Pre- and Postseason Dynamic Ultrasound Evaluation of the Pitching Elbow

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Purpose: To use ultrasound imaging to document changes over time (i.e., preseason *v* postseason) in the pitching elbow of high school baseball pitchers. **Methods:** Twenty-two high school pitchers were prospectively followed. Pitchers were evaluated after a 2-month period of relative arm rest via preseason physical exams, dynamic ultrasound imaging of their throwing elbow, and the Quick Disabilities of the Arm, Shoulder, and Hand (QuickDASH) assessment. Players were reevaluated within 1 week of their last game. Dynamic ultrasound images were then randomized, blinded to testing time point, and evaluated by 2 fellowship-trained musculoskeletal radiologists. **Results:** Average pitcher age was 16.9 years. Average pitches thrown was 456.5, maximum velocity 77.7 mph, games pitched 7.3, and days off between starts 6.6. From preseason to postseason, there were significant increases in ulnar collateral ligament (UCL) thickness (P = .02), ulnar nerve cross-sectional area (P = .001), UCL substance heterogeneity (P = .001), and QuickDASH scores (P = .03). In addition, there was a nonsignificant increase in loaded ulnohumeral joint space (P = .10). No pitchers had loose bodies on preseason exam, while 3 demonstrated loose bodies postseason. The increase in UCL thickness was significantly associated with the number of bullpen sessions per week (P = .01). The increase in ulnar nerve cross-sectional area was significantly associated with the number of pitches (P = .04), innings pitched (P = .01), and games pitched (P = .04). **Conclusions:** The stresses placed on the elbow during only one season of pitching create adaptive changes to multiple structures about the elbow including UCL heterogeneity and thickening, increased ulnohumeral joint space laxity, and enlarged ulnar nerve cross-sectional area. **Level of Evidence:** Level II prospective observational study.

Pitching a baseball is a complex activity that has the potential to place tremendous loads on the elbow. Werner and colleagues have estimated that a valgus torque of approximately 120 N-m is imparted in the late cocking and early acceleration phase of the overhand pitching motion.[1] Given the high loads and the repetitive nature of pitching, it is perhaps not surprising that injuries to the medial ulnar collateral ligament (UCL), that is, the primary restraint to valgus loads from 20° to 120°,[2] are common in baseball pitchers.[3,4] For example, previous studies have indicated that medial elbow symptoms account for approximately 90% of elbow complaints in pitchers.[5] Research has also shown that pitchers are at a higher risk for injury than position players[6,7] and that 50% of professional pitchers will experience elbow or shoulder pain that will disable them from throwing at some point in their career.[8,9] These injuries are painful, hinder performance, and can require surgical intervention that may ultimately end an athlete's ability to perform his or her sport at a high level. Although the etiology of UCL injuries is not entirely understood, it is generally believed that UCL pathology is an overuse phenomenon that occurs in response to the repetitive valgus stresses placed on the elbow.[10]

The most common imaging modalities for evaluating the elbow and UCL include radiographs, MRI, and ultrasound. Radiographs have demonstrated osteophyte formation, joint space narrowing, subchondral sclerosis, loose bodies, and UCL ossification in the elbows of professional baseball pitchers,[11] while MRI has been shown to have upward of 100% specificity in identifying UCL tears.[12] Compared with radiographs and MRI, ultrasound is unique in its ability to provide a

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dynamic evaluation of the elbow and soft tissues. Specifically, dynamic ultrasound evaluation has the capacity to identify partial and full-thickness tears of the UCL, joint effusion, and joint instability.[13] Furthermore, dynamic ultrasound can provide an indirect assessment of ligamentous integrity through real-time monitoring of joint space widening while applying a valgus stress. For example, Nazarian and colleagues acquired dynamic ultrasound images of 26 asymptomatic major league baseball pitchers and reported that the ulnohumeral joint space in the throwing elbow was significantly greater than in the nonthrowing elbow when a valgus stress was applied to the elbow.[13]

Previous studies have evaluated the elbows of pitchers using MRI, stress radiographs, and dynamic ultrasound at a single time point.[11-16] These studies have provided valuable information regarding the chronic changes to elbow structures in pitchers. Evaluating the elbow before and after a season of pitching may provide clinicians with a better understanding of the pathologic changes that occur to the UCL and other elbow structures. The objective of this study was to use ultrasound imaging to document changes over time (i.e., preseason v postseason) in the pitching elbow of high school baseball pitchers. We hypothesized that there would be discernable changes to the throwing elbow soft-tissue structures, specifically increased laxity and UCL thickness, that would be seen on ultrasound owing to the stresses placed on it during a season of pitching.

Methods

Following Institutional Review Board approval, we performed a prospective observational study. High school athletic trainers or coaches from 8 high schools recruited male high school varsity baseball pitchers for participation. To be eligible for participating in the study, subjects were required to be a current high school varsity baseball players whose primary position (per the coaching staff) was pitcher. In addition, the subjects were required to be asymptomatic in regards to arm pain and capable of unrestricted baseball activity. Pitchers could also not have played or pitched in a live baseball game in the 2 months leading up to the study period. Pitchers were excluded from participating in the study if they could not participate in baseball owing to elbow or shoulder pain, if they could not be imaged before the beginning of their high school season, or if they had previous known elbow injury or surgery.

A complete dynamic elbow ultrasound evaluation was performed on each pitcher in the study at the participating institution. Ultrasound images were acquired using a Logiq E9 ultrasound system with a 12 MHz linear array transducer (GE Healthcare, Little Chalfont, UK). Images were acquired of the elbow according to American Institute of Ultrasound in Medicine practice guidelines for musculoskeletal ultrasound by the same experienced ultrasonographer. All structures were imaged in short- and long-axis planes relative to the structure being imaged. Images of the anterior band of the UCL were obtained with the player in a seated position, shoulder maximally externally rotated, and arm at 30° of flexion as measured by goniometry. To evaluate the elbow medial joint line and UCL dynamically, the pitcher's elbow was placed in 30° of flexion and a single orthopaedic surgeon (R.A.K.) examiner manually applied a valgus load to the elbow until a functional endpoint (i.e., resistance to joint motion) was detected. UCL substance was evaluated for hypoechoic foci and calcifications, both of which are echotextural abnormalities suggestive of intraligamentous morphologic and structural irregularity.

In addition to the ultrasound examination, shoulder and elbow physical examinations were performed including goniometric measurements of shoulder internal and external rotation. Goniometry shoulder rotation was assessed with the pitcher positioned supine with the arm abducted to 90° in the scapular plane. The scapula was stabilized by the same orthopaedic surgeon for all subjects. The arm was then externally rotated to the point right before the participant's scapula moved under the stabilizing hand. Measurements were taken using a goniometer with the stationary arm at 0, the axis at the elbow, and the moving arm along the ulnar boarder. Players also completed a questionnaire regarding throwing history and arm injury as well as Quick Disabilities of the Arm, Shoulder, and Hand (QuickDASH) assessment.

Dynamic ultrasound imaging was performed on the throwing elbows of each pitcher before the start of their high school season. Players then participated in a single season of high school baseball. After the season, players were reevaluated, with 21 of the 22 pitchers evaluated within 6 days after their final game. One pitcher was evaluated 8 days after his last game owing to an illness. Pitchers also answered another questionnaire regarding arm pain throughout the season and were assessed with a QuickDASH questionnaire. Season pitching statistics—specifically, number of games pitched, number of innings pitched, number of pitches thrown, maximum velocity, average velocity, percent of off-speed pitches, average days of rest between performance, and number of bullpen sessions a week—were also compiled for each pitcher in the study. Pitching statistics were collected by designated team representatives who consisted of scorekeepers and assistant coaches.

After the postseason evaluation, all ultrasound images were deidentified for time of exam and player name and evaluated in random order by 2 fellowship-trained musculoskeletal radiologists. Each radiologist evaluated

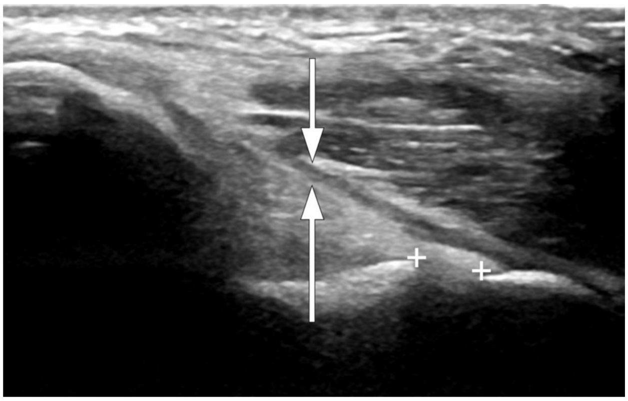

Fig 1. Long axis of the anterior band of the UCL with valgus stress applied to the right elbow. Ligament thickness is evaluated at the midportion of the ligament (between arrows). The ulnohumeral joint space is marked between the + signs.

every exam individually. Each image was evaluated for UCL thickness, substance, and tearing; medial ulnohumeral joint space distance in stressed and nonstressed exams; sublime tubercle spur; effusions; loose bodies; posteromedial olecranon spurring; and ulnar nerve cross-sectional area. In addition, each UCL was also categorized as heterogeneous, homogeneous, or hypoechoic (Figs 1 and 2). Continuous outcome measures consisted of the UCL thickness, unloaded ulnohumeral joint space, loaded ulnohumeral joint space, and ulnar nerve cross-sectional area.

The ultrasound findings were evaluated by comparing the preseason and postseason data for changes over time. These comparisons were done using a paired *t*-test for the continuous measures and a Fisher's exact test for the categorical measures. Differences between pre- and postseason ultrasound findings were correlated with player demographic data and measures of pitching stress, specifically pitch count, innings pitch, average days off between pitching, maximum pitching speed, average pitching speed, number of pitching appearances, number of bullpens sessions pitched per week, percentage of off-speed pitches, and games pitched. Correlations of the subject demographics and measures of pitching stress to the ultrasound findings were evaluated using analysis of variance, Spearman correlation, and logistic regression analysis. In addition, interobserver reliability between the 2 radiologists was evaluated using the interclass correlation coefficient (ICC) of the UCL thickness measurements.

Results

Twenty-two pitchers were recruited for this study. All pitchers asked to participate were eligible for participation with no pitchers meeting exclusion criteria. Demographics for the cohort include a mean (standard deviation) age of 16.9 (0.9) years (range, 15 to 18 years) and mean body mass index (BMI) of 24.7 (2.1). Cohort handedness consisted of 16 (73%) right-handed throwers and 6 (27%) left-handed throwers. Seven (32%) pitchers participated in other competitive overhead sports including swimming, tennis, and football. While 3 of 22 (14%) pitchers denied playing offseason travel baseball, 19 of 22 (86%) pitchers reported playing between 20 and 70 out-of-season baseball games for non−high school affiliated teams. No players pitched in live baseball games within 2 months before the high school season. In addition, no players played for non−high school baseball teams during the study period (Table 1).

Evaluation of preseason shoulder range of motion found significant differences in the maximal external rotation and internal rotation in the pitcher's throwing arm compared with the contralateral, nonthrowing arm. The average throwing arm external rotation was significantly greater compared with the nonthrowing arm (143.00° *v* 130.32°; P = .005). The average increased external rotation was found to be 12.7° (range, −10° to 40°). The average internal rotation of the pitcher's throwing arm compared with the nonthrowing arm was found to be significantly less (49.54° *v* 65.69°; P = .006). The average glenohumeral internal rotation deficit (GIRD) was found to be 16.36° (range, −2° to 45°). Total shoulder range of motion was found to be similar in both the throwing and nonthrowing shoulder (throwing shoulder 192.54° *v* nonthrowing shoulder 196.23°; P = .822).

All 22 pitchers competed throughout their high school season. The study participants pitched a mean (standard deviation) of 7.3 (4.0; range, 1 to 15) games and 27.0 (16.6; range, 2 to 58.67) innings and threw 456.5 (256.9; range, 25 to 917) total pitches. For comparison, a high school baseball team typically plays 20 to 30 games in a season. Four pitchers (18%) missed games owing to injuries that included mandible fracture, distal radius fracture, medial elbow pain, and torn

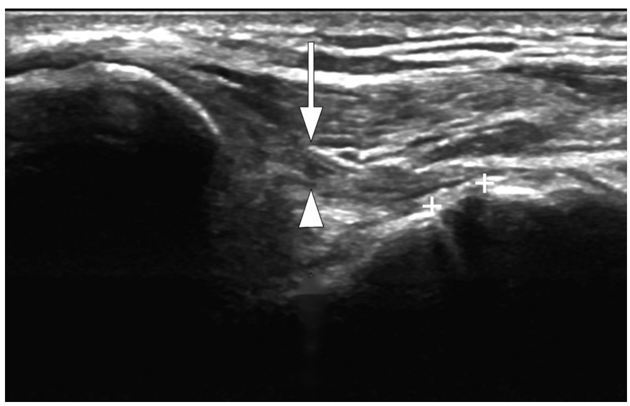

Fig 2. Anterior band of the UCL at rest of a postseason right elbow. The UCL is thickened with heterogeneous echotexture as seen between the arrow and arrowhead. The ulnohumeral joint space is marked between the + signs.

Table 1. Subject Demographics

Age, years	16.9 (0.9)
Height, inches	72.0 (2.0)
Weight, pounds	182.1 (15.6)
BMI	24.7 (2.1)
Handedness	
Right	6 (27)
Left	16 (73)
Other overhead sports played in addition to baseball	
Yes	7 (32)
No	15 (68)
Number of off-season games played	
0	3 (14)
20-40	10 (45)
40-70	9 (41)

NOTE. Standard deviations are in parentheses for age, height, weight, and BMI; percent is presented in parentheses for others.
BMI, body mass index.

meniscus. In all, 9 of 22 (41%) pitchers complained of arm pain while throwing at some point during the season.

In evaluating preseason UCL and elbow characteristics, 8 players were found to have posteromedial olecranon spurring. One pitcher was found to have a prior proximal UCL avulsion, and one pitcher was found to have an old avulsion of the medial epicondyle. One player was found to have a sublime tubercle spur. No players were found to have loose bodies.

From preseason to postseason there were statistically significant increases in the UCL thickness ($P = .02$; Table 2), ulnar nerve cross-sectional area ($P = .001$; Table 2), and UCL substance heterogeneity ($P = .001$; Table 3). QuickDASH scores also increased significantly from preseason (3.5 ± 6.6) to postseason (10.6 ± 14.7; $P = .03$) testing sessions. There was also an increase in the loaded ulnohumeral joint space from preseason to postseason, but this was not found to reach significance ($P = .10$; Table 2). In addition, there were 3 pitchers with sublime tubercle spur, compared with only one preseason ($P = .14$; Table 4). Furthermore, no pitchers were found to have loose bodies in the throwing arm on preseason exam, while 3 demonstrated having loose bodies on postseason exam (Table 4). The ICC of the

Table 2. Physical Dimensions of the UCL and Ulnohumeral Joint

Outcome Measure	Preseason	Postseason	*P* Value
UCL thickness, mm	1.85 (0.51)	2.20 (0.71)	**.02**
Unloaded ulnohumeral joint space, mm	3.13 (0.70)	3.36 (0.97)	.29
Loaded ulnohumeral joint space, mm	3.87 (1.03)	4.30 (1.16)	.10
Ulnar nerve cross-sectional area, mm^2	5.0 (0.01)	6.0 (0.03)	**.01**

NOTE. Data presented as mean (standard deviation). Significant *P* values are in bold.
UCL, ulnar collateral ligament.

Table 3. Ultrasonographic Appearance of the UCL

Appearance	Preseason, n (%)	Postseason, n (%)	*P* Value
Heterogeneous	7 (32)	9 (41)	**.001**
Homogeneous	13 (59)	11 (50)	.67
Hypoechoic	2 (9)	2 (9)	>.99

NOTE. Significant *P* values are in bold.
UCL, ulnar collateral ligament.

UCL thickness measurements was 0.67, suggesting good agreement between the 2 radiologists.

There was one demographic measure and several measures of pitching stress that were found to be significantly associated with changes in the ultrasound findings between preseason and postseason (Tables 5 and 6). Specifically, increased UCL thickness correlated with increased number of bullpen sessions per week ($P = .01$). Increased percent of off-speed pitches correlated with greater laxity, that is, an increase in the ulnohumeral joint space with dynamic stress ($P = .01$). Significant correlations were also found with increased UCL heterogeneity and higher BMI ($P = .02$). Increased ulnar nerve cross-sectional area correlated with a higher number of total pitches ($P = .04$), innings pitched ($P = .01$), and games pitched ($P = .04$). No correlations were seen in regards to GIRD or increased external rotation of the shoulder.

Discussion

Our findings indicated that there are significant changes in both the physical dimensions and the sonographic appearance of the UCL after one season of pitching. These findings, specifically increased laxity and UCL and ulnar nerve thickness, lend insight into the physiologic changes that can occur to the UCL over a relatively brief period of time.[5,17-19]

This study found statistically significant changes over time in UCL thickness ($P = .02$; Table 2) and UCL heterogeneity ($P = .01$; Table 3) from preseason to postseason evaluations. In addition, there was a nonsignificant increased ulnohumeral joint laxity under a valgus load ($P = .10$; Table 4). It is difficult to directly compare these changes with previous research,

Table 4. Pathologic Findings of the Elbow and UCL

Outcome Measure	Preseason, n (%)	Postseason, n (%)	*P* Value
Prior proximal UCL avulsion	1 (5)	0 (0)	—
Prior proximal UCL tear	0 (0)	0 (0)	—
Old avulsion medial epicondyle	1 (5)	0 (0)	—
Sublime tubercle spur	1 (5)	3 (14)	.14
Loose bodies	0 (0)	3 (14)	—
Posteromedial olecrenon spurring	8 (40)	7 (32)	.16

UCL, ulnar collateral ligament.

Table 5. Correlations (*r* Values) and Odds Ratios (OR) for Associations Among Demographic Factors, Clinical Assessment (QuickDASH), and Preseason to Postseason Changes in Ultrasound Findings

	Changes From Preseason to Postseason			
Factor	UCL Thickness	Loaded Joint Space	UCL Substance	Ulnar Nerve Cross-Sectional Area
Age	r = 0.08	r = 0.11	OR = 0.28	r = -0.13
	P = .73	P = .62	P = .32	P = .57
Height	r = −0.21	r = 0.03	OR = 1.17	r = 0.05
	P = .34	P = .87	P = .80	P = .84
Weight	r = 0.17	r = −0.12	OR = 0.94	r = −0.18
	P = .44	P = .60	**P = .04**	P = .44
BMI	r = 0.18	r = −0.06	OR = 0.55	r = −0.17
	P = .43	P = .79	**P = .02**	P = .46
GIRD	r = −0.31	r = −0.04	OR = 1.03	r = −0.07
	P = .16	P = .85	P = .33	P = .76
Shoulder external rotation	r = −0.16	r = 0.09	OR = 1.00	r = −0.01
	P = .47	P = .69	P = .83	P = .96
Change in QuickDASH	r = −0.11	r = 0.09	OR = 0.89	r = −0.01
	P = .60	P = .68	P = .36	P = .97

NOTE. Significant *P* values are in bold.
BMI, body mass index; GIRD, glenohumeral internal rotation deficit; QuickDASH, Quick Disabilities of the Arm, Shoulder, and Hand assessment; UCL, ulnar collateral ligament.

since previous studies have evaluated the UCL at only a single time point or with significant time between ultrasound exams and therefore were not designed to assess temporal changes due to the stresses of a season of pitching.[13-15,20] A recent study by Ciccotti and associates evaluated 131 pitchers who had multiple ultrasounds performed before the player's seasons temporally separated by a year or more. They found that 26% of players had increases in dynamic medial ulnohumeral joint space gapping with stress on subsequent studies but did not find any other statistically significant changes on ultrasound exam.[14] Like this current study, the aforementioned authors could not comment on whether the changes seen on recurrent exams could be modifiable via therapy or rest. Nor could they correlate changes seen with risk of subsequent injury. We hope that further longitudinal evaluation of pitchers will help to answer these questions.

Our finding of an increase in UCL thickness on postseason exam is consistent with previous studies that have reported that the UCL in the throwing arm is significantly thicker than that in the nonthrowing

Table 6. Correlations (*r* Values) and Odds Ratios (OR) for Associations Between Measures of Pitching Stress and Preseason to Postseason Changes in Ultrasound Findings

		Changes From Preseason to Postseason			
Measure of Pitching Stress	Season Statistical Averages (Range)	UCL Thickness	Loaded Joint Space	UCL Substance	Ulnar Nerve Cross-Sectional Area
Total pitches	456.5	r = 0.08	r = 0.01	OR = 1.00	r = 0.45
	(25-917)	P = .72	P = .98	P = .47	**P = .04**
Innings pitched	27.0	r = 0.14	r = −0.08	OR = 0.98	r = 0.60
	(2-58.67)	P = .53	P = .72	P = .57	**P = .01**
Average days off	6.6	r = 0.20	r = −0.31	OR = 1.27	r = 0.24
	(3-13)	P = .40	P = .18	P = .69	P = .34
Games pitched	7.3	r = 0.08	r = 0.03	OR = 0.78	r = 0.46
	(1-15)	P = .73	P = .88	P = .23	**P = .04**
Pitches per game	57.43	r = 0.15	r = −0.28	OR = 1.03	r = −0.05
	(25-97.25)	P = .49	P = .20	P = .96	P = .82
Fastest Pitch	77.7	r = 0.34	r = 0.12	OR = 1.03	r = −0.15
	(66-88)	P = .12	P = .57	P = .41	P = .51
Average Speed	71.9	r = 0.31	r = 0.23	OR = 0.99	r = −0.20
	(62.5-84.3)	P = .18	P = .32	P = .62	P = .42
% Off-speed pitches thrown	36	r = −0.01	r = 0.54	OR = 1.43	r = −0.29
	(20-60)	P = .97	**P = .01**	P = .21	P = .25
Number of bullpens/week	1.5	r = 0.60	r = −0.001	OR = 0.63	r = 0.17
	(0-4)	**P = .01**	P = .99	P = .21	P = .46

NOTE. Average days off = days off between pitching outings. Significant *P* values are in bold.
UCL, ulnar collateral ligament.

arm.[13,14,20] Similarly, these previous studies have also reported greater medial ulnohumeral joint laxity in the throwing arm when compared with the nonthrowing arm.[13,14,20] Specifically, Ciccotti and colleagues evaluated 368 professional pitchers before a season of pitching over a 10-year period. They reported that the pitching arm had increased UCL thickness and a wider medial ulnohumeral joint space under a valgus load compared with the nonpitching arm. Nazarian and colleagues evaluated 26 asymptomatic professional pitchers via the same methods and they too found a thicker UCL and wider ulnohumeral joint space under a valgus loads in players' pitching arms. In addition, both studies found that hypoechoic areas within the UCL were more frequently in the pitching arm.[13,14] Sasaki et al.[15] performed a similar study with 30 college baseball players. They also reported that medial joint space laxity was greater in the throwing arm of pitchers when compared with the contralateral arm. The changes reported in the current study occurred over a relatively brief time period (approximately 4 months), and these findings suggest that increased UCL thickening and heterogeneity may be the initial changes that occur in response to overuse. These temporal changes should be evaluated further to assess the extent to which they are associated with overuse and the extent to which they may be a predictor of future injury. In addition, it is not known whether this study's findings are transient changes to the throwing elbow that can be corrected with a rest period from throwing or if they are permanent additive changes to the elbow structures. More studies will be needed to assess whether these structural changes respond to a period of rest.

Pitchers also had increases in the amount of ligamentous substance heterogeneity. Ligamentous heterogeneity is echotextural abnormalities that include hypoechoic foci and calcifications (Fig 2). The normal state of the UCL, as seen via ultrasound, is with a uniformed echotecture. Previous studies have found similar heterogenous changes in injured tendon and ligamentous structures. In the study by Ciccotti et al.,[14] 12 of 368 pitchers evaluated via ultrasound went on to require UCL reconstruction. Of those that required UCL reconstruction, 42% had hypoechoic foci, whereas only 29% in the uninjured group exhibited these ligamentous changes. The investigators could not comment on specific correlation with injury owing to a limited sample size. More studies are required to evaluate the affects of these intrasubstance changes on ligmanetous pathology.

Although still within nonpathologic limits, we also found a statistically significant increase in ulnar nerve cross-sectional area ($P = .001$; Table 2). Ulnar neuritis has previously been described in baseball pitchers and is believed to result from excessive traction on the nerve that occurs in the late-cocking phase of pitching.[21,22] Conway and colleagues reported that approximately 40% of throwing athletes with medial elbow instability also have ulnar neuritis.[23] Despite this finding of increased ulnar nerve cross-sectional area, no pitchers in the current study reported any symptoms of ulnar neuritis. Consistent with the increases over time in UCL thickness and UCL heterogeneity, this increase in ulnar nerve cross-sectional area may be suggestive of medial soft-tissue overload and an early predictor of future injury.

Along with sonographic changes seen in the throwing arm, this cohort of pitchers had a statistically significant increase in QuickDASH scores after a season of play ($P = .03$). A previous study by Lyman and colleagues evaluated 476 youth pitchers for arm pain.[8] They reported that 15% of all pitching appearances resulted in elbow or shoulder pain, with half of all pitchers reporting shoulder pain at some point during the season. Previous research has suggested that a change in the QuickDASH score of 10 points is the minimally clinical important difference.[24] Consequently, the clinical significance of this change in the mean QuickDASH score from a preseason value of 3.5 to a postseason value of 10.6 remains unclear. However, there was appreciable variability across pitchers in the change in QuickDASH scores from preseason to postseason. Specifically, the changes in QuickDASH score ranged from −5.9 (indicating a more favorable postseason assessment than preseason assessment) to 59.1, with 7 of the 22 pitchers reporting no change in their QuickDASH score and 7 pitchers reporting a change in the QuickDASH score of greater than 10 points. Additional research is necessary to assess the extent to which changes in QuickDASH score are associated with sonographic changes in the elbow and UCL.

Elbow injuries in baseball pitchers appear to be an overuse phenomenon.[8,20,25,26] The current limits recommended by USA Baseball Medical and Safety Advisory Committee for teenage pitchers are 75 pitches per game, 1,000 pitches per competitive season, and 3,000 pitches per calendar year. These recommendations are based on research indicating an association between the number of pitches thrown and the risk of shoulder and elbow pain in youth baseball.[8] Although pitch counts are a convenient method for documenting usage, this approach overlooks a number of other factors—for example, throwing mechanics, overall conditioning, type of pitches thrown, intrinsic soft-tissue mechanical capacity, nonpitching usage, and so on—that may play a significant role in the development of elbow injuries. The findings from this study further emphasize this point. Specifically, the pitchers in this study pitched a mean of 456.5 pitches—that is, well below the 1,000 pitch limit for a competitive season recommended by USA Baseball—and yet there were significant changes in the elbow and UCL from preseason to postseason evaluations. In addition, in evaluating correlations with demographics and season stressors and changes seen on ultrasound, most correlations appeared to be related to overuse phenomena including bullpens per week, total pitches, innings pitched, and games pitched. It remains unclear whether the changes observed in this study are a normal physiologic response to pitching or an early indication of elbow pathology due to overuse.

Limitations

We acknowledge that there are several limitations in this study. First, the sample size of 22 pitchers is relatively small. However, this sample size was able to detect statistically significant changes over time in UCL thickness, UCL heterogeneity, and ulnar nerve cross-sectional area. Owing to the small sample size we were also not able to evaluate possible correlations of elbow soft-tissue changes with the pitchers playing alternate positions when not pitching. Another limitation of this study is that the valgus force applied when imaging the ulnohumeral joint was applied manually. The same orthopaedic surgeon examiner applied the valgus stress to every pitcher in the study, but the study may have benefited from applying a standardized load to all subjects via a Telos stress device. It would have been beneficial to evaluate the nonthrowing arm, both before and after the season, to assure that the changes seen were not just normal responses that are seen in both arms owing to sport participation. Lastly, it would have been beneficial to obtain a follow-up ultrasound examination approximately 3 months after postseason exams to assess for resolution of the soft-tissue changes that were seen.

Conclusions

The stresses placed on the elbow during only one season of pitching create adaptive changes to multiple structures about the elbow including UCL heterogeneity and thickening, increased ulnohumeral joint space laxity, and enlarged ulnar nerve cross-sectional area.

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