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Youth throwing athletes do not show bilateral differences in medial elbow width or flexor tendon thickness

Rudolph M. Morrow, Gary E. McIlvian, Jenifer Johnson, Mark K. Timmons

School of Kinesiology, Marshall University, Huntington, WV, USA

Background: Medial elbow laxity develops in throwing athletes due to valgus forces. Medial elbow instability in professional, collegiate, and high school athletes is well documented; however, the medial elbow of young throwing athletes has received less attention. This study investigated the medial elbow and common flexor tendon during applied elbow valgus stress of youth baseball players.
Methods: The study included 15 participants. The medial elbow width and thickness of the common flexor tendon were measured on ultrasound images.
Results: No significant side differences in medial elbow width or common flexor tendon were found at rest or under applied valgus stress. At rest, the medial elbow joint width was 3.34±0.94 mm on the dominant side and 3.42±0.86 mm on the non-dominant side. The dominant side increased to 3.83±1.02 mm with applied valgus stress, and the non-dominant side increased to 3.96±1.04 mm. The mean flexor tendon thickness was 3.89±0.63 mm on the dominant side and 4.02±0.70 mm on the non-dominant side.
Conclusions: These findings differ from similar studies in older throwing athletes, likely because of the lack of accumulated stress on the medial elbow of youth throwing athletes. Maintaining elbow stability in young throwing athletes is a vital step to preventing injury later in their careers.

Keywords: Ulnar collateral ligament; Youth injury; Athletic injury; Elbow

INTRODUCTION

Injuries to the medial elbow are common in overhead sports [1-3]. Injury to the ulnar collateral ligament (UCL) appears most common in overhead throwing athletes, with a lower prevalence in wrestlers, tennis players, javelin throwers, and football players [1]. Conte et al. [4] reported that an estimated 18% of relief pitchers in professional baseball have a history of UCL reconstruction. A study conducted over 5 years by the National Collegiate Athletic Association found 1936 UCL injuries occurred in collegiate baseball; 55% of these elbow injuries resulted in lost playing time, and 15% were season-ending [2]. Up to 74% of youth baseball players ages 8–18 report participating in their sport with some level of arm pain [5]. The same study reported 23% of youth baseball players to have a history of arm injury consistent with overuse [5]. Pytiak et al. [6] studied the elbow of the throwing arms in Little League Baseball players before and after a season of play to identify risk factors for pain. However, limited information is available on the stability of the medial elbow in youth throwing athletes.

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Correspondence to: Mark K. Timmons
School of Kinesiology, Marshall University, Gullickson Hall 109, 1 John Marshall Drive Huntington, WV 25755, USA
Tel: +1-810-333-1877, E-mail: timmonsm@marshall.edu, ORCID: https://orcid.org/0000-0002-6387-9521

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Injuries to the UCL occur due to the repetitive microtrauma experienced during overhead throwing [7]. Elbow stability is maintained by ligamentous static stabilization and muscular dynamic stabilization [8]. Damage to the stabilizing structures, especially the UCL, can cause instability or increase the medial joint space [1,7]. Fatigue of the dynamic stabilizers such as the wrist flexor muscle group can decrease overall stability and increase the medial joint space [8,9]. The repetitive stress of throwing begins to fatigue the flexor muscles and stretch the UCL, increasing medial elbow instability [7]. Nazarian et al. [10] reported a greater widening of the medial elbow joint space while placed under valgus stress in the throwing arm than in the non-throwing arm of healthy professional baseball pitchers. Glousman et al. [11] reported that pitchers with UCL injuries demonstrated decreased wrist flexor activity. Millard et al. [9] showed that fatigue of the wrist flexors might lead to an increase in medial elbow joint space. These differences have been found in professional and collegiate baseball players, though studies on youth athletes have not been reported [2,4,10,12,13]. The prevalence of UCL injury is higher in professional baseball players than collegiate baseball players [2,4]. As players age, elbow injury becomes more likely due to the stress placed on the UCL over time. Because these adaptations of the elbow develop over time, coaches and healthcare providers could intervene with preventative measures at the point when the elbow adaptation begins.

The purpose of the current study was to characterize the differences in the width of the medial elbow joint space and the thickness of the common flexor tendon between dominant and non-dominant arms in youth throwing athletes. Specifically, the hypothesis was that the medial elbow joint space is wider and the common flexor tendon is thicker on the dominant side when compared to the non-dominant side of youth throwing athletes.

METHODS

The Institutional Review Board of Marshall University approved this study (IRBNET # 1566840-1). All participants provided written informed assent and the participant's parent provided parental consent before participation.

Participants

Fifteen (14 male, 1 female) youth baseball players were included in the investigation. Descriptive data for all participants are found in Table 1. Thirteen participants were ages 10–13, while the remaining two were ages 6–7. All of the subjects were right-hand dominant. The study inclusion criteria included (1) active in organized youth baseball or softball, (2) under 18 years old, and (3) able to sit still for up to 5 minutes. In addition, participants were excluded from the investigation if the participant reported: (1) shoulder or elbow pain during or after throwing greater than 7 out of 10 on a numerical pain scale, (2) a history of shoulder or elbow surgery, (3) a history of an arm, rib, or shoulder fracture within the past year, or (4) greater than 50% loss of range of motion in the shoulder or elbow.

Table 1. Demographic characteristics

Variable	Mean ± SD
Age (yr)	10.5 ± 3.15
Participation (yr)	5.2 ± 3.3
Weight (kg)	48.7 ± 18.8
Height (cm)	149.2 ± 20.4
Dominate side strength	
Shoulder IR (kg)	21.7 ± 4.8
Shoulder ER (kg)	44.5 ± 6.1
Shoulder abduction (kg)	17.3 ± 8.6
Grip strength (kg)	10.8 ± 3.8
Non-dominate side strength	
Shoulder IR (kg)	17.2 ± 6.1
Shoulder ER (kg)	40.8 ± 6.9
Shoulder abduction (kg)	16.8 ± 7.6
Grip strength (kg)	11.9 ± 2.9

SD: standard deviation, IR: internal rotation, ER: external rotation.

Protocol

The participant's maximal voluntary isometric contraction (MVIC) strength was measured for internal shoulder rotation, external shoulder rotation, wrist extension, and grip strength using a hand-held dynamometer. The same investigator collected all ultrasound images, and a second investigator made all measurements of the medial elbow joint space and tendon thickness. The ultrasound images of the medial elbow joint space were taken as described by Ciccotti et al. [14] and DeMoss et al. [15]. The participant laid supine with their shoulder abducted to 90° and elbow flexed to 30°. The researchers measured the width of the medial elbow joint space in the unstressed condition and again during a valgus stress test. Then, measurements of the common flexor tendon thickness were collected. Each measurement was collected twice. This procedure was then repeated on the contralateral side. The order in which the sides were tested was randomized.

The investigators used a Mindray m5 US unit (Mindray Ltd. and National Ultrasound Inc., Duluth, GA, USA) with an adjustable 8.0–12.0 MHz frequency transducer. Measurements of force were made using a hand-held dynamometer (microFET2; Hoggan Scientific LLC, Salt Lake City, UT, USA). Grip strength was assessed using a Jamar Hand Dynamometer (Lafayette Instruments, Lafayette, IN, USA).

Procedures

Manual muscle strength

Assessment of shoulder girdle muscle strength was performed using techniques described by Kendall et al. [16]. Muscle strength was measured using hand-held dynamometry. Investigators measured each participant's grip strength in both arms with the hand-held dynameter set at position two. Each strength measurement was made twice, with a minimum 60-second rest given between each measurement; the mean of the two measures (Table 1) was used for analysis [17,18].

Ultrasound imaging

The elbow images were collected with and without an elbow valgus stress test (Fig. 1). In addition, ultrasound images of the common flexor tendon were also collected. The ultrasound probe was oriented along the long axis of the UCL to view the medial elbow joint space, using the trochlea of the humerus and the sublime tubercle of the ulna as landmarks [14]. The medial elbow joint space width was defined as the distance between the trochlea of the humerus and the coronoid process of the ulna [14].

Pilot testing completed in preparation for the current investigation revealed moderate to excellent reliability for measuring the width of the medial elbow joint space and common flexor tendon thickness. For the unstressed measurement, the intraclass correlation coefficient (ICC) was 0.97 and 0.82 for the dominant and non-dominant sides, respectively. The ICC for the stressed measure was 0.74 and 0.71 for the dominant and non-dominant sides, respectively. The ICC for tendon thickness was 0.67 and 0.90 for the dominant and non-dominant sides, respectively. The minimal detectable change for the unstressed elbow, stressed elbow, and tendon thickness was 0.08 mm, 0.26 mm, and 0.37 mm, respectively. The standard error was 0.06 mm, 0.18 mm, and 0.26 mm, respectively.

Data Analysis

The investigation used IBM SPSS ver. 21 (IBM Corp., Armonk, NY, USA) for all statistical analysis. Paired t-tests were used to determine the side-to-side differences in the width of the joint space. Statistical significance was determined at $p < 0.05$.

RESULTS

The results for width of the medial elbow joint space and common flexor tendon thickness are presented in Table 2. The mean width of the medial elbow joint space of the dominant side was 3.34 ± 0.94 mm (mean ± standard deviation) in the unstressed position and 3.83 ± 1.02 mm with the applied valgus stress. The mean joint widths for the non-dominant side were 3.42 ± 0.86 mm in the unstressed position and 3.96 ± 1.04 mm with the applied valgus stress. The increase in the width of the medial elbow joint space during the valgus stress reached statistical significance on both the dominant (mean difference, 0.49 mm; $t = -6/274$, $1\text{-}\beta = 0.997$, $p < 0.001$) and non-dominant (mean difference, 0.54 mm; $t = -4.141$, $1\text{-}\beta = 0.997$, $p = 0.001$) sides. The mean flexor tendon thickness was 3.89 ± 0.63 mm on the dominant side and 4.02 ± 0.70 mm on the non-dominant side; this difference did not reach statistical significance ($p > 0.05$).

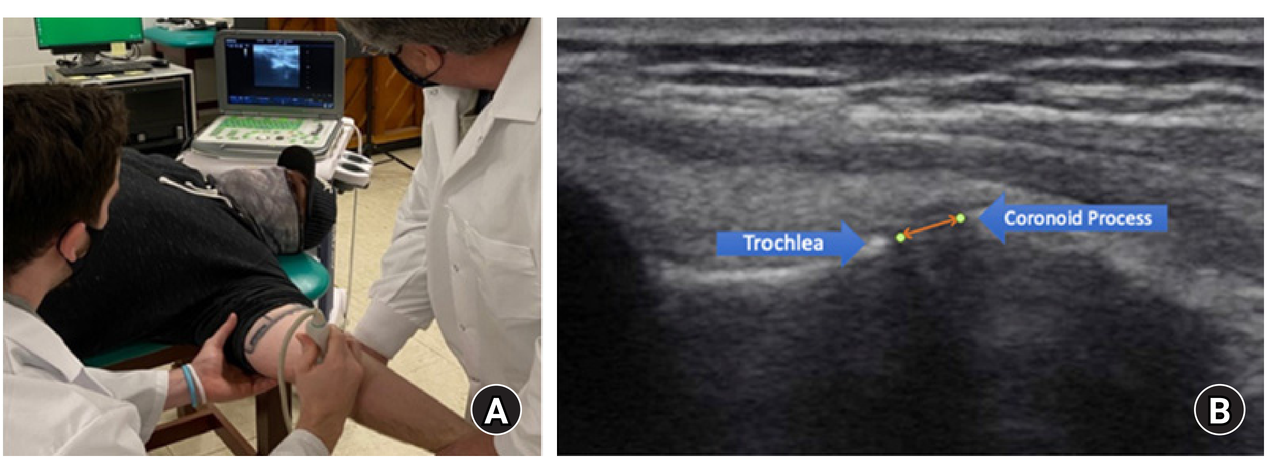

Fig. 1. Ultrasound testing position and ultrasound image of the medial elbow. Test subject positioning during ultrasound imaging (A) and an ultrasound image of the medial elbow joint with labels signifying the trochlea and the coronoid process (B).

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Table 2. Medial elbow joint width and common flexor tendon thickness

Measurment	All participants		Older participant		Younger participant	
	Dominate	Non-dominate	Dominate	Non-dominate	Dominate	Non-dominate
Joint width (mm)						
No stress	3.34 ± 0.94	3.42 ± 0.86	3.39 ± 0.91	3.43 ± 0.78	3.02 ± 1.52	3.37 ± 1.73
Stress	3.83 ± 1.02*	3.96 ± 1.04*	3.86 ± 0.99*	3.99 ± 1.06*	3.67 ± 1.73	3.80 ± 1.27
Common flexor tendon (mm)	3.89 ± 0.63	4.02 ± 0.70	3.99 ± 0.52	4.1 ± 0.57	3.25 ± 1.20	3.17 ± 1.09

Values are presented as mean ± standard deviation. The width of the medial elbow with and without valgus stress measured on ultrasound images presented along with the thickness of the common flexor tendon.
*Statistically greater than no stress condition, $p < 0.05$.

In older subjects (age 10–13 years), the mean width of the medial elbow joint space on the dominant side was 3.39 ± 0.91 mm and 3.86 ± 0.99 mm (unstressed and valgus-stressed, respectively). The mean width of the medial elbow joint space on the non-dominant side was 3.43 ± 0.78 mm, 3.99 ± 1.06 mm (unstressed and valgus-stressed respectively), demonstrating a non-statistically significant difference in joint space width between the dominant and non-dominant side elbow under valgus stress ($t = -1.947$, $1-\beta = .997$, $p = 0.075$). There was a significant increase in joint space (mean difference, 0.46 ± 0.31 mm; $t = -5.358$, $1-\beta = 0.750$, $p < 0.001$) with the applied valgus stress on the dominant side. There was a similar increase (0.55 ± 0.52 mm, $t = -3.818$, $p < 0.01$) seen on the non-dominant side. The mean flexor tendon difference between the dominant and non-dominant sides was statistically significant (–0.16 ± 0.24 mm, $t = -2.419$, $p = 0.03$)

In the younger subjects (age 6–7 years), the mean width of the medial elbow joint space on the dominant side was 3.02 ± 1.52 mm and 3.67 ± 1.73 mm (unstressed and valgus-stressed, respectively). The mean joint space width on the non-dominant side was 3.37 ± 1.73 mm, 3.80 ± 1.27 mm (unstressed and valgus-stressed respectively), demonstrating no statistically significant difference in joint space width between the dominant and non-dominant sides under valgus stress ($t = 0.42$, $p = 0.67$). There was a non-significant increase in the width of the joint space (mean difference, 0.65 ± 0.21 mm; $t = 4.333$, $p = 0.144$) with the applied valgus stress on the dominant side. There was a similar increase (0.42 ± 0.45 mm, $t = 1.308$, $p = 0.416$) seen on the non-dominant side. The mean flexor tendon difference between the dominant and non-dominant sides was –0.35 mm ± 0.07 mm ($t = 2.333$, $p = 0.258$).

DISCUSSION

This study aimed to characterize differences in the width of the medial elbow joint space between the dominant and non-dominant arms and the common flexor tendon thickness in youth throwing athletes. However, there was no significant difference between dominant and non-dominant arms. Therefore, our results did not support our hypotheses. In addition, we observed no difference in the width of the medial elbow joint space in the resting position between dominant and non-dominant arms. Both findings contrast with similar studies conducted in older throwing athletes.

The absence of a side-to-side difference can be attributed to the subjects' relative lack of exposure to medial elbow stress. The specific adaptations in question are thought to be due to accumulated stress over long periods [7]. The participants in the current study are relatively new to their sport (mean duration of participation, 5.17 ± 3.31 years) and to overhead throwing. An increased medial elbow joint width has been documented in professional baseball [10,14], collegiate [2], and high school level baseball athletes [19-21]. The absence of a difference between elbow joint space width in the youth baseball athletes could be attributed to the subjects' overall inexperience with throwing sports. The youth throwing athletes have not developed the medial elbow instability found in older throwing athletes.

Tajika et al. [19] and Sakata et al. [22] examined the elbows in youth throwing athletes via ultrasonography. Both studies reported finding osteochondritis dissecans and epicondylar apophysis (little leaguer's elbow) in youth throwers. However, neither paper reported changes in medial elbow joint space width. Little leaguer's elbow and osteochondritis dissecans are common in youth throwing athletes—much more than medial elbow instability [19,22]. The prevalence of these abnormalities could result from the forces generated during the throwing motion being distributed to anatomical structures other than the UCL in the young elbow, such as immature epiphysial plates, resulting in the literature's abnormalities.

Hattori et al. [21] measured the dominant arm's medial elbow joint space width in high school baseball players, using the same method as the present study. Hattori et al.'s study [21] showed that with the applied valgus stress on the medial elbow, the average width measurement was 5.6 ± 0.9 mm, compared to our 3.83 ± 1.03 mm [21]. The wider joint space width measured by

Hattori et al. [21] could be due to the average age of their participants being 16.6 years old with an average of 8.8 years of baseball experience. Our participants were much younger with significantly less baseball experience. The wider joint space found in Hattori's sample [21] may result from accumulated stress due to those athletes having greater playing experience than the athletes in our sample.

Keller et al. [23] conducted a similar study measuring the width of the medial elbow joint space and UCL thickness of high school pitchers before and after a competition season. The average joint width was 3.1 ± 0.7 mm in the unloaded position and 3.9 ± 1.0 mm with the applied valgus load during the pre-season [23]. The given results show a slightly smaller medial elbow gapping than our sample's data, which is unexpected. In addition, the participants in the Keller et al.'s study [23] had an average age of 16.9 years, compared to the average age being 10.5 years in the present study. This difference may be attributed to the measurement protocol used in their research. Keller et al. [23] measured the subjects sitting upright in a chair with their shoulder in maximum external rotation and elbow flexed to 30º. The measurements in our study were taken with the participant lying supine with their elbow flexed to 30º. Subjects in the supine position may relax more than subjects in a seated position, allowing for greater valgus movement in the medial elbow with added stress.

Tajika et al. [20] measured the medial elbow joint space during a valgus stress test of 132 high school baseball pitchers (age 15–17 years). Like the present study, the authors found a significant increase in the joint space width with applied valgus stress. Consistent with the current research, Tajika et al. [20] did not report side differences in the medial joint space width. Also like the present study, the side-to-side difference during the valgus stress test was not statistically significant. Sasaki et al. [13] used ultrasound to examine elbow laxity in 30 collegiate baseball players (average age, 21.7 years). Using ultrasound to view the medial elbow under gravity-valgus stress, they observed a significant increase in joint space width on the dominant side (2.7 ± 1.4 mm) compared to the contralateral side (1.6 ± 1.4 mm) [13]. These results show that an increase in medial elbow joint space can be observed in collegiate baseball players, most likely due to the longer time spent participating in the sport than youth players. However, their results were smaller in magnitude than the results of our study, meaning the joint space width observed in their collegiate sample was smaller than the width observed in our youth sample. This could be due to the method used by Sasaki et al. [13], where the subject was in a supine position with their elbow at 90° flexion. The authors reasoned that the 90° flexed position more accurately emulated the positioning of the elbow during the throwing motion [13]. However, this examination position is not commonly used among researchers and clinicians and may affect the results of their measurements. As the elbow flexes, the ulna's sublime tubercle comes closer to the humerus' trochlea, resulting in a shorter distance between the landmarks. Positioning the elbow in 90° flexion results in the medial joint space appearing smaller than when measured with the elbow at 30° flexion, like in the present study.

Ellenbecker et al. [24] reported a statistically significant increase of 0.32 mm in the width of the medial joint space on the dominant side compared to the non-dominant side with valgus stress applied in professional baseball pitchers. While statistically significant, this minor increase would be unidentifiable using manual orthopedic laxity tests. These results oppose those of other authors who examined the elbow joint space width of professional baseball players, such as Nazarian et al. [10], who observed increased laxity on pitchers' dominant arms. The use of stress radiography compared to dynamic ultrasound to measure medial elbow joint space could be the source of the discrepancies in the results. Typically, a 0.5 mm difference seen using stress radiography is used to differentiate between injured and uninjured conditions regarding medial elbow laxity [24]. The current study reported a mean increase of 0.34 mm in width of the medial joint space, which, considering the sample population was uninjured athletes, falls within and supports the use of the 0.5 mm designation for injured patient populations [24].

There was no difference in thickness of the flexor tendon between dominant and non-dominant arms in the current study. According to a study by Pexa et al. [25], the wrist flexor muscles play a role in maintaining elbow stability when a valgus force is applied to the medial elbow. The contraction of these muscles creates a varus moment, decreasing the width of the medial joint space. This stabilizing force acts against the valgus force applied during the throwing motion's acceleration phase. Therefore, it would be expected for an experienced baseball pitcher to see an increase in the thickness of the flexor tendon as an adaptation to repetitive loads. However, our results do not support such findings. This may be credited to the inexperience of our sample population. Our subjects have not participated in throwing sports for enough time to accumulate that repetitive load. Therefore, the younger throwing athletes do not exhibit the adaptations seen in older throwing athletes.

The current study supports the theory that increased laxity of the dominant elbow in throwing athletes directly correlates with the amount of time an individual has spent participating in throwing sports. Tajika et al. [19] identified multiple risk factors for elbow pain in youth throwers, including age > 11 years and

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height >150 cm (~5 ft). Sakata et al. [22] also identified increased age as a risk factor for developing elbow pain, in addition to the position one plays; pitchers have a higher risk for elbow pain than non-pitchers. Pytiak et al. [6] documented that youth athletes who participate in year-round baseball also have a higher risk of developing medial elbow abnormalities such as little leaguer's elbow. These risk factors support the theory that repetitive stress applied to the UCL and the medial elbow results in adaptations to these structures that predispose athletes to injury later in their careers.

Hattori et al. [21] reported medial joint space width measured in high school-aged pitchers during and after a pitching protocol of 100 pitches. The authors [21] reported increased joint space width as more pitches were thrown: 6.0 mm after 20 pitches, 6.2 mm after 40, 6.4 mm after 60, 6.7 mm after 80, and 7.0 mm after 100. These results exhibit the effect that fatigue and acute stress have on the stability of the medial elbow. It is important to consider how long these acute changes take to resolve. Khalil et al. [26] measured elbow joint space in the throwing arms of 11 collegiate pitchers after a season of play and then again prior to the upcoming season. The authors [26] found that both UCL thickness and medial elbow joint space increased after a season of play compared to pre-season baselines. However, after the off-season rest period, both measures returned to the pre-season baseline [26]. Furthermore, Millard et al. [9] found that the medial elbow exhibited increased laxity during a valgus stress test when the wrist flexor muscles were fatigued. Combining the results of these studies with the knowledge that increased elbow laxity increases the risk of an acute elbow injury, we can support the implementation of injury prevention strategies in youth baseball, such as pitching limits.

There were several limitations to the current investigation. First, our sample of convenience of 14 youth throwers limits the application of our results. The pilot data we gathered previously determined that with 25 subjects, our measures' reliability would be moderate and would have a standard error of 0.2 mm and a minimal detectable change of 0.16 mm. With only 14 participants, those values are expected to be higher, making it more difficult to apply our findings to the general population of youth throwing athletes. Secondly, our sample population was relatively heterogeneous in that they had different levels of experience in throwing sports, a wide age range, and a wide range of height/weight. These disparities further complicate the applicability of our results to larger populations.

Bilateral ultrasound evaluation of the medial elbow joint space width and flexor tendon thickness in youth throwing athletes revealed non-significant differences between the dominant and non-dominant arms with and without applied valgus stress. The study also found no difference in the thickness of the flexor tendon between the dominant and non-dominant sides. The authors expected this lack of side-to-side differences as youth throwing athletes have less exposure to the throwing motion and experience lower valgus forces during the acceleration phase. The current study results underscore the importance of coaches and healthcare providers closely monitoring injury prevention measures for young throwing athletes. Further research that includes more subjects is needed to generalize these results to youth throwing athlete populations. Following these athletes yearly may provide a more precise timeline for when adaptations to throwing begin to develop in the life cycle of throwing athletes.

ORCID

Gary E. McIlvian https://orcid.org/0000-0002-8533-3087
Mark K. Timmons https://orcid.org/0000-0002-6387-9521

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