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# Flexor pronator muscles' contribution to elbow joint valgus stability: ultrasonographic analysis in high school pitchers with and without symptoms

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A R T I C L E I N F O

*Keywords:*
Baseball
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*Level of evidence:* Basic Science Study; Kinesiology

**Background:** Few researchers have examined the different contributions of flexor-pronator muscles to valgus stress in high school baseball pitchers with and without elbow symptoms. This study used ultrasonography to assess these muscles' dynamic contributions to elbow valgus joint stability in high school pitchers.

**Methods:** A self-administered questionnaire on throwing-related elbow joint pain sustained during the prior year was completed by 89 high school baseball pitchers. Gravity stress ultrasonographic elbow examinations with 30° of flexion were done before and after isometric contraction of the flexor-pronator muscles. For study participants with and without a history of elbow symptoms, we compared differences of ulnohumeral joint space without gravity stress and isometric contraction of the flexor-pronator muscles and with gravity stress only and with isometric contraction of the flexor-pronator muscles under gravity stress.

**Results:** For each pitcher, the ulnohumeral joint space in the condition with valgus stress was significantly larger than in the condition without valgus stress. Also, the ulnohumeral joint space in the condition with valgus stress was significantly larger than in the condition with valgus stress and flexor-pronator isometric muscle contraction. Participants with and without elbow symptom history showed no differences of ulnohumeral joint space in the unloaded and loaded flexor-pronator muscle contracted conditions.

**Conclusion:** Ultrasonographic assessment demonstrated that flexor-pronator muscles contribute to elbow valgus stability. No difference was found in the flexor-pronator muscle contribution in high school baseball pitchers with and without elbow symptom history.



Active constraint of the flexor-pronator muscles contributes to dynamic valgus stability at the elbow.[4,7–9,12,13,15–17,23] An earlier anatomic study demonstrated that flexor-pronator muscles converge to the anterior bundle of the ulnar collateral ligament (UCL) and that they are assisted by sharing of static and dynamic forces related to the medial elbow joint.[15] Biomechanics researchers have examined which of the flexor-pronator muscles contribute best to valgus stability of the elbow.[12,17,23] Furthermore, several reports of the relevant literature have described in vivo contributions of the flexor-pronator muscles to valgus stability of the elbow. Reportedly, active contraction of the flexor carpi radialis muscle and pronator teres (PT) muscles, the flexor digitorum superficialis (FDS) muscle, and flexor digitorum profundus (FDP) muscle contributes to dynamic stabilization of elbow joints against

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valgus stress in healthy volunteers.[16,19] Nevertheless, little is known about flexor-pronator muscle functions for stabilization against valgus stress in baseball pitchers with elbow symptoms.

The aim of this ultrasonography (US)-based study[14,20] was to assess differences of the medial elbow joint space at rest, under valgus stress, and under valgus stress with flexor-pronator muscle (flexor carpi ulnaris [FCU], FDS, FDP, and PT) contraction in high school baseball pitchers with and without elbow symptoms.

## Materials and methods

In February 2017, this study examined 89 pitchers (15-17 years old, mean age 16.5 years), all of whom participated voluntarily after recruitment from local high schools, to assess their physical condition during the winter off-season. They had played baseball for an average of 9.2 years (range 6-12 years). Each participant had a minimum of 3 years of experience competing in organized baseball as a starting pitcher. They underwent physical examinations of bilateral elbows and completed a self-administered questionnaire with items related to the throwing side and the history of throwing-related elbow joint pain sustained during the prior year.

They reported their self-satisfaction scores for throwing. The score reflects their self-assessment of ball control, ball speed, and throwing condition. For this study, we defined elbow joint pain as any condition, caused directly by throwing, that results in participation loss. Elbow measurements were recorded during preseason winter training medical checkups. The elbow range of motion was measured with the participant sitting with the shoulder in 90° of flexion and the forearm in full supination. The fulcrum of the goniometer was placed over the lateral epicondyle of the humerus. We positioned one arm of the device in the center of the humerus to the tip of the acromion process and positioned the other arm in the center of the radius to the radial styloid process. We established intrarater validity and goniometer reliability.[21]

### *Milking maneuver test*

We assessed the milking maneuver to evaluate the UCL. The examiner supinated the forearm of a participant fully and flexed the elbow of the participant beyond 90°. The thumb was then pulled laterally by the examiner to produce a valgus force on the elbow. Maneuver test—positive was defined as subjective pain, instability, or apprehension of the elbow.[18]

### *Grip strength test*

A digital dynamometer (Takei Scientific Instruments Co, Ltd, Tokyo, Japan) was used to measure the grip strength. Grip testing was done using a standardized position recommended by the American Society of Hand Therapists. Subjects were seated with the shoulder in adduction and neutral rotation, with the elbow flexed at 90°, the forearm in a neutral position, and the wrist between 0° and 30° of extension and 0° and 15° of ulnar deviation.[2]

### *US technique*

US examination of the elbow was done with participants in a supine position. We scanned the elbow at 30° of flexion (Fig. 1, *A*). Gravity stress was applied to the forearm straining the UCL (Fig. 1, *B*). We obtained images of UCLs with and without gravity stress on the bilateral side each time. We instructed the participants to produce isometric contraction of flexor-pronator muscles with gravity valgus stress. Finger full flexion with wrist ulnar flexion and isometric forearm pronation muscle contraction was performed with gravity valgus stress to the elbow (Fig. 1, *C* and *D*). The medial

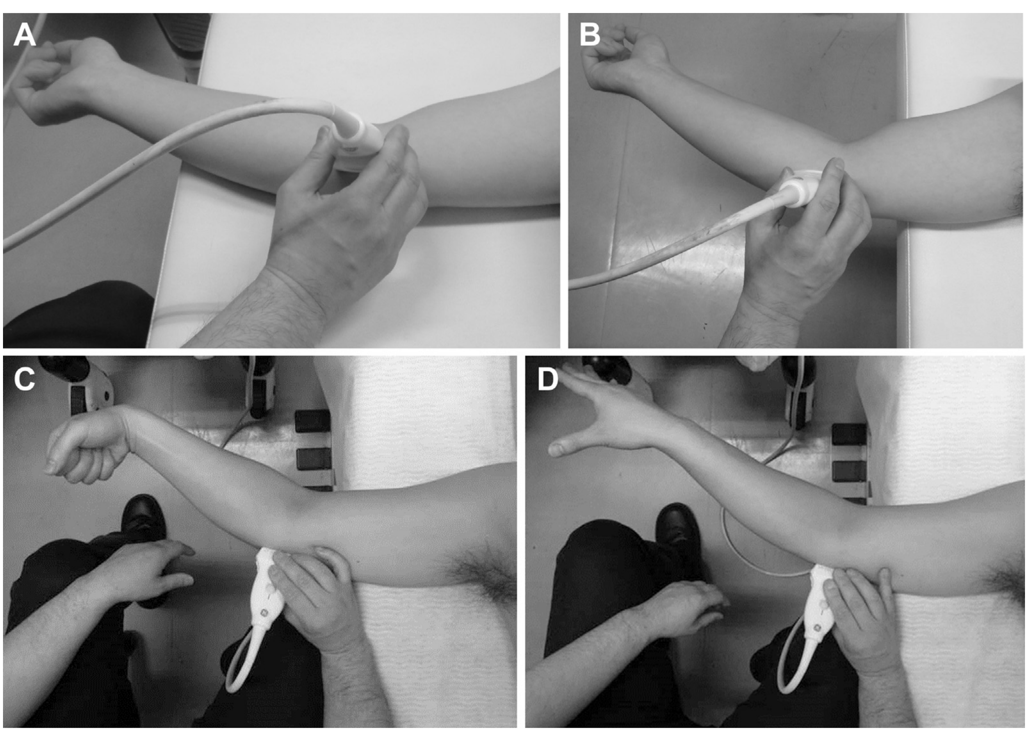


**Figure 1** (**A**) Supine subjects were scanned with the elbow at 30° of flexion without gravity stress. (**B**) Supine subjects were scanned with the elbow at 30° of flexion with gravity stress. (**C**) We instructed the participants to perform finger full flexion with wrist ulnar flexion. Subjects in a supine position were scanned with the elbow at 30° of flexion with isometric contraction of flexor digitorum superficialis and profundus muscle and flexor carpi ulnaris muscle under gravity stress. (**D**) We instructed the participants to perform forearm full pronation. Supine subjects were scanned with the elbow at 30° of flexion with isometric contraction of the pronator muscle under gravity stress.

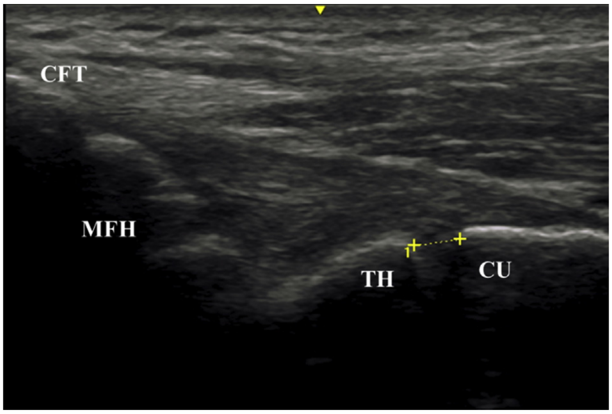


**Figure 2** We measured the ulnohumeral joint width at the level of the anterior band with and without valgus stress on the bilateral side. We defined the ulnohumeral joint space as the distance from the edge of the trochlea of the humerus to the edge of the coronoid process of the ulna. *CFT*, common flexor tendon; *MFH*, medial epicondyle of the humerus; *TH*, trochlea of the humerus; *CU*, coronoid process of the ulna.

elbow joint space was measured using US to assess the contribution of the flexor-pronation muscle contraction against gravity valgus stress under 4 distinct conditions: at rest, under gravity valgus stress only, with maximal grip contraction with wrist ulnar flexion contraction under gravity stress, and forearm pronation contraction under gravity stress on bilateral sides. We applied US imaging using a multifrequency 12-MHz linear-array transducer (LOGIQe; GE Healthcare, Chicago, IL, USA). Also, we used conventional 30° elbow flexion for US evaluation of the anterior band of the UCL by verifiable gravity valgus stress method.[22] This method was used by an orthopedic surgeon with 10 years of experience in musculoskeletal US; the surgeon was blinded to other items during evaluation. Using electronic calipers, the ulnohumeral joint width at the level of the anterior band was measured without gravity valgus stress on the bilateral side (Fig. 2). We defined the ulnohumeral joint space as the distance from the edge of the trochlea of the humerus to the edge of the coronoid process of the ulna. The width of the ulnohumeral joint with and without valgus stress and with valgus stress during production of isometric contraction of flexor-pronator muscles on the bilateral side was calculated. We had earlier established intrarater validity and the reliability of measuring the ulnohumeral joint space using electronic calipers.[22]

We stratified participants according to their respective histories of elbow pain, or lack thereof. Of all participants, 29 pitchers reported a history of elbow pain and 60 pitchers reported no history of elbow pain. We compared the difference between the width of ulnohumeral joint space without gravity valgus stress and with gravity stress during isometric contraction of the flexor-pronator muscles during throwing between the 2 groups (Elbow Pain Group vs. No Elbow Pain Group). All participants and their parents gave informed consent to participation in this study, which was approved by the institutional review board.

### *Statistical analysis*

Steel-Dwass testing was used to identify the width of ulnohumeral joint space changes in each pitcher under each elbow condition. Two groups were compared using either a Mann-Whitney *U* test or an independent *t* test for continuous variables: age, height, weight, body mass index, grip strength, elbow range of motion, and a pitching assessment score. Differences between the proportion of positivity and negativity of Milking maneuver test in the 2 groups were calculated using Fisher exact test. We compared differences of ulnohumeral joint space width without gravity stress and with gravity stress after isometric contraction of the flexor-pronator muscles. Data are presented as means and standard deviations. Results with a *P* value of less than .05 were inferred as statistically significant.

## Results

Physical characteristics of participants with and without elbow symptoms are presented in Table I. Comparison of the 2 groups revealed that flexion of the elbow in the Elbow Pain Group was decreased significantly on both the throwing and nonthrowing sides. A significant difference was also found between the 2 groups in terms of the proportion of positive milking maneuver test results. The US findings of 6 participants with a history of elbow pain indicated calcification along the UCL. We measured the ulnohumeral joint space width separately under 4 conditions: at rest, with gravity stress, with full finger flexion and wrist ulnar flexion under gravity stress, and with forearm pronation under gravity stress. Significant differences were found between results for horizontal distance obtained with gravity stress and with full finger

**Table I**
Physical characteristics of participants with and without elbow pain

| | Elbow pain (n=29) | No elbow pain (n=60) | *P* value |
|---|---|---|---|
| Age, yr | 16.5 ± 0.5 | 16.4 ± 0.5 | .77 |
| Height, cm | 171.8 ± 5.6 | 172.7 ± 6.1 | .32 |
| Weight, kg | 70.1 ± 7.9 | 67.5 ± 8.0 | .22 |
| Body mass index | 23.7 ± 2.2 | 22.6 ± 2.2 | .02 |
| Years of experience | 9.6 ± 1.8 | 9.1 ± 1.5 | .13 |
| Elbow range of motion | | | |
| Dominant elbow, degrees | | | |
| Extension | 2 ± 7 | 4 ± 5 | .24 |
| Flexion | 140 ± 5 | 143 ± 4 | .003 |
| Nondominant elbow (deg) | | | |
| Extension | 8 ± 5 | 7 ± 5 | .25 |
| Flexion | 143 ± 4 | 145± 4 | .02 |
| Dominant grip strength, kg | 38.4 ± 7.4 | 37.2 ± 5.3 | .42 |
| Nondominant grip strength, kg | 37.9 ± 5.7 | 37.5 ± 6.0 | .75 |
| Positivity or negativity in Milking maneuver test, n | | | |
| Positive | 8 | 1 | .0004 |
| Negative | 21 | 59 | |
| Pitching performance score | 62 ± 21 | 67 ± 17 | .22 |

Unless otherwise noted, values are means ± standard deviations.
Significance: $P < .05$.

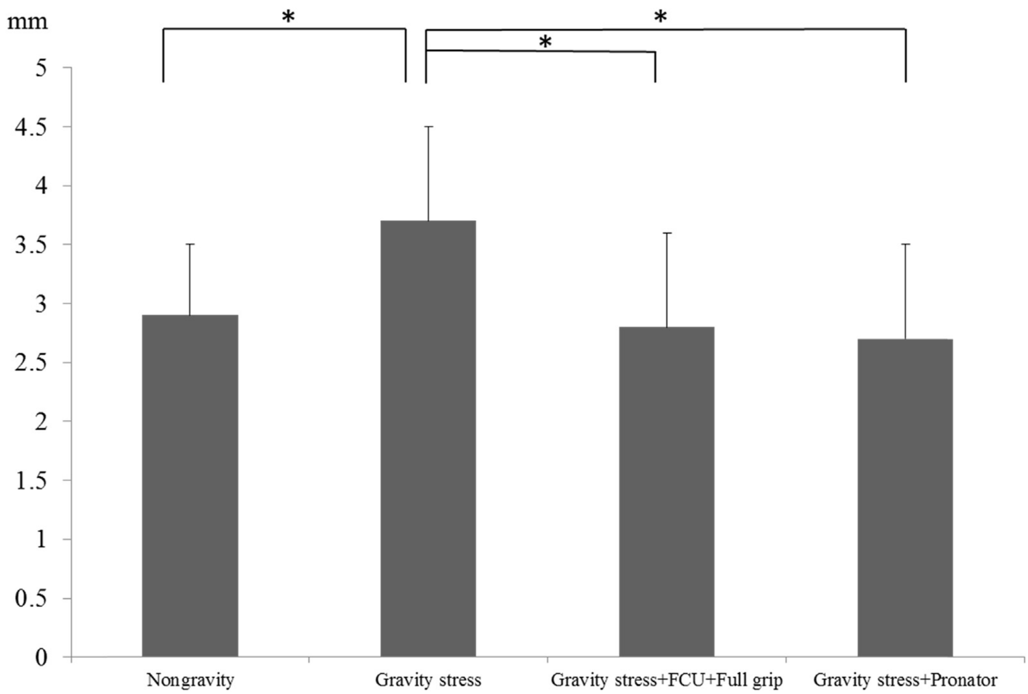


**Figure 3** Effects of isometric contraction of flexor-pronator muscles on gravity stress with 30° elbow flexion. *$P < .001$ compared to nongravity stress, finger full flexion with wrist ulnar flexion under gravity stress, and forearm pronation under gravity stress.

flexion and wrist ulnar flexion under gravity stress, and forearm pronation under gravity stress (with gravity stress, 3.7 ± 0.8 mm; with full finger flexion and wrist ulnar flexion under gravity stress, 2.8 ± 0.8 mm; with forearm pronation under gravity stress, 2.7 ± 0.8 mm, $P < .05$). However, no significant difference in horizontal distance was found between groups without gravity stress (at rest, 2.8±0.8 mm) and with full finger flexion and wrist ulnar flexion under gravity stress, with forearm pronation under gravity stress (Fig. 3).

No difference was found between the ulnohumeral joint space in the unloaded condition and the ulnohumeral joint space in the loaded–each contracted conditions. Moreover, none was found between participants with and without a history of elbow symptoms (Table II).

## Discussion

Distinguishing characteristics of our study include the fact that medial elbow joint space increases under gravity stress and then decreases when flexor-pronator muscle contraction is performed by high school baseball pitchers. Earlier studies revealed that the anterior band of the UCL is the primary elbow stabilizer of valgus stress during pitching,[1,5] and that the flexor-pronator muscles are put forward to act as secondary valgus support.[3,4,6–9,12,13,15–17,23] Davidson et al[6] reported, based on results of an anatomic study, that the FCU and FDS muscles are positioned to support valgus torque of the elbow. Otoshi et al[15] reported that PT muscle contraction might reinforce the anterior band of UCL to dynamic and static traction forces of the medial elbow joint as anatomic components of the elbow joint capsule structure. In an earlier biomechanical and cadaveric study, An et al[3] demonstrated by multiplying the moment arm of the muscle by its physiological cross-sectional area that the potential moment contribution to flexion-extension and varus-valgus rotation of the FDS is greatest in the elbow extended and flexed position with neutral forearm rotation. Park et al[17] loaded the FCU, FDS, and PT with 15 N to assess the flexor-pronator mass contribution to valgus stability in UCL-deficient elbows in cadavers. They reported that FCU provided greater reduction of the valgus angle than either FDS or PT.[17] Our study showed that each of FDS, FDP, and FCU combined isometric muscle contractions, and PT-muscle-only contractions decrease the ulnohumeral joint space under valgus gravity stress in high school baseball pitchers. No difference of decrease of ulnohumeral joint was found in these participants among FDS, FDP, and FCU combined isometric muscle contractions and PT-muscle-only contraction. These results suggest that PT muscle contraction against the valgus

**Table II**
Difference of the width of ulnohumeral joint space between at rest and with flexor-pronator muscle contraction under gravity stress

| | Elbow pain (n = 29) | No elbow pain (n = 60) | *P* value |
|---|---|---|---|
| Difference between the width of ulnohumeral joint space at rest and the width of ulnohumeral joint space under gravity stress, mm | 0.8 ± 0.5 | 0.9 ± 0.6 | .81 |
| Difference between the width of ulnohumeral joint space at rest and the width of ulnohumeral joint with a maximal grip contraction with wrist ulnar flexion under gravity stress, mm | −0.1 ± 0.6 | 0.1 ± 0.6 | .4 |
| Difference between the width of ulnohumeral joint space at rest and the width of ulnohumeral joint with forearm pronation under gravity stress, mm | −0.2 ± 0.6 | 0.0 ± 0.8 | .11 |

Values are means ± standard deviations.
Significance: $P < .05$.

load applied to the elbow might contribute to a greater degree than either FDS, FDP, or FCU.

A few earlier reports have described in vivo investigations of the contribution of flexor-pronator muscle contractions.[16,19] Otoshi et al[16] investigated 12 healthy adult men to ascertain whether active contraction of flexor-pronator muscles improves stabilization of the medial elbow joint against the manual valgus load. They used US to measure the medial elbow joint space. Their results showed that the PT and flexor carpi radialis function better as dynamic stabilizers against the valgus load than either FDS or FCU.[16] Pexa et al[19] used US to evaluate the contributions of flexor-pronator muscle contractions to valgus elbow stability to measure the medial elbow joint space at rest, under valgus stress, and under valgus stress with finger and forearm flexor contraction. For their study, they asked 22 healthy male participants to hold a handgrip dynamometer. Their findings indicate that wrist and finger flexor muscle contraction decreased the medial elbow joint space under a valgus load.[19] However, participants in earlier in vivo studies were all healthy volunteers, whereas those examined in our study were high school baseball pitchers.

Gripping a ball is a fundamental part of the throwing motion. Pitchers hold the ball with an adequate amount of finger force to throw, to prevent ball slippage, and to control various breaking balls.[10] One earlier biomechanical study[11] revealed that pitchers can alter pronation acceleration at the time of ball release to manipulate the magnitude of vertical ball movement. To improve UCL injury prevention, it is meaningful to investigate the association between activation of the flexor-pronator muscles and medial elbow joint instability in baseball pitchers who drive these muscles to throw pitches of various types.

Electromyographic studies have shown that pitchers with symptomatic valgus instability have decreased flexor-pronator muscle activity in pitching motion, which suggests a contribution of dynamic muscle instability to elbow valgus force.[8] The flexor-pronator muscle dysfunction might be associated with clinical symptoms of instability and pain in baseball pitchers experiencing repetitive elbow valgus stress. We stratified participants according to their respective histories of elbow pain, or lack thereof. Then we compared differences between the 2 groups in terms of the width of ulnohumeral joint space without gravity valgus stress and with gravity stress during isometric contraction of the flexor-pronator muscles of throwing. Our results indicate no difference between participants with and without an elbow symptom history for the ulnohumeral joint space in the unloaded condition and the ulnohumeral joint space in the loaded—each contracted condition. Elbow pain, as defined in this study, is not necessarily medial joint pain. However, the pitchers who tested positive in the milking maneuver test in the Elbow Pain Group were significantly more numerous than those in the No Elbow Pain Group. Our definition of elbow pain might affect this result.

Our study has several limitations. First, we defined the elbow symptoms of participants as a condition caused directly by throwing and which caused participation loss during the prior year. Furthermore, we did not confine elbow symptoms solely to medial elbow pain and did not assess the elbow symptom severity. This definition of elbow pain might not have produced significant results for the width of the stressed ulnohumeral joint space. Second, we were unable to confirm the exact pathology of elbow pain objectively because results were based on responses to the questionnaire survey and findings obtained from physical examination and US. Third, we have not compared US measurements of ulnohumeral joint space to the reference standard for ulnohumeral joint space of nonstress and stress radiography. Fourth, we were unable to assess the effects of isometric FDS muscle contraction, FDP muscle contraction, and FCU muscle contraction on elbow valgus stability independently. However, the motion of finger flexion under wrist ulnar flexion is apparently based on wrist and forearm actions during pitching motions. We evaluated the flexor-pronator muscle contraction effects on elbow valgus instability under these conditions based on the pitching motion. Further studies should be undertaken for in vivo assessment of the actions as stabilizers against the elbow valgus load during pitching motions.

## Conclusion

Our results indicate that the flexor-pronator muscle contractions decreased the width of the ulnohumeral joint under valgus gravity load in 89 high school baseball pitchers.

In addition, PT muscle contraction against the valgus load applied to the elbow might contribute to a greater degree than either FDS, FDP, or FCU. However, no difference was found in the roles of the flexor-pronator muscle contribution in high school baseball pitchers with and without history of elbow symptoms. Further studies must be undertaken to assess the association between the pathology-caused medial elbow subjective symptoms and the potential for contributions of flexor-pronator muscles in baseball pitchers.

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