




A Novel Ultrasound Assessment Technique of the Ulnar Collateral Ligament to Account for the Valgus Stress Effect of Gravity on the Medial Elbow

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Background: The ulnar collateral ligament (UCL) of the elbow is commonly injured in baseball athletes. When assessed in the supine abducted and externally rotated (ABER) position using stress ultrasonography (sUS), even before applying a valgus load, gravity pulls on the forearm, creating an initial valgus load that may distort the resting joint space measurement.

Purpose/Hypothesis: The purpose of this study was to measure the valgus stress effect of gravity on the resting joint space and determine if a varus-stressed joint space provides a better baseline measurement. It was hypothesized that there would be a greater resting joint space in the throwing arm in the ABER position as a result of UCL laxity but no difference in joint space under varus stress compared to the nonthrowing arm.

Study Design: Cross-sectional study; Level of evidence, 3.

Methods: Bilateral elbows of asymptomatic male collegiate baseball players with no history of elbow injury were evaluated via sUS. Ulnohumeral joint space was measured at rest (gravity stress), under varus stress, and under manually applied valgus stress. Joint gap differences from rest to varus, rest to valgus, and varus to valgus were compared between throwing and nonthrowing arms. We also examined joint space measurements in throwing arms with and without ultrasonography-identified UCL abnormalities.

Results: A total of 50 athletes were included. Compared to nonthrowing arms, throwing arms had greater resting (3.4 ± 0.6 mm vs 2.9 ± 0.6 mm) and valgus-stressed (3.8 ± 0.7 mm vs 3.4 ± 0.6 mm) joint spaces, but the varus-stressed joint space did not differ between sides. Varus-to-valgus joint gap was significantly greater in throwing arms (1.3 ± 0.5 mm) versus nonthrowing arms (1.0 ± 0.4 mm), while rest-to-valgus differences were not significant. Valgus stress joint space (4.1 ± 0.7 mm vs 3.7 ± 0.7 mm, $P = .07$) and rest-to-valgus joint gap (0.6 ± 0.5 vs 0.3 ± 0.3 , $P = .08$) were wider in throwing elbows with UCL abnormalities compared to those without, but these between-group differences did not reach significance.

Conclusion: Asymptomatic male collegiate baseball players' throwing arm had a significantly greater resting joint space when exposed to gravity stress than the nonthrowing arm in the ABER position, possibly as a result of adaptive UCL laxity. However, the bilateral similarity in varus-stressed measurements suggests it may serve as a better baseline for sUS assessments. Future research incorporating varus stress as a baseline in symptomatic athletes may improve the accuracy and clinical relevance of medial elbow laxity evaluations.

Keywords: ulnar collateral ligament; stress; ultrasound; elbow; ultrasonography

repetitive stress.²⁰ Pain and instability can arise from UCL sprains. Accurately and precisely diagnosing UCL pathology can be challenging at times, especially if the athlete has a UCL sprain that causes pain, but the instability is not sufficient to be clinically relevant or functionally limiting.⁴

Stress ultrasonography (sUS) of the elbow has been shown to be a valid and reliable imaging modality to accurately detect UCL pathology, including both partial- and full-thickness tears, comparable to the gold standard magnetic resonance imaging with arthrography.^{7,10,11,25} It is an efficient, inexpensive, and noninvasive modality.^{7,10,11,25} sUS involves performing a dynamic evaluation of the soft tissue stabilizers of the medial elbow, mainly the anterior band of the UCL, both with and without applied loads.⁹ In a sUS evaluation, the ulnohumeral joint space is measured at rest. The average joint space measurement at rest ranges from 2.9 to 3.2 mm.^{21,34,39} Then, a valgus stress is applied to the elbow under live ultrasonography (US) imaging, and the ulnohumeral joint space is measured again. The rest-to-valgus joint gap difference is calculated to determine if there is UCL laxity. Validated diagnostic thresholds that suggest UCL instability are a rest-to-valgus joint gap >1.5 mm in the throwing arm and/or a valgus stress difference of >1 mm compared to the contralateral side, but as Sutterer et al³⁷ discussed, the pathologic cutoff indicating injury may vary depending on measurement technique.^{12,21,34,39}

Various methods to apply this valgus stress have been described. In the original description of the sUS technique, 1 examiner holds the arm and applies a valgus force until a firm endpoint is noted, while the second examiner performs the US imaging.^{11,27} Later, a series of studies applied a standardized valgus force using the Telos device with the forearm resting on the table and defined the parameters used above for UCL instability.⁸⁻¹⁰ Unfortunately, this technique of applying valgus force with the Telos device has various limitations: (1) the elbow can only be evaluated at 30° of flexion to fit in the device, (2) most practitioners do not have a Telos device in the clinic, and (3) many patients do not tolerate the discomfort that the Telos device's valgus stress can cause. Another sUS technique has been described and tested in which the patient lies supine with the shoulder in the throwing position in abduction and external rotation (ABER sUS), the elbow at the edge of the table with the edge acting as a fulcrum, and the hand and forearm hanging off the table with nothing supporting it.^{34,37} The resting joint space of the medial elbow is measured in that position. Then, a valgus stress is applied by either manually pressing the forearm

down until an endpoint is noted or applying an external force with a weight or a dynamometer.^{3,6,29,36} The joint space is measured under this valgus stress.^{3,6,29,36} The rest-to-valgus joint gap difference is then calculated as mentioned above. Many practitioners in sports medicine clinics use this ABER sUS technique since it can be performed by a single practitioner without the need for an additional device (ie, Telos).

Recent studies have acknowledged an important confounding variable that is not usually accounted for with this ABER sUS technique and may underestimate the true amount of ulnohumeral joint gapping: the valgus stress effect of gravity on the elbow.^{35,37} The force of gravity on the hand and forearm when hanging off the edge of the table in the “resting position” applies valgus stress on the elbow.³⁵⁻³⁷ This contributes to an initial widening of the ulnohumeral resting joint space that is not typically accounted for and may lead to an underestimation of the true joint gap of the medial elbow upon application of a valgus force. This is illustrated in Figure 1, in which an elbow with a third-degree sprain of the UCL had a resting joint space of 4.9 mm and a valgus stress joint space of 6.3 mm, yielding a joint space gap of 1.4 mm. In the context of an equivocal physical examination and nonspecific symptoms during sport, sUS may provide useful additional data points to tip the scale toward operative or nonoperative management, which may be unaccounted for with current sUS techniques. By definition, this sUS evaluation would not suggest UCL instability because the joint space gap was <1.5 mm and would lead to a false-negative stress test. However, this patient's US imaging clearly shows a third-degree sprain of the UCL.

Sutterer et al³⁷ proposed a new baseline joint space measurement calculated by applying a varus stress to the elbow by lifting the forearm to manually reduce the ulnohumeral joint back to its anatomically aligned position, counteracting the force of gravity and measuring the joint space in a “gravity-eliminated” position (varus stress joint space). They suggested that the joint space measured in this “varus stress” position may provide a better baseline measurement to use when calculating the joint gap (varus-to-valgus gap). In the prior patient from Figure 1, when a varus force was applied to the elbow, the joint space narrowed to 2.8 mm (Figure 2). The varus-to-valgus joint gap was therefore 3.5 mm, which is compatible with prior literature documenting the average joint space gap of a third-degree sprain of the anterior bundle of the UCL.

This study aimed to compare the standard resting position against a varus-stressed position that counteracts gravity as a baseline for evaluating ulnohumeral joint

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Ethical approval for this study was obtained from Ascension IRB (IRB #RAL20230020).

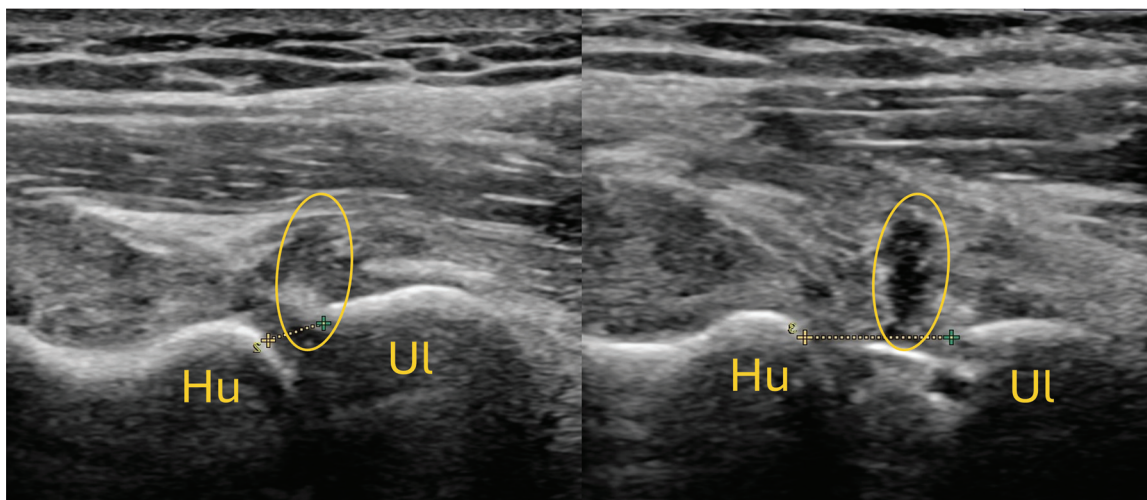


Figure 1. Left: Ulnohumeral resting joint space measuring 4.9 mm. Right: Ulnohumeral joint space under valgus stress measuring 6.3 mm. (Orange oval: elbow ulnar collateral ligament complete tear.)

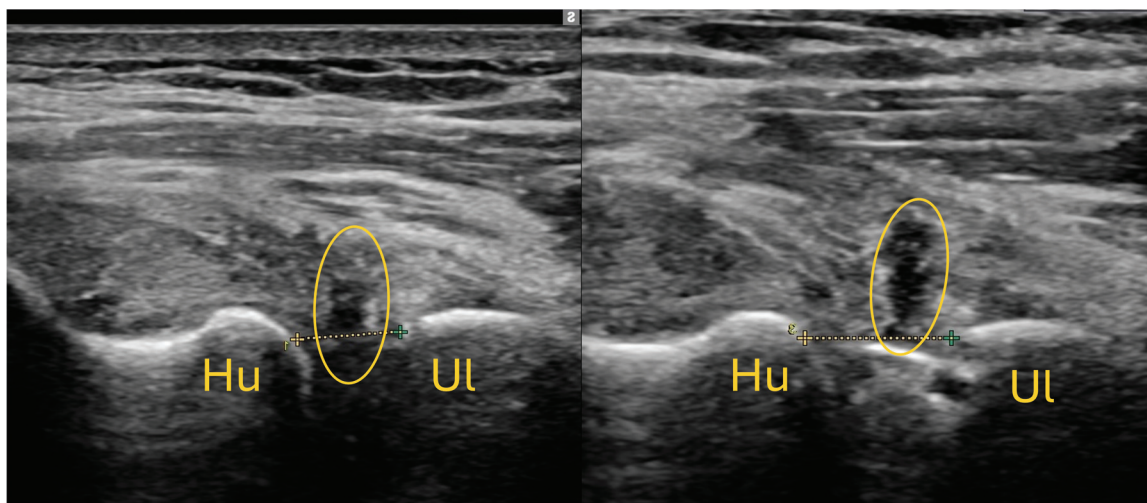


Figure 2. Left: Ulnohumeral joint space under varus stress measuring 2.8 mm. Right: Ulnohumeral joint space under valgus stress measuring 6.3 mm. (Orange oval: elbow ulnar collateral ligament complete tear.)

gapping during sUS in the ABER position. Collegiate baseball players were studied, as it is known that baseball players develop UCL laxity in the throwing arm during their career.^{1,6,10,16} Hence, the throwing arm of each player was considered the experimental arm, and the nonthrowing arm was the control arm in this study. We hypothesized that the throwing arm would demonstrate a greater resting joint space gap as a result of UCL laxity, while there would be no between-arm difference in the varus-stressed joint space gap. In addition, we further hypothesized that the standard rest-to-valgus joint gap would not account for the valgus stress effect of gravity; however, the varus-to-valgus joint gap would account for this expected laxity. It is hoped that this study will lead to future work evaluating symptomatic patients with UCL injuries with the ABER sUS.

METHODS

Athlete Cohort and Study Design

Institutional review board (IRB) approval was obtained from the Ascension IRB (IRB #RAL20230020) prior to initiating the study. In January 2024, asymptomatic collegiate male baseball athletes in National Collegiate Athletic Association Division I with no history of a UCL injury were invited to participate in the study before the collegiate season began. Players were excluded if they had an ongoing elbow injury, elbow symptoms, a history of a second- or third-degree sprain of the UCL, or a history of any elbow surgery. All players were also evaluated with a valgus stress test and were excluded if they had signs suggestive of UCL sprains, including pain during the

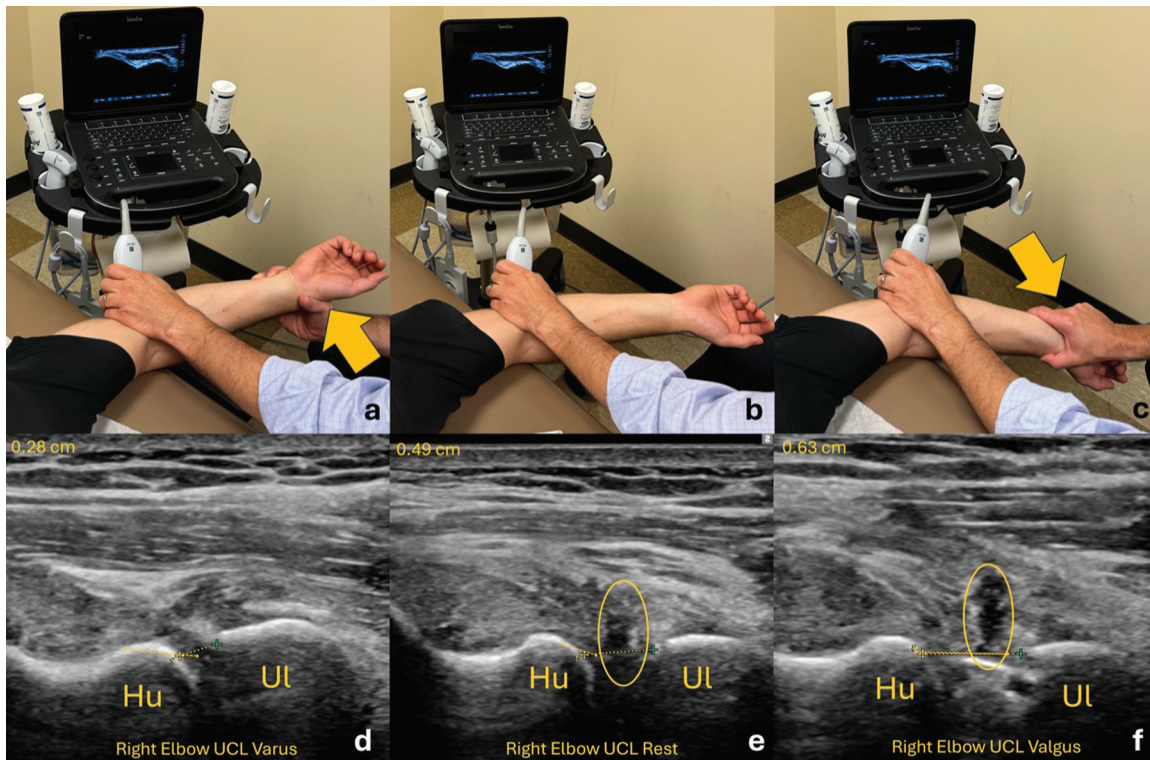


Figure 3. Stress ultrasound technique with varus stress, at rest, and with valgus stress, with corresponding measurements in a patient with a ulnar collateral ligament (UCL) tear. With varus stress applied (a), ultrasound measurement (d) of the ulnohumeral joint space narrows to 2.8 mm. At rest (b), ultrasound measurement (e) of the ulnohumeral joint space is 4.9 mm. With valgus stress applied (c), ultrasound measurement (f) of the ulnohumeral joint space widens to 6.3 mm. Hu, humerus trochlea; Ul, ulnar sublime tubercle. Dashed lines represent ulnohumeral joint space measurements. Arrows indicate directions of varus (a) and valgus (c) force applied. Orange oval indicates elbow ulnar collateral ligament complete tear.

moving valgus stress test between 70° and 120° ²⁸ or a subjective feeling of instability and medial joint line gapping >3 or 4 mm, as described by Hyman et al.¹⁸ Written informed consent to participate was obtained prior to enrollment and data collection. Following informed consent, athletes completed a survey to collect demographic data and history of athletic/baseball participation. An ultrasound examination was performed of the UCL tissue quality of both the throwing elbow and the contralateral, nonthrowing elbow by a single Registered Musculoskeletal Sonographer sports medicine physician with 13 years of experience (R.E.C.) who was blinded to the players' throwing arm and position played. The athletes were also blinded to the findings of the sUS examination. The athlete was excluded from the study if the ultrasound examination revealed a second- or third-degree UCL sprain—identified by a partial or complete hypoechoic discontinuity of the anterior band of the ligament—or gapping on sUS surpassed diagnostic thresholds for UCL tearing: side-to-side difference >1 mm or rest to valgus >1.5 .³⁴ The experimental group consisted of the data of the throwing arms, and the control group was the nonthrowing arms' data. US imaging measurements of the ulnohumeral joint space under the UCL were made in the supine ABER position with the elbow at 30° at rest (with valgus stress from

gravity), with manually applied varus stress, and with a manually applied valgus stress until an endpoint was noted, as described below.

Ultrasound Evaluation Technique

The ABER sUS technique for UCL evaluation was adapted from the existing, validated technique.^{9,10,34} A single-examiner medial elbow stress ultrasound examination was performed. Participants were positioned on the examination table lying supine with the shoulder in 90° of abduction and 90° of external rotation, described in the literature as the ABER position.^{19,35} The elbow was placed with the lateral epicondyle perched off the edge of the table at 30° of flexion, chosen as the degree of flexion where the olecranon releases from its fossa and the UCL becomes the primary restraint to valgus stress.²⁷ A 15- to 6-MHz musculoskeletal linear array transducer (Edge II-MSK Ultrasound system with HFL50x probe; Fuji-Sonosite) was placed over the medial epicondyle on one end and the sublime tubercle on the other end to visualize the anterior band of the UCL at the midpoint of the anterior band (Figure 3). The quality of the ligament was evaluated for pathologic changes described in prior US

studies, specifically looking for hyperechoic or hypoechoic changes suggesting chronic or partial sprain of the ligament, respectively.^{1,10,24,27}

Joint space was defined as the distance between the medial edge of the trochlea in the humerus and the sublimus tubercle in the ulna directly under the anterior band of the UCL.²⁷ Joint space was measured under 3 conditions as described below: resting, varus stress, and valgus stress. Resting joint space was measured with the hand and forearm hanging off the table unsupported. For the varus stress condition, a varus force was applied by the examiner to the elbow until a firm endpoint was noted and no additional decrease in joint space was visualized in the live ultrasound imaging, as suggested by Sutterer et al.³⁷ Valgus stress was measured when a firm endpoint was noted with no additional gapping visualized in the live ultrasound imaging and minimum flexor-pronator muscles' reflexive guarding, as described in prior studies.^{11,27,34,40} The joint gaps between these parameters were calculated as follows: (a) rest-to-varus gap = resting joint space – varus stress joint space; (b) rest-to-valgus gap = valgus stress joint space – resting joint space; and (c) varus-to-valgus gap: valgus stress joint space – varus stress joint space. All measurements and calculations were obtained for both the throwing and nonthrowing arms. Because of strict limits placed on the baseball teams during preseason physicals, only 1 provider was allowed to conduct 1 set of measurements.

Statistical Analyses

All statistical analyses were performed using SPSS Statistics, version 28.0 (SPSS, Inc). We calculated summary and descriptive statistics for demographic, clinical, athletic participation, and elbow US data (counts and proportions for categorical data; means and standard deviations for continuous data). We further calculated counts of US-identified UCL abnormalities within the throwing elbow and the nonthrowing elbow separately. Prior to performing group comparisons, we assessed normality using Shapiro-Wilk tests and Q-Q plots, as well as verified homogeneity of variances with Levene's test. We compared US variables of interest (resting joint space, varus stress joint space, valgus stress joint space, varus-to-valgus joint gap, rest-to-valgus joint gap, and rest-to-varus joint gap) between the throwing elbow and the nonthrowing elbow using paired *t* tests. Within the throwing elbow only, we also compared each US variable of interest using paired *t* tests. Additionally, we compared throwing elbow US variables of interest between pitchers and nonpitchers, as well as between those with and without US-identified UCL abnormalities, using independent *t* tests. Lastly, we examined potential demographic and athletic predictors (age, body mass index, and time playing baseball) of US joint space measurements (resting joint space and varus-to-valgus joint gap), using linear regression modeling. For all analyses, *P* < .05 was considered significant.

TABLE 1
Demographic and Position-Related Data
for the Baseball Athlete Cohort^a

| Variable | Included Cohort (n = 50) |
|--------------------------------------|--------------------------|
| Age, y | 20.5 ± 1.3 |
| Height, m | 1.84 ± 0.07 |
| Mass, kg | 88.3 ± 7.7 |
| BMI, kg/m ² | 26.1 ± 2.4 |
| Primary position | |
| Pitcher | 20 (40) |
| Infielder | 14 (28) |
| Outfielder | 9 (18) |
| Catcher | 6 (12) |
| Utility | 1 (2) |
| Self-reported years playing baseball | 15.7 ± 2.1 |

^aData are presented as mean ± standard deviation or number (%). BMI, body mass index.

TABLE 2
Comparison of Throwing Arm and Nonthrowing
Arm Joint Spaces and Joint Gaps^a

| Variable | Throwing | Nonthrowing | <i>P</i> Value |
|---------------------------|-----------|-------------|-------------------|
| Resting joint space | 3.4 ± 0.6 | 2.9 ± 0.6 | <.01 ^b |
| Varus stress joint space | 2.5 ± 0.5 | 2.4 ± 0.5 | .24 |
| Valgus stress joint space | 3.8 ± 0.7 | 3.4 ± 0.6 | <.01 ^b |
| Rest-to-varus joint gap | 0.9 ± 0.5 | 0.5 ± 0.4 | <.01 ^b |
| Rest-to-valgus joint gap | 0.4 ± 0.4 | 0.4 ± 0.4 | .48 |
| Varus-to-valgus joint gap | 1.3 ± 0.5 | 1.0 ± 0.4 | <.01 ^b |

^aAll data are presented as mean ± standard deviation, and units are in millimeters.

^bIndicates *P* < .05.

RESULTS

We enrolled 50 male baseball athletes from 2 National Collegiate Athletic Association Division I baseball teams and evaluated a total of 100 elbows. Demographic and sport-related data are shown in Table 1. Players ranged from 18 to 23 years old. The most common positions of baseball athletes tested were pitchers (n = 20, 40%), followed by infielders and then outfielders (Table 1). None of the players reported pain during the ABER sUS.

Across all tested baseball athletes, the throwing elbow demonstrated significantly greater resting joint space and valgus stress joint space compared to the nonthrowing elbow, with an average difference of 0.5 mm and 0.4 mm, respectively (Table 2). The nonthrowing elbow and the throwing elbow did not show a significant difference in varus stress joint space. The rest-to-varus and varus-to-valgus joint gaps were significantly greater in the throwing arm than the nonthrowing arm, whereas rest-to-valgus joint gaps showed no difference between arms. US measurements of throwing elbows between pitchers and

TABLE 3
Comparison of the Throwing Elbow Joint
Spaces and Joint Space Gaps Between
Pitchers and Nonpitchers^a

| Variable | Pitchers (n = 20) | Nonpitchers (n = 30) | P Value |
|--------------------------------|----------------------|-------------------------|---------|
| Joint space at rest | 3.3 ± 0.7 | 3.4 ± 0.6 | .44 |
| Joint space with varus stress | 2.4 ± 0.6 | 2.5 ± 0.5 | .45 |
| Joint space with valgus stress | 3.6 ± 0.8 | 3.9 ± 0.7 | .29 |
| Rest-to-varus joint gap | 0.9 ± 0.6 | 0.9 ± 0.5 | .87 |
| Rest-to-valgus joint gap | 0.3 ± 0.4 | 0.4 ± 0.4 | .47 |
| Varus-to-valgus joint gap | 1.2 ± 0.5 | 1.3 ± 0.6 | .64 |

^aData are presented as mean ± standard deviation, and units are in millimeters.

TABLE 4
Comparison of the Throwing Elbow Joint Spaces
Between Those With and Without
Ultrasound-Identified UCL Abnormalities^a

| Variable | US UCL Abnormalities (n = 11) | No Abnormalities (n = 39) | P Value |
|---------------------------|-------------------------------------|---------------------------------|---------|
| Resting joint space | 3.5 ± 0.4 | 3.3 ± 0.7 | .32 |
| Varus stress joint space | 2.7 ± 0.6 | 2.4 ± 0.5 | .22 |
| Valgus stress joint space | 4.1 ± 0.7 | 3.7 ± 0.7 | .07 |
| Rest-to-varus joint gap | 0.9 ± 0.5 | 0.9 ± 0.6 | .96 |
| Rest-to-valgus joint gap | 0.6 ± 0.5 | 0.3 ± 0.3 | .08 |
| Varus-to-valgus joint gap | 1.4 ± 0.6 | 1.2 ± 0.5 | .28 |

^aData are presented as mean ± standard deviation, and units are in millimeters. UCL, ulnar collateral ligament; US, ultrasound.

nonpitchers showed no statistically significant differences in any of the throwing elbow US measurements (Table 3).

Table 4 demonstrates throwing elbow US measurements compared between those with US-identified UCL abnormalities (n = 11) and those without (n = 39). US-identified abnormalities were more common in the throwing elbows (22%) than in the nonthrowing elbows (2%). All of the UCL abnormalities included subtle hyperechoic changes near the proximal UCL origin. One of the throwing elbow abnormalities also showed an asymptomatic, low-grade partial UCL sprain, evidenced by a hypochoic signal near the proximal origin. There were no significant differences in throwing elbow US measurements between those with and without US-identified UCL abnormalities. Nonetheless, elbows with UCL abnormalities had wider valgus stress joint space ($P = .07$) and a larger rest-to-valgus joint gap ($P = .08$) compared to elbows with no UCL abnormalities, but neither of these measurements reached significance compared to elbows with no abnormalities. Rest-to-varus joint gaps did not differ between elbows with ultrasound UCL abnormalities and without (0.9 vs 0.9, $P = .96$).

Linear regression showed that, within the throwing elbow group, there were no significant associations between resting joint space and current age ($P = .27$), age when starting to play baseball ($P = .46$), or years playing baseball ($P = .94$). Similarly, there were no significant associations between varus-to-valgus joint gap and current age ($P = .40$), age when starting to play baseball ($P = .98$), or years playing baseball ($P = .61$). Greater body mass index was associated with wider resting joint space in the throwing elbow ($P < .01$; $R^2 = 15.4\%$) but was not associated with greater varus-to-valgus joint gap ($P = .34$).

DISCUSSION

Existing sUS techniques do not adequately capture the effect of gravity contributing a valgus stress on the forearm, leading to a potential underestimation of true joint gapping. We sought to evaluate the valgus stress effect of gravity on the medial elbow's resting joint space and determine if a varus-stressed joint space provides a better baseline measurement. We found that the resting joint space in this study was significantly greater in the throwing arm compared to the nonthrowing arm, in line with our hypothesis that there is a valgus stress effect of gravity on the elbow. Applying a varus force effectively closed the joint space and mitigated this difference, as there was no difference in varus joint space between sides. Current sUS techniques cannot definitively distinguish between adaptive laxity from throwing and pathologic laxity as a result of injury, and using the gravity-stressed resting position as a baseline may lead to missed laxity during the rest-to-valgus measurement. Consequently, varus-to-valgus joint gap measurement captured elbow laxity as a result of gravity that may have otherwise been missed if only the rest-to-valgus joint gap had been measured.

Sasaki et al³⁵ also demonstrated that the valgus stress from gravity in the supine ABER position caused a statistically significant gapping of the throwing elbow compared to the nonthrowing arm. When evaluating throwing athletes for UCL laxity and injuries, obtaining the most accurate measurement of a baseline joint space is crucial. Various biomechanical and clinical studies have established that healthy overhead athletes' UCLs undergo morphologic changes and gradually acquire laxity throughout their career upon exposure to throwing in the short, mid, and long term.^{1,6,10,16} Shanley et al³⁶ demonstrated that professional pitchers with a wider resting joint space had a trend toward sustaining a UCL injury in the following season. Hence, it is important to make sure that the joint space used as a baseline for calculating the joint gap in the ABER sUS is not affected by the valgus stress of gravity, which may lead to a false-negative stress test.

The presence of asymptomatic laxity in the throwing arm may suggest that the medial elbow's structures adapt over time to permit an effective transfer of energy across the kinetic chain and accommodate the repetitive supra-physiologic forces involved with high-volume throwing, as with other soft tissue and osseous adaptations of overhead

athletes' throwing arms.^{14,33} Various mechanisms for these adaptations have been proposed, including bony and soft tissue changes.³¹ Future studies should evaluate if there would be an even greater resting joint space noted in symptomatic and injured athletes in the ABER sUS evaluations.

The present study also found that the varus stress joint space measurement proposed by Sutterer et al³⁷ was similar in both elbows. This suggests that the varus stress joint space may serve as a more reliable baseline measurement to calculate the joint gap. In the throwing arms, the varus-to-valgus joint gap averaged 1.3 mm in this study. The diagnostic threshold for a UCL tear based on the standard rest-to-valgus joint gap ranges from 1.4 to 2.4 mm,^{9,34} and the pathologic cutoff indicating injury is not yet standardized and may vary depending on measurement technique.³⁷ Future studies looking at a greater value for a diagnostic threshold may be required to adequately prevent excessive false positives, since the absolute joint gap from a varus-loaded to a valgus-loaded position is expected to be greater.

Although players in our study were asymptomatic, we identified sonographic abnormalities of the UCL in some throwing arms. Comparing players with and without US abnormalities, there was a greater rest-to-valgus joint gap in those with abnormal UCLs compared to those with normal UCLs, but this difference did not reach significance (0.6 ± 0.5 vs 0.3 ± 0.3 , $P = .08$). While this may suggest that ligaments with pathologic changes but no tears ceded further under applied loads than those without pathologic changes, a larger sample size may be needed to adequately power this comparison. Sonographic abnormalities such as increased ligament thickness and laxity have been described as adaptive changes in baseball players' throwing arms, but their clinical significance is unclear.^{1,10,27,37} Further clinical studies will be warranted to determine whether these sonographic abnormalities correlate with a higher risk of developing UCL injuries.

The weight of the hand and forearm demonstrated a direct correlation with the valgus stress effect of gravity on the elbow. In this study, a greater body mass index was associated with wider resting joint space in the throwing elbow. As Beason et al² found, however, height and weight are not necessarily correlated with UCL strength. Using the average body mass and height from our study, along with average inertial properties of upper extremity segments,^{17,38} the force of gravity on the forearm and hand hanging off the table created an estimated 7.1 N-m of valgus torque. For comparison, valgus torque generated during pitching in college baseball players reaches approximately 70 N-m.¹³ A stress radiography study demonstrated that the average force of a manually applied valgus stress is 25 N.²² Thus, taken together, gravity may be applying an average of 28% of the total force that is typically applied manually. This supports the need to account for the valgus stress effect of gravity with ABER sUS.

Stress ultrasonography lacks standardization with regard to positioning, amount of valgus load applied, how it is applied, and the elbow flexion angle used.³⁷ The Telos device has been the gold standard to evaluate the UCL with stress ultrasonography, applying 150 N to a resting

elbow at 30° of flexion. However, this device is not readily available in sports medicine clinics, and it is not tolerated by many athletes with UCL injuries. The ABER sUS is also commonly used.^{11,27,35} Podesta et al³² demonstrated that the supine ABER position is a valid and reproducible position to test the elbow. They documented no significant difference in the change in UCL length, UCL width, or the ulnohumeral joint space when comparing an ABER sUS with a dumbbell versus an ABER sUS with the Telos device. If the valgus stress effect of gravity is accounted for, the ABER sUS may provide a technique that can be easily reproduced in the clinic setting by a single provider without depending on additional devices.

Finally, magnetic resonance imaging (MRI)-based valgus stress tests have emerged with the flexed elbow valgus external rotation (FEVER) view proposed by Lund et al.²³ In 44 professional pitchers, the FEVER view MRI detected a 1.8-mm (95% CI, 1.58-2.03 mm) joint space gap compared to the standard resting position for an elbow MRI, thus allowing for increased detection of abnormal signal, injury grade, ligament retraction, and diagnostic confidence. A subsequent study by Patel et al³⁰ in 91 professional pitchers found correlations between FEVER view findings and level of play and innings pitched. While these findings point toward the promise of this new MRI modality in assessing the UCL, certain caveats in the technique itself and in comparison to dynamic sUS must be acknowledged.

As described by Lund et al,²³ 2 sandbags totaling 3.4 kg are placed on the distal forearm at 90° of abduction and external rotation, similar to the ABER view. This position is similar to the sUS position we use, but it is limited by the fact that it is a static rather than a dynamic assessment. In applying stress manually and ranging the patient through flexion and extension during sUS evaluation, the examiner can respond to reflexive guarding of the forearm flexor-pronator mass, known to decrease joint space gapping and, additionally, to explore distinct flexion angles, which may allow for wider gapping.³⁷ Furthermore, the authors of studies reporting on FEVER views acknowledge that prognosis with future injury risk has not been established. In contrast, Shanley et al³⁶ have established the short-term risk of next-season injury in professional baseball pitchers with gapping on sUS >5.6 mm. Furthermore, Hanna et al¹⁵ noted sUS utility for assessing injury risk longitudinally by noting that the increase in mean dominant UCL thickness (0.94 vs -0.60 mm, respectively; $P = .038$) in the season prior was a predictor of undergoing UCL reconstruction in a sample of 203 professional pitchers over 18 years. The FEVER-view MRI is promising and may potentially serve as an adjunct to the dynamic sUS in guiding treatment considerations.

Limitations

Limitations of this study should be recognized. As mentioned, the varus stress was manually applied until a firm endpoint was noted, but the force applied was not quantified and standardized with a dynamometer. Future studies could quantify how much force should be applied


when measuring the varus stress joint space. As with all ultrasound assessments, an operator-dependent component when performing the ABER sUS may lend itself to variability upon external validation of the study. The examiner was blinded to the players' throwing arms, but there was no way to blind the examiner when UCL pathology was noted, raising the potential for observer bias in the measurements showing side-to-side differences in the setting of visible changes in the ligament. As a result of strict limitations placed by the baseball teams, only 1 fellowship-trained physician was allowed to perform the sUS assessments, potentially limiting evaluation of interrater reliability. Additionally, this study was not sufficiently powered for subgroup analyses, such as comparing the resting joint space based on the positions they play. Studies with a larger number of participants are needed to confirm the findings of this study. Future studies to validate the sensitivity and specificity of this ABER sUS technique could consider comparing these findings with MR arthrography for identifying UCL pathology. Furthermore, Shanley et al³⁶ demonstrated that baseball players with an absolute valgus joint space measurement >5.6 mm were 6 times more likely to need surgery. Future studies could potentially identify a similar risk ratio based on defined sonographic findings of UCL pathology and a defined resting joint space in the supine, ABER position that would be diagnostic of a complete UCL tear.

CONCLUSION

Asymptomatic male collegiate baseball players' throwing arm had a significantly greater resting joint space when exposed to gravity stress than the nonthrowing arm in the ABER position, possibly as a result of adaptive UCL laxity. However, the bilateral similarity in varus-stressed measurements suggests it may serve as a better baseline for sUS assessments. Future research incorporating varus stress as a baseline in symptomatic athletes may improve the accuracy and clinical relevance of medial elbow laxity evaluations.

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