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Medial Elbow Joint Laxity in Professional Baseball Pitchers

A Bilateral Comparison Using Stress Radiography

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ABSTRACT

Injuries to the ulnar collateral ligament frequently occur in throwing athletes because of large, repetitive valgus stresses to the elbow during the cocking and acceleration phases of throwing. Identification of injury to this ligament is important in evaluating the throwing elbow. The purpose of this study was to determine whether differences in medial elbow laxity exist between the dominant and nondominant extremities in uninjured baseball pitchers. Forty uninjured professional baseball pitchers were tested bilaterally with a Telos GA-IIE stress radiography device. Joint space width between the trochlea of the humerus and the coronoid process of the ulna was measured on anteroposterior radiographs obtained with no stress applied and with a 15-daN valgus stress. Results showed significant differences between the medial joint space opening of the dominant and nondominant elbows with no stress applied. With stress, the dominant elbow opened 1.20 ± 0.97 mm, while the nondominant elbow opened 0.88 ± 0.55 mm. A significantly greater difference in medial joint space opening between the stressed and unstressed elbows was measured in the dominant elbow compared with the nondominant elbow (0.32 ± 0.42 mm). This study identifies increased medial elbow laxity in the dominant arm in uninjured pitchers.

Kinetic and kinematic research investigations of the throwing elbow clearly demonstrate the excessive valgus stresses imparted to the medial elbow during the late cocking and acceleration phases of the throwing motion.[2,4] Injury to the ulnar collateral ligament (UCL) most commonly occurs in the throwing elbow, whether from the baseball pitch, javelin throw, or tennis serve. Poor mechanics, lack of flexibility and conditioning, and muscular fatigue from overuse can have a cumulative effect that leads to a decrease in active muscular protection of the medial elbow and hence greater stress imparted to the UCL.[6]

Stability of the elbow is provided by a combination of the bony congruity, provided by the articular geometry, and the capsuloligamentous structures.[7] The UCL comprises three specific sections on the medial aspect of the ulnohumeral joint. The humeral origin of the anterior band of the UCL is eccentrically located with respect to the axis of elbow extension and flexion and thus provides stability throughout the range of elbow motion. The insertion of the anterior band of the UCL is into the coronoid of the ulna, giving it a mechanical advantage in controlling valgus forces. The relative contribution to elbow stability by the bony and ligamentous structures is range of motion dependent. With the elbow in complete extension, the UCL and bony articulation of the ulnohumeral joint each contribute 31% of the restraining force to resist valgus stress.[7] With the elbow in a flexed position, similar to the position of the elbow during peak valgus stress during the acceleration phase of the throwing motion,[2,3] the bony articulation accounts for 33% of the restraining force to valgus stress, with 54% coming from the UCL.[7] Because of the excessive and repetitive loads imparted to the UCL in the throwing athlete, evaluation of the ligament's integrity is imperative in both preventive and postinjury environments.

Evaluation of the UCL is usually performed clinically using a manual valgus stress test.[1] The elbow is placed in 20° to 25° of flexion to unlock the olecranon from the

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surrounding bony fossa. As in other manual orthopaedic tests, bilateral comparison of the degree of laxity and endfeel are performed and used to estimate integrity of the ligamentous structures. Computed tomography and MRI have also been used in the evaluation of the UCL. In a prospective study of 25 baseball pitchers, Timmerman et al.[12] used both CT and MRI to evaluate the elbow before surgery. Computed tomography arthrograms detected abnormalities in 12 of 14 patients with UCL injury (86% sensitivity), whereas MRI revealed abnormalities in 8 of 14 patients (57% sensitivity). In another study, Timmerman and Andrews[11] described a "T" sign visible with a CT arthrogram that represents an undersurface tear of the UCL. In a CT arthrogram of this injury, dye leaks around the detachment of the UCL from its bony insertion but is contained within the intact superficial layer of the UCL and joint capsule.

In addition to the CT arthrogram and MRI, stress radiography has been used as a diagnostic technique to identify laxity of the medial elbow structures. Forty-two injured and four uninjured athletes were evaluated by Rijke et al.[8] using a stress radiography technique. Anteroposterior radiographs were taken of both elbows with 0 and 15 daN (34 pounds) of valgus force applied using a Telos GA-IIE stress radiography device (Austin & Associates, Fallston, Maryland). The increase in joint space width between the trochlea of the humerus and the ulnar coronoid process from the 0 stress to 15 daN valgus stress condition was used to assess the extent of the ligament tear.

The patient population used included uninjured athletes, those with small UCL tears, and patients with large or complete tears of the UCL. Results indicated that virtually all patients with uninjured and minimally torn UCLs showed a difference between the injured and uninjured extremities of 0.5 mm or less, with patients diagnosed with large or complete tears of the UCL having a significantly ($P < 0.001$) greater difference (>0.5 mm) between the injured and uninjured extremities. To validate the stress radiography technique, Rijke et al. tested five cadaveric limbs with varying degrees of UCL ligament disruption. The intact cadaveric limb showed a 0.2-mm increase in joint-space width with stress applied and a linear progression with percent transection of the ligament to 2.8 mm with complete transection.[8] These authors also identified no significant difference between elbows with injured UCLs and elbows with uninjured UCLs on AP radiographs with no stress applied. The application of 15 daN of valgus stress, compared with the no-stress condition, was required to identify injury of the UCL. The use of 15 daN of valgus stress was recommended by Rijke et al.,[8] who found medial joint opening with application of this level of stress in cadaveric limbs.

The purpose of this study was to determine whether significant differences exist in medial elbow laxity between the dominant and nondominant elbows as measured by stress radiography in a population of uninjured professional baseball pitchers. Identification of normal medial elbow joint laxity patterns in this population will facilitate the application and interpretation of elbow stress radiography in the diagnosis of UCL injury. Population-specific laxity patterns are necessary to optimize the use of stress radiography in clinical application.

MATERIALS AND METHODS

Forty professional baseball pitchers with no history of elbow injury participated in this study. Subjects signed an informed consent form and an upper extremity injury and baseball history form before participation in this study. Subject characteristics are reported in Table 1. A physical therapist performed an upper extremity screening examination that included varus and valgus stress tests, provocation tests for medial and lateral epicondylitis, and Tinel's test. The presence of a positive clinical test would have precluded the inclusion of any subject in this study.

Active Range of Motion Measurement

Active range of motion for elbow extension and flexion and wrist extension and flexion were measured using a standard universal goniometer before performing the stress radiography procedure. The axis of the goniometer was placed just distal to the lateral epicondyle and both its proximal and distal arms were placed along the midline of the forearm and brachium to measure elbow extension and flexion active range of motion. Wrist extension and flexion were recorded with the elbow in an extended position with the goniometer axis aligned just distal to the ulnar styloid process, with the proximal arm placed in line with the lateral border of the ulna. The distal arm was aligned along the lateral aspect of the fifth metacarpal. The same investigator (TSE) performed these measurements in one trial each on all 40 subjects in this study. Intrarater reliability of goniometric measurement of elbow extension and flexion has been subjected to scientific study and previously reported as reliable.[3]

Stress Radiography

A Telos GA-IIE stress device (Telos, Weiterstadt, Germany) was used to provide consistent extremity positioning and for application of the valgus stress to the elbow. The elbow was placed into the Telos device positioned in 25° of flexion using foam blocks. The elbow flexion position was verified using a standard universal goniometer. The patient was seated on a stool with the Telos device placed on the radiography table with the shoulder abducted 65° and externally rotated. The forearm was positioned in full

TABLE 1
Characteristics of the Professional Baseball Pitchers Studied

Characteristic	Mean	SD
Age (years)	21.7	2.79
Height (inches)	73.3	4.27
Weight (pounds)	202.5	22.49
Age started pitching (years)	10.0	3.86
Years professional pitching (years)	2.76	1.79

supination. This was accomplished by having the patient grasp a handle on the Telos device (Fig. 1).

Anteroposterior radiographs of both elbows were taken in random order using a standard radiographic unit (Gendex 5000, Universal Inc., Chicago, Illinois). Exposure settings for the standard radiographs were 5 mA/sec and 60 kVp. Radiographs of each elbow were obtained with 0 force and 15 daN of valgus force applied to the lateral aspect of the elbow joint. The valgus force was applied with a screw-threaded shaft that permits gradual increases in stress. The applied force was monitored on a light-emitting diode digital readout. To test the reliability of the Telos stress radiography device, unilateral radiographs were retaken on one randomly selected extremity of every fifth subject using identical procedures.

The distance (d) between the trochlea of the humerus and the ulnar coronoid process was measured by means of a loupe (×7) with a calibrated scale with 10 divisions to the millimeter (Bausch & Lomb, Rochester, New York) (Fig. 2). Readings were made to the nearest 0.05 mm. The distances at 15 daN (d15) and 0 force (d0) were compared with those of the contralateral extremity. The difference between the distances in the elbow in the valgus stress condition and the elbow with no stress applied (d15 minus d0) was also compared bilaterally and used to represent the degree of laxity of the medial elbow structures. All radiographs were taken by one technician with the assistance of the senior author (TSE), and all radiographs were read and interpreted by a board-certified radiologist (EAE).

Data Analysis

A dependent *t*-test was used to test for medial elbow laxity differences between the dominant and nondominant extremities with significance at the 0.05 level. A dependent *t*-test was also used to test for bilateral differences in elbow and wrist extension and flexion active range of motion. An intraclass correlation coefficient (ICC-2,k) was used to determine test-retest reliability.

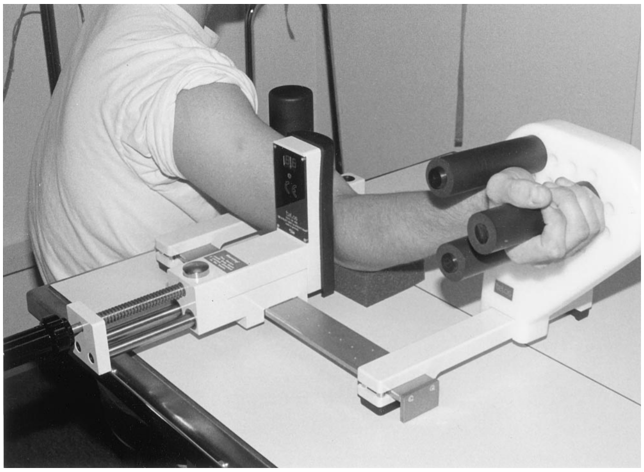

Figure 1. A Telos GA-IIE stress radiography device set up for the right elbow.

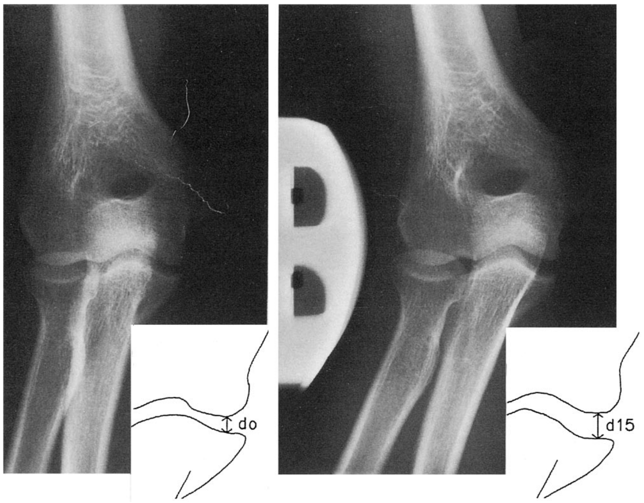

Figure 2. Anteroposterior radiograph of the left elbow with 0 force (d0), and 15 daN force (d15) applied to the elbow joint, showing increased medial joint spacing with application of stress. (Reprinted with permission from Rijke et al.[8])

RESULTS

Bilateral Differences

The findings of the bilateral stress examinations from the 40 subjects are presented in Table 2. Significant ($P < 0.01$) bilateral differences were found in medial elbow laxity (d15 minus d0) between the dominant and nondominant extremities. The dominant extremity, on average, had 0.32 ± 0.42 mm greater medial joint width increases with application of the valgus stress. The values taken from the radiographs of the dominant and nondominant extremities with no stress applied (d0) did not identify a significant difference between extremities. No significant difference between extremities was measured in the valgus stress condition (d15).

Test-Retest Reliability

The intraclass correlation coefficient generated from retesting one extremity of every fifth subject using the Telos device was 0.95.

Extremity Range of Motion

Goniometric range of motion measured before stress radiography is presented in Table 3. A significant ($P < 0.001$) decrease in elbow extension was measured on the dominant arm compared with the nondominant extremity. Significant ($P < 0.01$) decreases in elbow flexion and wrist extension range of motion were also measured on the dominant extremity compared with the nondominant ex-

TABLE 2
Stress Radiography Values

Measurement	Extremity		t	P
	Dominant (Mean ± SD)	Nondominant (Mean ± SD)		
Joint width no stress (d0)	3.53 ± 0.59	3.58 ± 0.60	−0.75	Not significant
Joint width with stress (d15)	4.72 ± 1.23	4.46 ± 0.86	1.66	Not significant
Joint width difference (d15-d0)	1.20 ± 0.97	0.88 ± 0.55	2.49	<0.01

TABLE 3
Goniometric Range of Motion Before Stress Radiography

Movement pattern	Extremity		t	P
	Dominant (Mean ± SD)	Nondominant (Mean ± SD)		
Elbow extension	−4.87 ± 7.43	1.26 ± 5.53	7.91	0.001
Elbow flexion	143.54 ± 3.89	145.21 ± 4.75	2.50	0.01
Wrist flexion	74.18 ± 7.09	71.97 ± 10.58	1.65	Not significant
Wrist extension	74.46 ± 8.83	77.10 ± 8.09	2.70	0.01

tremity. No difference was measured in wrist flexion range of motion between the dominant and nondominant extremities.

DISCUSSION

The findings reported in this study are in agreement with previous research by Rijke et al.,[8] who measured less than a 0.5-mm difference in medial elbow laxity between extremities with intact UCLs. Stress radiography using the Telos device did identify an increased joint widening of 0.32 mm on the dominant extremity in a population of baseball pitchers without elbow injury. No significant difference was found between elbows without stress and between elbows with the application of 15 daN valgus stress. Accuracy is improved when patient-to-patient variability is eliminated by comparing each athlete's dominant elbow with his or her nondominant elbow and using the no-stress condition as a baseline reading on each extremity. Therefore, the difference between the valgus stress and no-stress conditions provides a statistically reliable estimate of medial joint laxity and identifies a side-to-side difference in the uninjured pitcher.

The 0.32-mm difference was statistically significant between the dominant and nondominant extremities, but clinically would be an almost unidentifiable difference with manual orthopaedic laxity tests. The significance of this finding is that slightly greater medial joint opening is present in the dominant arm in uninjured professional baseball pitchers, and identification of similarly small laxity differences in the injured thrower may not indicate abnormal amounts of laxity but a sport-specific response to repetitive stress. While dominant versus nondominant differences were statistically significant in this investigation, the clinical significance lies in the identification of these sport-specific laxity patterns in uninjured pitchers as a baseline measure. Use of a small, detailed scale of measurement is necessary to identify the subtle increases in medial joint space opening concomitant with UCL injury.

The difference in joint-space opening between the valgus stress condition and the no-stress condition has been used in the diagnosis of UCL laxity.[8] Validation of the stress radiography technique used in this investigation was performed by Rijke et al.[8] using cadaveric limbs. The fact that sectioning the UCL increased medial joint space laxity portrays the important function of the UCL in stabilizing the medial elbow in the presence of valgus stress. Previous stress radiography research has used a technique termed the gravity valgus test in which the force of gravity and the weight of the patient's forearm are used to provide a valgus stress to the elbow during radiographic evaluation.[9]

Rijke et al. used the d15 minus d0 bilateral difference to differentiate between patients with moderate or large tears and those with normal or minimally injured UCLs. The critical value reported and used by Rijke and colleagues to differentiate between the injured and uninjured patient populations was 0.5 mm. The results of this study clearly support the use of this value, as uninjured professional baseball pitchers demonstrated a significant increase in medial elbow laxity, but not greater than 0.5 mm, between extremities. The repetitive valgus stresses imparted to the throwing elbow described in biomechanical studies helps to explain the presence of small amounts of increased laxity in the medial elbow in the professional baseball pitcher. The chronic attenuation of this structure can ultimately lead to injury, particularly with improper mechanics and poor dynamic muscular stabilization.[4,6]

The goniometric measurements taken during this investigation serve to support the use of 25° of elbow flexion during testing and to minimize the possible stabilizing influences from the musculature. The professional pitchers had 5° less extension of their dominant elbows and 4° less extension of their dominant wrists compared with the nondominant side. Tightness of the muscle-tendon units of the flexor-pronator mass, anterior capsular fibrosis, and osseous adaptations have all been proposed as causes of limited elbow extension in the upper extremity athlete.[5,10] Flexion contractures of the throwing elbow have been reported previously and were found in 50% of professional baseball pitchers studied by Woods et al.[13]

The reliability of the Telos stress radiography procedure was again tested in this study. Consistent with the results previously reported by Rijke et al.,[8] statistical testing produced high intrarater reliability coefficients. The reliability coefficients were high, indicating that the Telos device can provide a reliable stress to the elbow joint that results in medial joint space widths that can be reliably measured on AP radiographs when the radiographs are read by one radiologist. Further study is needed to determine the reliability between interpreters.

The clinical application of this study lies in the identification of a baseline laxity value in the uninjured professional baseball pitcher. Use of the critical value of 0.5 mm can be supported by this study because the uninjured elbows in our study exhibited consistently smaller medial elbow laxity differences with the stress radiography procedure than did the injured elbows. The high test-retest reliability and noninvasive nature of the stress radiography make this procedure a favorable option for objective identification of medial elbow laxity and UCL injury. The use of standard radiographs also make this procedure a cost-effective option as compared with other diagnostic procedures. The Telos GA-IIE stress device is an additional cost and requirement for application of this procedure.

CONCLUSION

A stress radiography procedure for the elbow in a sample of 40 professional baseball pitchers without elbow injury has identified statistically greater medial elbow laxity in the dominant extremity when compared with the nondominant extremity. The baseline differences between extremities are in agreement with previous research using this stress radiography technique. The stress radiography procedure used in this study proved to be a reliable, noninvasive technique to test medial elbow laxity in this population. Further research is necessary to determine medial elbow laxity patterns in other uninjured upper extremity athletes and to correlate stress radiography results with UCL injury.

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