ulnohumeral joint space laxity.

Clinical Relevance: Preseason ultrasound examination of the high school pitching elbow lacks the adaptive changes to the elbow as seen in professional pitchers. These changes likely occur later in a pitcher's career.

Keywords: ulnar collateral ligament; pitcher; throwing injury; baseball

The overhead throwing athlete places tremendous stress on the elbow throughout the throwing motion.[1,2,5,9] As the primary restraint to valgus stress in the elbow between 20° and 120° of flexion, the medial ulnar collateral ligament (UCL) is at increased risk of injury.[12-14] Because of the continual repetitive stress, baseball pitchers in particular are more prone to UCL injuries to the elbow than other athletes.[1,10,16] As the incidence of UCL reconstruction increases, evaluation of the initial pathologic changes about the elbow is important to help guide prevention.

The initial pathologic changes to the UCL are typically the result of prolonged repetitive trauma to the ligament rather than an acute event that causes injury.[10,11] Changes in the ligament over time, documented via several imaging modalities,[3,7,8,11,15,18]

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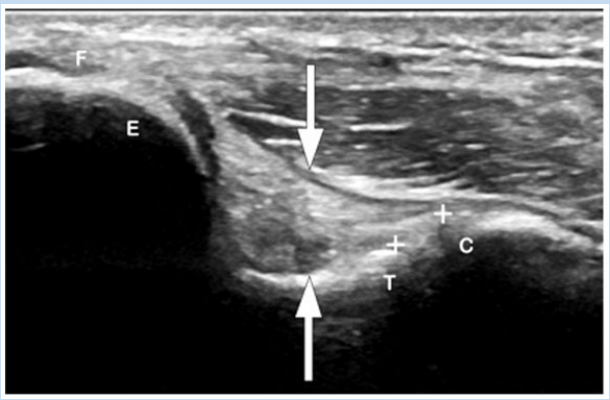

Figure 1. Normal ulnar collateral ligament (UCL), unstressed (Nazarian) (arrows). Long axis of the anterior band of the UCL and technique for measuring its thickness.[15] Bony landmarks include the medial epicondyle of the humerus (E), the trochlea of the humerus (T), and the coronoid process of the ulna (C). The common flexor tendon (F) is superficial to the anterior band of the UCL and can be seen attaching onto the medial epicondyle. The ulnohumeral joint space is marked (+).

Figure 2. Normal ulnar collateral ligament (UCL) with valgus stressing, ligament-only measurement. Long axis of the anterior band of the UCL with applied valgus stress. Modified technique for measuring UCL thickness: perpendicular to the plane of imaging and at the midportion of the UCL but including only the ligament itself (between arrows). The UCL is taut, and there is slight radial displacement of the ulna (between plus signs) with valgus stress. In this normal UCL, the ulnohumeral joint space does not widen.

include ligament thickening, hypoechoic foci, and calcifications within the ligament.[3,15] Dynamic evaluation of the UCL also allows for evaluation of potentially pathologic ligamentous laxity when combined with valgus stress.[3,15]

Although there have been several studies of these adaptive changes to the pitching elbow, few studies are able to show when these changes first occur. The high school pitcher is of obvious importance, as not only is this the largest cohort of competitive baseball players, but it is also a stage of increased physical and performance maturity. This is a time when pitch velocity increases and bony maturity occurs.

The hypothesis of this study was that even at this young age group, pitchers would show significant changes to their throwing elbow as a result of the repetitive trauma to the arm.

METHODS

Our institutional review board approved this study, and informed consent was obtained from each athlete.

Participants

Twenty-two male, high school varsity pitchers were recruited from 8 different high schools. No player participated in organized baseball in the 2 months prior to evaluation. Pitchers underwent focused shoulder and elbow physical examination along with dynamic ultrasonography of both elbows prior to the start of the high school varsity baseball season. The pitchers also answered a questionnaire about prior shoulder and elbow injuries, participation in other throwing sports, positions played besides pitcher, out-of-season baseball leagues, and games played out of season.

Radiographic Evaluation

A single experienced sonologist performed the ultrasound evaluation on a Logiq E9 machine with a 12-MHz linear array transducer (GE Healthcare). Evaluation of the anterior band of the UCL was performed with the arm at 30° of flexion, as used in previous studies.[3,15] The quality and consistency of the ligament was evaluated, specifically noting for hypoechoic foci as well as ligament calcifications. Measurement of the thickness of the ligament as well as the width of the ulnohumeral joint space at the level of the anterior band was performed. Two separate UCL thickness measurements were used: a measurement at the midportion of the ligament measuring from the ligament to the bone (Nazarian) (Figure 1)[15] and a modified measurement of only the thickness of the ligament (Figure 2). These 2 measurements are compared in Figure 3. Manual valgus stress of the elbow was performed at 30° of flexion.[15] The largest ulnar nerve cross-sectional area was measured at the elbow. The same examination was then performed on the pitcher's nonthrowing arm. The ultrasound images were later randomized and evaluated while the examiner was blinded to the throwing arm of the pitcher.

Statistics

Interobserver reliability between the 2 radiologists was evaluated using the intraclass correlation coefficient of the UCL thickness measurements. Ultrasound data of the throwing arm versus the nonthrowing arm were compared using a paired *t* test for the continuous measures and a Fisher exact test for the categorical measures. Significance was set at $P < 0.05$.

Figure 3. Ulnar collateral ligament (UCL) thickness at rest, pitching arm with calcifications (ligament-only). Anterior band of the UCL imaged at rest. The UCL is thickened with heterogeneous echotexture (calcifications). For comparison, the Nazarian technique of measuring thickness is shown (arrows),[15] and the modified ligament-only technique is noted by the upper arrow and arrowhead.

RESULTS

Demographics

Twenty-two high school varsity pitchers from 8 different high schools were evaluated, with an average age of 16.9 years (range, 15-18 years). Pitcher demographics collected are listed in Table 1. The mean number of games pitched after ultrasound evaluation was 7.3 games (SD, 4.0; range, 1-15), mean innings pitched was 27.0 innings (SD, 16.6; range, 2-58.67), and the mean number of pitches thrown was 456.5 pitches (SD, 256.9; range, 25-917).

Shoulder external rotation was significantly greater ($P < 0.05$) and internal rotation was significantly less ($P < 0.05$) in throwing shoulders compared with nonthrowing shoulders. Total shoulder range of motion as well as elbow range of motion was similar (Table 2). The mean glenohumeral internal rotation deficit was 16.36°.

Ultrasound Findings

The mean thickness of the UCL of the throwing arm was 6.54 mm as compared with 6.71 mm in the nonthrowing arm ($P = 0.48$) (Figure 1).[15] The mean thickness of the UCL was 1.85 mm in the throwing arm and 1.89 mm in the nonthrowing arm using the ligament-only method ($P = 0.82$) (Figure 2). The interobserver reliability of the UCL ligament-only method had an intraclass correlation coefficient of 0.67, suggesting good agreement between the 2 radiologists. Laxity of the medial ulnohumeral joint space was similar between throwing and nonthrowing arms. There were no changes in the diameter of the ulnar nerve between throwing elbows and nonthrowing elbows (Table 3).

Calcifications of the ligament were found in some of the throwing elbows and were similar to the nonthrowing elbow.

Table 1. Pitcher demographics[a]

Age, y, mean (SD)	16.9 (0.9)
Years of organized baseball, mean (SD)	8.3 (1.4)
Handedness	
Right	16 (73)
Left	6 (27)
Other positions played	
Outfield	9 (41)
First base	6 (27)
Third base	3 (14)
Shortstop	3 (14)
Second base	1 (5)
Play other overhead sports	
Yes	7 (32)
No	15 (68)
Off-season games played	
0-20	3 (14)
21-40	10 (45)
41-70	9 (41)

[a]Values listed as n (%) unless otherwise indicated.

Hypoechoic foci were found in a small number of throwing arms, which was similar to the nonthrowing arm. The rest of the elbows had normal echogenicity (homogeneous without calcifications) and therefore normal findings in the ligament. These values were similar from throwing elbow to nonthrowing elbow ($P = 0.11$) (Table 4). The osteoarticular structures did show some adaptations to the throwing elbow. Posteromedial olecranon spurring, joint effusions, and joint synovitis were noted in several throwing elbows. These findings were also seen in some of the nonthrowing elbows ($P > 0.99$). There were no loose bodies in the throwing elbow of any pitchers but 1 in the nonthrowing elbow. One sublime tubercle spur was identified on both the throwing and nonthrowing arm (Table 4).

DISCUSSION

Injury of the UCL is typically preceded by chronic adaptive changes to the ligament due to the repetitive increased stress through the elbow.[10,11] These changes are present in collegiate and professional baseball pitchers.[3,15]

Previous studies found UCL changes with hypoechoic foci in 69% and 28% of throwing arms (12% and 1.6% nonthrowing)

Table 2. Mean shoulder and elbow range of motion with standard deviations in the throwing arm compared with the nonthrowing arm

	Throwing Arm, Mean (SD)	Nonthrowing Arm, Mean (SD)	*P* Value
Shoulder external rotation, deg	143.00 (14.9)	130.32 (13.5)	<0.05
Shoulder internal rotation, deg	49.54 (16.6)	65.69 (14.79)	<0.05
Total shoulder rotation, deg	192.54 (26.5)	196.23 (23.4)	0.822
Elbow extension, deg	–2.50 (5.0)	–2.81 (5.9)	0.23
Elbow flexion, deg	138.41 (5.7)	139.81 (7.6)	0.16

Table 3. Physical dimensions of the UCL, ulnohumeral joint, and ulnar nerve[a]

	Throwing Arm	Nonthrowing Arm	*P* Value
Nazarian: UCL thickness, mm	6.54 (0.83)	6.71 (1.05)	0.48
Ligament-only UCL thickness, mm[b]	1.85 (0.51)	1.89 (0.59)	0.82
Unloaded ulnohumeral joint space, mm	3.13 (0.71)	3.17 (0.80)	0.84
Loaded ulnohumeral joint space, mm	3.87 (1.03)	4.11 (0.88)	0.30
Ulnar nerve cross-sectional area, mm^2	5.0 (1.0)	5.0 (2.0)	0.29

UCL, ulnar collateral ligament.
[a]Values reported as means with standard deviations. Nazarian UCL thickness measured from ligment to bone[15] and ligament-only measuring only the UCL thickness.
[b]Intraclass correlation coefficient of 0.67, representing good interobserver reliability between radiologists.

Table 4. Consistency of UCL (calcifications, hypoechoic foci) and osteoarticular findings[a]

	Throwing Arm	Nonthrowing Arm	*P* Value
Calcifications in UCL	7 (32)	8 (36)	0.11
Hypoechoic foci in UCL	2 (9)	0 (0)	0.11
Posteromedial olecranon spur	8 (36)	5 (23)	>0.99
Effusion	6 (27)	3 (14)	>0.99
Synovitis	2 (9)	2 (9)	>0.99
Loose body	0 (0)	1 (5)	>0.99

UCL, ulnar collateral ligament.
[a]Values recorded as totals with percentages.

and calcifications in 35% and 25% (0% and 1.6% nonthrowing), respectively.[3,15] Both studies also found significant ligament thickening as well as joint laxity with valgus stress in throwing arms. Our pitchers showed far less hypoechoic foci and similar calcifications compared with these previous studies. This difference from previous studies is likely because of the younger age group in this population and the lack of chronic stress to the elbow in this group.

Much of the previous literature has been limited to cohorts that are older and at a higher level of performance (collegiate and professional level pitchers). The mean age of our cohort was 16.9 years as compared with 27.1 years[15] and 22.8 years.[3] This cohort still took on a heavy load of baseball, as the majority of pitchers play in off-season games and had played for many years of organized baseball prior to evaluation. These findings suggest that players at a younger age and lower level of competition may not show identifiable adaptive changes on ultrasound in their throwing elbow.

This current study was limited to ultrasound evaluation. Previous magnetic resonance imaging evaluation of the elbow found asymmetric ligament thickening in 65% of pitchers and posteromedial olecranon spurring in 61%.[8] This is in contrast to this study, where UCL thickness was similar with posteromedial olecranon spurring in 36% of throwing elbows. This difference not only may be attributed to the radiographic modality employed but also may be related to when the pitching cohorts were evaluated. This cohort was evaluated before the start of the baseball season, with 2 months of relative arm rest, as compared with the previous study where no temporal relation was noted.

Although our pitchers did show changes in their shoulder range of motion with regard to increased external rotation and decreased internal rotation of the throwing arm, the overall arc of range of motion was preserved and was the same in both shoulders. Previous studies show that loss of overall arc of shoulder range of motion is a risk factor for UCL injury.[4,6,17] These pitchers did not show a change in overall range of motion, which may be a protective factor for the elbow.

There are several limitations to this study, one of which is the sample size, which may have led to the lack of correlative findings. Another limitation is that the valgus force applied during imaging was manual. Strengths of this study include the ultrasound evaluation being performed by 1 sonologist, providing consistency of data. The images were all randomized, blinded, and evaluated by 2 separate fellowship-trained musculoskeletal radiologists. All pitchers were also evaluated at 1 consistent time point before the start of the baseball season, helping eliminate any changes to the elbow due to recent competitive play.

CONCLUSION

Sonographic findings in the throwing elbow, including hypoechoic foci and calcifications in the UCL, posteromedial olecranon osteophytes, and joint effusions can be seen in high school–aged pitchers. These changes, however, are similar to the nonthrowing arm. This group of high school pitchers had not developed many of the pathologic elbow changes seen in collegiate and professional pitchers.

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