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## Relationship between pain, elbow valgus instability, and the function of flexor pronator muscles in baseball players



Issei Noda, PT <sup>a,b,c</sup>, Shintarou Kudo, PT, PhD <sup>a,c,d,\*</sup>

<sup>a</sup> Graduate School of Health Sciences, Morinomiya University of Medical Sciences, Osaka, Japan

<sup>b</sup> Ashiya Orthopedics Sports Clinic, Hyogo, Japan

<sup>c</sup> Inclusive Medical Science Research Institute, Morinomiya University of Medical Sciences, Osaka, Japan

<sup>d</sup> AR-Ex Medical Research Center, Tokyo, Japan

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**Hypothesis:** We hypothesize that ulnohumeral joint space distance due to gravity valgus stress may not be related to pain in the medial elbow of the dominant arm in baseball players.

**Methods:** Thirty-one male baseball players were divided into an ulnar collateral ligament (UCL) injury group (n = 16) and a Healthy group (n = 15). The injury groups were diagnosed with UCL injury by magnetic resonance imaging, and was defined as having pain during throwing. The medial elbow of each player's throwing arm was imaged by ultrasonography under valgus stress. The ulnohumeral joint space was measured for horizontal and vertical distances. The examiner added resistance force on the subject in order to produce isometric contraction of the forearm pronator muscles (FPMs). Measurements were taken at rest and at FPM isometric contraction. The Mann-Whitney *U* test was used to compare data between the dominant and nondominant sides, and between the UCL injury group and the Healthy group.

**Results:** The horizontal and vertical distance at rest on the dominant side was not significantly different between 2 groups. The vertical distance during contraction of the flexor carpi radialis (FCR), flexor carpi ulnaris (FCU), and pronator teres (PT) muscles was significantly different between the UCL injury group and the Healthy group ( $P < .05$ ) and was shifted laterally. A shift in the lateral direction indicates an increase in valgus instability.

**Conclusions:** The dominant side suggested that the space in the ulnohumeral joint space was wider, with or without pain. It was suggested that players with medial elbow pain may have impaired FCR, FCU, and PT function.

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Injuries of the medial elbow in baseball players can be caused by the excessive valgus torque at the elbow during throwing. It is estimated that 34.6 Nm of valgus torque is applied to the ulnar collateral ligament (UCL), with the medial elbow tissue, including the UCL, being subjected to 290 N of tension, during pitching.<sup>4</sup> In addition, it has been reported that the amount of torque required to damage the UCL is 32.2 Nm, and the average failure load is 260 N.<sup>10</sup> Thus, the UCL may receive more than the torque required for damage with each throw. Thus, the medial support structure of the elbow, including the UCL, may fail with repeated valgus stress.

This study was approved by the Ethics Review Committee of the Morinomiya University of Medical Sciences (approval no. 2019-019).

\* Corresponding author: Shintarou Kudo, PT, PhD, Graduate School of Health Sciences, Morinomiya University of Medical Sciences, 1-26-16 Nankoukita Suminoe Ward, Osaka, Osaka Prefecture, 559-8611, Japan.

E-mail address: [kudo@morinomiya-u.ac.jp](mailto:kudo@morinomiya-u.ac.jp) (S. Kudo).

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Currently, the UCL is assessed using ultrasonographic (US) imaging. Ciccotti et al<sup>2</sup> assessed the UCL thickness, gap of the ulnohumeral joint space with valgus stress, and echo-textural abnormalities (hypoechoic foci and calcifications) of the medial elbow, and reported no significant difference between a group of individuals with a UCL injury and a healthy group. Therefore, in addition to UCL injury, it may cause pain such as forearm pronator muscle (FPM) injury and ulnar neuropathy.

Dynamic muscle contraction of the FPMs plays a key role in stabilizing the elbow against valgus forces. Anatomic studies have demonstrated 2 tendinous septa between the pronator teres (PT) and flexor digitorum superficialis (FDS) muscles, and between the FDS and the flexor carpi ulnaris (FCU) muscles that are connected to the medial part of the brachialis tendon, deep aponeurosis of the FDS, and FCU to form a tendinous complex linking the ulnohumeral joint.<sup>6</sup> According to biomechanical studies, the FPMs, including the FDS and FCU muscles, have been assumed to contribute to dynamic

stabilization against valgus stress.<sup>12</sup> In addition, the FPMs exhibit an increase in muscle activity throughout the cocking phases of throwing to maximum muscle activity in the acceleration phase for pitchers.<sup>5</sup> In a study using US, the ulnohumeral joint space was reported to decrease significantly during isometric contraction of forearm pronation muscles (PT), wrist ulnar flexion muscles (FCU), and finger flexion muscles (FDS).<sup>9</sup> However, other previous studies have not demonstrated the function of FPMs against valgus stress in baseball players with pain using US.

In this study, we clarify the relationship between medial elbow pain, ulnohumeral joint space due to gravity valgus stress distance, and the function of the FPMs. We hypothesize that ulnohumeral joint space distance may not be related to pain in the medial elbow of the dominant arm in baseball players.

## Methods

Thirty-one male, junior high school, high school, and university-level baseball players with and without medial elbow pain during throwing were recruited from one orthopedic clinic to participate in this study. The average age of the subjects was 15.8 years (range, 13–20 years). The UCL injury group consisted of 16 baseball players, and the Healthy group consisted of 15 baseball players. In the UCL injury group, 5 players were pitchers and 11 were fielders. In the Healthy group, 6 players were pitchers and 9 were fielders. If you are playing multiple positions, the primary position is listed. In the UCL injury group, all players were diagnosed as “injury to the medial collateral ligament” by the same orthopedic surgeon. The diagnostic criteria for UCL injury on magnetic resonance imaging were defined as UCL heterogeneity and hyperintense signal. In addition, medial elbow pain during throwing was the complication associated with all of the players in the UCL injury group. Players in the injury group were measured within 1 month of diagnosis. In addition, all players in the injury group have been treated with rehabilitation. Exclusion criteria of the UCL injury group were players with osteochondritis dissecans or olecranon disorder and baseball players who did not have pain during throwing. The medial elbow was imaged by B mode, ultrasonography (Noblus, Hitachi Aloca, Tokyo, Japan) using an 18-MHz linear-array transducer. Bilateral elbows of all players were inspected ultrasonographically by the same examiner and assistant. The examination position was as described previously. All players were positioned supine on the bed with maximal external rotation of shoulder, the arm in 90° of abduction, the elbow flexed to 90°, and the forearm in the neutral position (Fig. 1). In this position, the examiner applied gravity valgus stress to the arm of the players. The medial side of the elbow was imaged from the top of the medial epicondyle, to the anterior bundle of UCL, and to the sublime tubercle (ST) (Fig. 2). The ulnohumeral joint space was imaged as a low-echo space between the distal-medial corner of the trochlea and the proximal edge of the ST. The horizontal and vertical distances at rest were measured. The horizontal distances were measured as the ulnohumeral joint space between the distal-medial corner of the trochlea and the proximal edge of the ST. In addition, the vertical distance designated the medial or lateral shift of the ST. If the proximal edge of the ST was positioned medial when compared with the distal-medial corner of the trochlea, the vertical distance was shown as a positive value. The vertical distance was shown as a negative value when the proximal edge of the ST was positioned lateral when compared with the distal-medial corner of the trochlea. The examiner added a resistance force on the subject in order to produce isometric contraction of the forearm pronator, wrist palmar flexor, wrist ulnar flexor, and finger flexor muscles. Prior to measurement, we practiced the exercise task and confirmed that it could be implemented on the US. Measurements were taken at rest



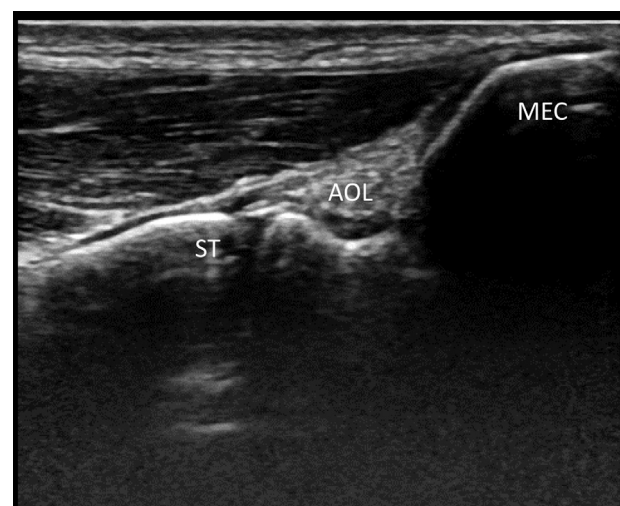
**Figure 1** Clinical images at rest and with valgus stress in the pitching arm. All players were positioned supine on the bed with maximal external rotation of shoulder, the arm in 90° of abduction, the elbow flexed to 90°, and the forearm in the neutral position. In this position, the examiner applied gravity valgus stress to the arm of the players.

and at each FPM isometric contraction. All players had no pain at rest or in contraction during the measurements. The Mann-Whitney *U* test was used to compare data between the dominant and nondominant sides, and between the UCL injury group and the Healthy group. The comparison between the dominant and nondominant side was performed only in the Healthy group. After that, the relationship between the horizontal and the vertical distance at rest and contraction was compared using Pearson correlation coefficient. A *P* value <.05 was considered significant. Statistical analyses were carried out using SPSS Statistics version 25 (IBM, Armonk, NY, USA).

The summary and purpose of the study was discussed with each subject and his or her consent to participate was obtained.

## Results

There were no significant differences in age, height, weight, exercise amount (per week), and exercise time (in hours) between



**Figure 2** Ultrasonographic images of the ulnar collateral ligament (UCL). The top of the MEC, the AOL, and the ST are obtained. MEC, medial epicondyle; AOL, anterior oblique ligament; ST, sublime tubercle.

**Table I**  
Baseball player demographics

	Healthy group (n = 16)	Injury group (n = 15)
Age	15.5 ± 1.8	16.2 ± 1.8
Height, cm	171.6 ± 4.9	172.2 ± 6.8
Weight, kg	65.1 ± 8.1	65.8 ± 9.5
Exercise sessions per week	4.8 ± 1.2	5.5 ± 1.7
Exercise time, h	5.1 ± 1.1	4.6 ± 1.4
Position	Pitcher 5 Fielder 11	Pitcher 6 Fielder 9

the groups (Table I). There was no significant difference in the angle of external rotation of the shoulder during the measurement.

In the Healthy group, the horizontal distance in the ulnohumeral joint space at rest on the dominant side was significantly wider than that of the nondominant side ( $P < .01$ ) (Table II). Also, in the UCL injury group, the horizontal distance in the ulnohumeral joint space at rest on the dominant side was significantly wider than that of the nondominant side ( $P < .01$ ). However, the horizontal distance at rest on the dominant side was not significantly different between the UCL injury group and the Healthy group. During contraction of each muscle, the horizontal distance of the ulnohumeral joint space on the dominant side was significantly increased compared with that of the nondominant side in both the Healthy and UCL injury groups. However, the horizontal distance during contraction of each muscle was not significantly different between the UCL injury group and the Healthy group for all muscles.

The vertical distance at rest in the Healthy group was significantly shifted laterally on the dominant side than that of the nondominant side ( $P < .02$ ) (Table III). Also, the vertical distance at rest in the UCL injury group was significantly shifted laterally on the dominant side than that of the nondominant side ( $P < .01$ ). However, the vertical distance at rest on the dominant side was not significantly different between the UCL injury group and the Healthy group. The vertical distance during contraction of each muscle was significantly different between the FCR, FCU, and PT and was shifted more laterally in the UCL injury group than the Healthy group ( $P < .05$ ).

No correlation was observed between the horizontal and the vertical distances both at rest and during muscle contraction.

**Table II**  
Horizontal distance

	Rest	FCR	FCU	FDS	PT
Healthy group, mm, mean ± SD					
Dominant side	4.8 ± 0.91	3.68 ± 0.61	3.95 ± 0.60	3.37 ± 0.63	3.21 ± 0.67
Nondominant side	3.69 ± 0.91	3.01 ± 0.71	3.11 ± 0.95	2.83 ± 0.65	2.65 ± 0.67
Injury group, mm, mean ± SD					
Dominant side	4.51 ± 0.97	3.69 ± 0.73	3.69 ± 0.83	3.1 ± 0.65	3.1 ± 0.64
Nondominant side	3.51 ± 0.77	2.74 ± 0.63	2.84 ± 0.89	2.55 ± 0.61	2.43 ± 0.81

SD, standard deviation; FCR, flexor carpi radialis; FCU, flexor carpi ulnaris; FDS, flexor digitorum superficialis; PT, pronator teres.

**Table III**  
Vertical distance

	Rest	FCR	FCU	FDS	PT
Healthy group, mm, mean ± SD					
Dominant side	-0.03 ± 0.62	0.45 ± 0.7	0.53 ± 0.72	0.49 ± 0.67	1.01 ± 0.58
Nondominant side	0.69 ± 0.7	0.63 ± 0.65	0.54 ± 0.64	0.66 ± 0.67	0.87 ± 0.67
Injury group, mm, mean ± SD					
Dominant side	-0.25 ± 0.61	-0.01 ± 0.54	0.07 ± 0.5	0.33 ± 0.35	0.66 ± 0.53
Nondominant side	0.58 ± 0.79	0.54 ± 0.84	0.61 ± 0.84	0.53 ± 0.63	0.86 ± 0.85

SD, standard deviation; FCR, flexor carpi radialis; FCU, flexor carpi ulnaris; FDS, flexor digitorum superficialis; PT, pronator teres.

## Discussion

In this study, we examined the valgus instability and the contribution of FPMs in baseball players with or without throwing arm elbow pain. At rest, the ulnohumeral joint space was significantly larger on the dominant side and was significantly shifted laterally on the dominant side in both the Healthy and UCL injury groups, and no significant difference was observed between the 2 groups. These results suggest that ulnohumeral joint space distance due to gravity valgus stress has a weak association with medial elbow pain in the throwing arm of baseball players. The horizontal distance of the ulnohumeral joint space during contraction of each muscle was wider on the dominant side in both groups, and there was no significant difference between the 2 groups. The vertical distance during FCR, FCU, and PT contraction was significantly higher in the injury group than the healthy group ( $P < .05$ ). These results suggest that dysfunction of the FCR, FCU, and PT in the UCL injury group may be associated with pain.

Valgus laxity associated with UCL injury has been considered a problem with throwing elbow injuries, especially the medial elbow. Willemot et al<sup>13</sup> reported that, with repetitive valgus stress, ligament failure may occur, making it impossible for the athlete to continue their throwing activities. On the other hand, the results of the present study demonstrated that the ulnohumeral joint space of the dominant side was not significantly different between the UCL injury group and the Healthy group. According to Ciccotti et al,<sup>2</sup> high school baseball pitchers should show adaptive changes in the UCL, such as calcifications and hypoechoic foci, thickening, and increased ulnohumeral joint laxity. In this study, the gravity valgus load of the arm was applied to the measurement. The ulnohumeral joint space was larger on the dominant side than on the nondominant side in both Healthy and Injury groups, even though the valgus load was lighter than the throwing load. Based on these findings, it was suggested that the dominant side has valgus laxity with or without pain.

Previous studies have shown that many cases with medial elbow disorders have decreased FPM function. In an electromyographic study, the muscle activity of the FCU and FCR were decreased in pitchers with injured elbows when compared with that in pitchers with normal elbows in all phases of the throwing motion.<sup>5</sup> Tajika et al<sup>11</sup> also reported that FCU muscle strength correlated with pitching performance score and grip strength. The

results of an ultrasonographic in vivo dynamic study by Otoshi et al,<sup>10</sup> using the same method as the present study has, suggests that the PT, FCR, and FDS function as dynamic stabilizers against elbow valgus stress, but the function of these muscles has not been studied in patients with medial elbow pain. In this study, the ST was located lateral relative to the distal-medial corner of the trochlea in the injury group during contraction of the FCR, FCU, and PT. By contracting each muscle, the ST can be shifted inward from resting, and dynamic stabilization of FPMs functions against valgus loading. However, the injury group failed to shift medial to the position of the ST in the Healthy group and nondominant side. Therefore, this study suggests that FCR, FCU, and PT function may be impaired in the painful injury group. A lateral shift of the proximal edge of the ST suggests an increase in elbow valgus. Deterioration of elbow valgus instability may be caused by increased traction stress on the medial elbow. Therefore, if the ST is located significantly more lateral to the nondominant side, even after the FPMs are contracted, it is suggested that the FPMs have decreased function.

It has been reported that strains or tears may develop in the forearm flexors and affect the ability of a professional athlete to throw, resulting in significant time on the disabled list in Major League Baseball.<sup>1,7</sup> The flexor-pronator muscles provide dynamic support to the repetitive valgus stresses experienced in the throwing elbow.<sup>8</sup> As a result, combined injuries of the flexor pronator muscles and UCL may occur. Flexor pronator muscle injury near the origin of the medial epicondyle was observed at the time of operative treatment for 13% of pitchers with UCL failure in a large case series, highlighting the possibility of concomitant injury to the flexor-pronator mass among pitchers with valgus instability.<sup>3</sup> In other words, the functional depression of FPMs is important in the throwing injury, and the early accurate evaluation is required, but the evaluation of the stabilization function of FPMs has been insufficient until now. This study's results suggest that dysfunction of the FCR, FCU, and PT in the UCL injury group may be associated with pain.

This study has several limitations. First, each muscle may not have been able to contract. In this study, muscle contraction is performed using an exercise task unique to each muscle. Contractions of each muscle were checked by US before the contractions were performed. However, it is possible that compensatory movements by other muscles may have occurred because of wrist flexion. Second, this is a cross-sectional study and no longitudinal studies were performed. The causal relationship between the function of FPM and pain has not been clarified because the measurement was performed cross-sectionally. Prospective research is required to examine how pain changes because of changes in FPM function. In the future, it may be possible to clarify the relationship between FPM function and pain by observing longitudinal changes in FPM function.

## Conclusion

The ulnohumeral joint space distance on the dominant side was wide in both the Healthy group and the UCL injury group.

In this study, the ST was located lateral relative to the distal-medial corner of the trochlea in the injury group during contraction of the FCR, FCU, and PT. Therefore, it suggests that dysfunction of the FCR, FCU, and PT in the UCL injury group may be associated with pain. Additional research is needed to further clarify these results.

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## Disclaimer

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