The Effects of Elbow Bracing on Medial Elbow Joint Space Gapping Associated With Repetitive Throwing in High School Baseball Players

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Background: Throwing athletes risk medial elbow injury from extreme valgus stress generated across the medial elbow during throwing. Braces have been developed to protect the elbow joint; however, no previous study has investigated the effects of elbow bracing on medial elbow joint space gapping associated with repetitive throwing.

Hypothesis/Purpose: The purpose of this study was to investigate the effects of elbow bracing on medial elbow joint space gapping during repetitive throwing. Our hypothesis was that an elbow brace may reduce mechanical stress on the elbow by reducing medial elbow joint space gapping.

Study Design: Controlled laboratory study.

Methods: Twenty-five high school baseball players participated in this study. Each subject pitched 100 times under 2 conditions: control (without elbow brace) and elbow brace. The ulnohumeral joint space was measured ultrasonically before pitching and after every block of 20 pitches. Measurement of the ulnohumeral joint space was carried out using ultrasound with the forearm hanging by the side. Two-way repeated-measures analysis of variance and post hoc tests were used to compare ulnohumeral joint space with repeated pitching and between the elbow brace and control conditions.

Results: In the control condition, ulnohumeral joint space after 60 pitches was significantly greater than that before pitching ($P < .01$). In contrast, in the elbow brace condition, ulnohumeral joint space was not significantly different after repeated pitching. When comparing these 2 conditions, ulnohumeral joint space in the control condition was significantly greater than that in the elbow brace condition after 60 pitches ($P < .01$).

Conclusion: An elbow brace has the effect of preventing medial elbow joint space gapping with repeated throwing when determined ultrasonically by measuring the ulnohumeral joint space under gravity load.

Clinical Relevance: An elbow brace worn during baseball pitching practice may help reduce mechanical stress on the elbow by reducing medial elbow joint space gapping.

Keywords: elbow; elbow brace; medial elbow joint space gapping; baseball; ultrasound

Overhead throwing athletes risk medial elbow injury from extreme valgus stress generated across the elbow during the late cocking and acceleration phases of throwing.[10,12,13,42] Valgus moments during throwing have been estimated at 50 to 120 N·m[2,12,42] and are resisted primarily by the anterior bundle of the ulnar collateral ligament (UCL).[8,31,32] These moments may induce large tensile stress on medial soft tissues (eg, UCL) and large compressive stress on lateral hard tissues such as the radiocapitellar articulation.[13] Microtrauma from repetitive tensile stress overloading the ligament causes inflammation and microscopic tears in the ligament and can eventually lead to ligament attenuation or failure.[4,10,24]

In recent years, several studies have considered possible etiologies for elbow injury in baseball pitchers. For

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example, studies have investigated the effect of throwing on medial elbow joint space gapping using ultrasound imaging or radiography[5,7,11,17,34,38,39] and have assessed the relationship between pitching form and valgus load applied to the elbow joint using a 3-dimensional motion analysis system.[2,29,35,40] The results of these studies have been used to set individual pitch limits during a game.[25] These studies have also utilized elbow screening protocols,[18] but despite these efforts, elbow injury from baseball pitching remains a common occurrence.

Medial elbow joint space gapping and medial elbow injury have been reported among a wide variety of ages from Pony and Little League to collegiate pitchers in the United States and Japan.[1,15,28,39] Harada et al[18] reported that 45 of 108 young baseball players had elbow pain, and 28 players had abnormal bone fragments in the medial aspect of the elbows confirmed by ultrasonography. Meanwhile Hang et al[16] revealed that 52% of baseball pitchers had medial elbow pain, and 57% had separation of the medial epicondyle. Conte et al[9] also reported that in Major League Baseball, disability associated with elbow pain had a substantial impact on the team from lost competition days and associated economic costs. Because of the high prevalence of elbow injuries among baseball players, pitching limitations for adolescents have been set both in Japan and the United States.[22,25] Despite these limits, elbow injuries continue to occur in these countries. As the current countermeasures to prevent elbow injury are not completely effective, we sought to identify additional measures that might protect the elbows of young baseball players.

Previous studies have demonstrated asymmetrical and irreversible changes of medial elbow joint space gapping for a prolonged period of time in baseball pitchers.[5,7,11,17,34,38,39] Despite this evidence, no study has actually measured immediate changes in medial elbow joint space gapping associated with repetitive throwing. To protect the elbow joint during the throwing action, sports tape is sometimes applied in an attempt to prevent medial elbow joint space gapping and consequent damage to the medial elbow structures. Although taping has been shown to influence elbow joint motion,[41] there are drawbacks in that the protective effect is short lived, only lasting 10 to 30 minutes.[3,14] In addition, tape needs to be applied many times during training and games and is therefore expensive to use. As an alternative to taping, braces have been developed to protect the elbow joint during the throwing action. Braces have a better long-term effect than taping, with reduced expense,[23,36] and braces have had a positive effect in other elbow injuries.[21] As a result, braces have several advantages over tape; however, no previous study has investigated the effects of elbow bracing during the pitching action.

The purpose of our study was to investigate the effects of elbow bracing on medial elbow joint space gapping during a repetitive throwing task. If bracing can be shown to reduce medial elbow joint space gapping, it has the potential to reduce medial elbow joint stress during practice and games in adolescents.

TABLE 1
Descriptive Characteristics of the Sample (N = 25)

Measure	Mean	SD
Age, y	16.6	0.7
Height, cm	172.6	6.3
Weight, kg	66.1	7.1
Baseball experience, y	8.8	1.9

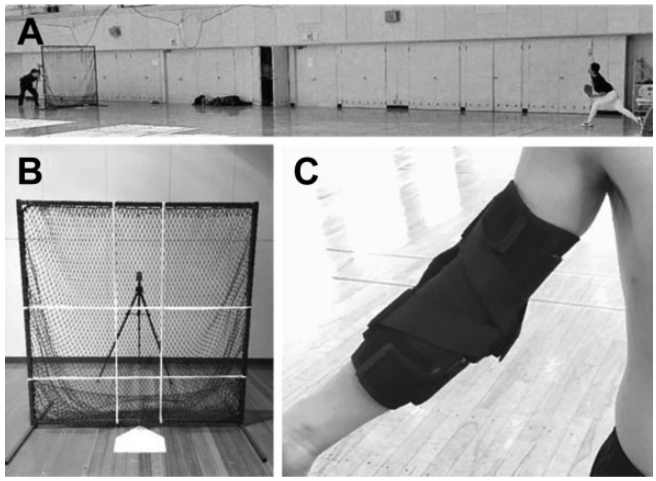

Figure 1. Pitching setup. (A) Throwing distance was the official pitching distance of 18.44 m. (B) A net and speed gun were placed behind home plate. White lines show the strike zone on the net. (C) An elbow brace with valgus suppression strap was used in the elbow brace condition.

METHODS

Participants

Twenty-five healthy high school baseball players volunteered to participate in this study. Participant characteristics are shown in Table 1. Participants were excluded from the study if (1) they had pain during the throwing action; (2) they had a history of orthopaedic shoulder, elbow, or hand surgery; or (3) they had pitched in the 24 hours prior to measurement. All participants agreed to sign an informed consent declaration. This study followed the Declaration of Helsinki and was approved by the Ethics Committee at the Saitama Medical University, Saitama, Japan (M-66).

Setup and Protocol

To standardize the throwing conditions, measurements were carried out indoors in a gymnasium. The throwing distance was the official standard pitching distance of 18.44 m (Figure 1A). A net (Uzawa Net Co, Ltd) was placed at the rear end of the home plate to collect the balls, and rubber on the net showed the strike zone for pitching. The high and low strike zone markers were set to a player height of 170.7 cm, which is the average height of the male

high school seniors that were shown in the 2015 School Health Survey by the Ministry of Education, Culture, Sports, Science and Technology.[30] A speed gun (SR3600; Sports Radar Co, Ltd) with increments set at 1.6 km/h was placed 1.5 m behind the home plate and 1.4 m above the floor using a tripod to measure ball velocity (Figure 1B). Participants wore a t-shirt, shoes with rubber soles, and a glove on the nonthrowing upper limb.

Measurement commenced after performing a preparation routine of stretching and warm-up throwing. The exercise program consisted of 100 fastballs (20 sets of 5 pitches at ball intervals of 15 seconds) at maximum effort from the set position toward the simulated strike zone. An official ball (weight range, 141.7-148.8 g; MIZUNO Co, Ltd) was used during this exercise program. We calculated mean ball velocity for the first 20 pitches, and any throws that were 70% less than this value were not included.

The experiment was a within-participant crossover design with elbow brace condition (pitching with elbow brace) and control (pitching without elbow brace). The order of testing was block randomized in blocks of 2. The pitching interval was set to 1 week to wash out fatigue and joint stress due to the pitching program. For the elbow brace condition, participants used a PO elbow support 3 with valgus suppression straps (weight range, 120-132 g; Japan SIGMAX Co, Ltd) (Figure 1C). The size of the elbow brace was determined by the participant's elbow circumference.

Measurements

Measurements were focused on the medial elbow joint space. The ulnohumeral joint space was measured sonographically before and following repetitive pitching in the elbow brace and control conditions and was the primary outcome measure. Ball velocity and accuracy of pitching were also measured, as well as the comfort of the elbow brace.

Measurement of the ulnohumeral joint space was carried out ultrasonically (Aloka Co, Ltd) before pitching and after every 20 pitches. Ultrasound imaging of the medial aspect of the throwing elbow was performed with use of a 10-MHz annular array transducer. Gravity stress was applied to the forearm to strain the medial aspect of the elbow and to assess medial elbow joint space gapping. Gravity stress used in this study has been reported as being useful in the assessment of medial elbow joint space gapping and is similar to an evaluation using the commonly used Telos device.[17] Participants were placed supine on the bed with the shoulder in 90° of abduction, 0° of horizontal abduction, and maximum external rotation; the elbow in 90° of flexion; and the forearm in neutral position. The elbow joint lay off the side of the bed.[17,19,33,38] A towel roll and a digital inclinometer were used to maintain the humerus in the horizontal plane. No participants experienced elbow pain during the examination. The time taken for measurement was less than 5 minutes in total (Figure 2).

The ultrasound transducer was placed on the medial aspect of the elbow in such a position that ultrasound imaging included both the top of the medial epicondyle of the humerus and the medial tubercular portion of the ulnar coronoid process. The degree of medial elbow joint space gapping was assessed by measuring the ulnohumeral joint space between the distal-medial corner of the trochlea of the humerus and the proximal edge of the medial tubercular portion of the ulnar coronoid process. The distance of the 2 points (the distal-medial corner of the trochlea of the humerus and the proximal edge of the medial tubercular portion of the coronoid process of the ulna) on the image was measured by using the ultrasound distance measurement method (minimum unit, 0.1 mm). The mean of 3 trials was used for data analysis (Figure 3).

Figure 2. Ultrasound imaging of the medial aspect of the throwing elbow was performed with use of a 10-MHz annular array transducer. Gravity stress was applied to the forearm to strain the medial aspect of the elbow and to assess medial elbow joint space gapping.

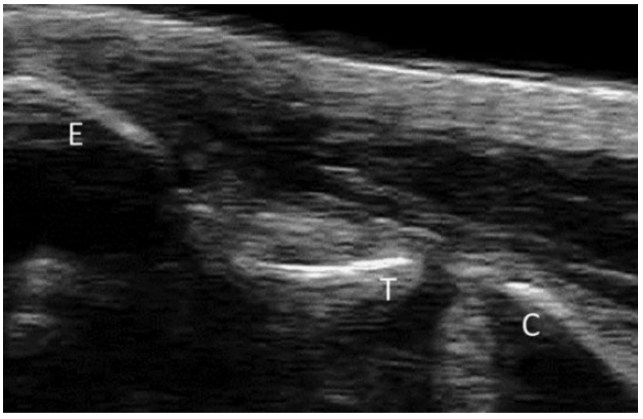

Figure 3. Ultrasound imaging of the ulnohumeral joint. The distance between the trochlea of the humerus and the coronoid process of the ulna was measured from the image. C, coronoid process; E, medial epicondyle; T, trochlea.

Measurement of ball velocity was carried out using the speed gun in all pitches. The mean ball velocity of every 20 pitches was used for data analysis.

The accuracy of pitching was measured in all pitches. When a ball passed through or contacted the simulated strike zone, the pitch was recorded as a strike. The pitching accuracy of every 20 pitches was used for data analysis. The

TABLE 2
Comparison of Ulnohumeral Joint Space Gapping Measured Prior to Pitching and at Intervals of 20 Pitches Between the Elbow Brace Condition and Control (N = 25)[a]

	Before Pitching	20 Pitches	40 Pitches	60 Pitches	80 Pitches	100 Pitches
Ulnohumeral joint space under gravity stress						
Elbow brace condition, mm	5.02 ± 0.74	5.09 ± 0.73	5.12 ± 0.75	5.14 ± 0.77[b]	5.16 ± 0.77[b]	5.17 ± 0.83[b]
Control, mm	4.97 ± 0.90	5.23 ± 0.90	5.52 ± 0.84	5.83 ± 0.91[c]	6.01 ± 1.08[c]	6.22 ± 1.06[c]

[a]Data expressed as mean ± SD.
[b]Significant difference between elbow brace condition and control ($P < .01$).
[c]Significant difference between before pitching and after every 20 pitches ($P < .01$).

TABLE 3
Mean Ball Velocity and Accuracy of Pitches Between Each of 6 Pitching Sets and 2 Conditions (N = 25)[a]

	1-20 Pitches	21-40 Pitches	41-60 Pitches	61-80 Pitches	81-100 Pitches
Mean ball velocity					
Elbow brace (km/h)	100.0 ± 7.7	100.8 ± 7.8	100.8 ± 7.8	100.7 ± 8.2	100.8 ± 8.7
Control (km/h)	102.1 ± 8.1	103.0 ± 8.6	102.9 ± 8.4	102.4 ± 8.2	102.6 ± 8.5
Accuracy of pitches					
Elbow brace (times)	10.1 ± 3.3	11.4 ± 2.5	11.2 ± 3.1	11.2 ± 2.8	11.4 ± 3.0
Control (times)	10.2 ± 3.0	11.3 ± 2.8	10.9 ± 3.5	10.9 ± 3.2	10.4 ± 2.5

[a]Data are expressed as mean ± SD. There were no significant interactions between condition for pitch count or main effect.

comfort of the elbow brace was sought from all participants by asking pitchers how comfortable the brace felt while pitching.

Statistical Analysis

All data were analyzed using SPSS Statistics version 22.0 (IBM Corp). Repeated-measures analysis of variance and post hoc tests were used to compare ulnohumeral joint space, mean ball velocity, and accuracy of pitching between 6 pitching sets (before pitching, 20 pitches, 40 pitches, 60 pitches, 80 pitches, and 100 pitches) and 2 conditions (elbow brace condition vs control). Significant differences were set at a level of .05.

RESULTS

Descriptive statistics for ulnohumeral joint space gapping under gravity stress are shown in Table 2. There was a significant condition–pitching count interaction for ulnohumeral joint space. There was no significant difference in ulnohumeral joint space gapping between the elbow brace condition and control prior to pitching. In the control condition, ulnohumeral joint space gapping increased significantly after 60 pitches when compared with prior to pitching ($P < .01$). In the elbow brace condition, ulnohumeral joint space gapping did not increase significantly at any time. When comparing the 2 conditions, the ulnohumeral joint space gapping in the elbow brace condition was significantly less than that in the control condition after 60 pitches ($P < .01$).

Descriptive statistics for mean ball velocity and accuracy of pitching of every 20 pitches and pitching performance are shown in Table 3. For mean ball velocity and accuracy of pitching of every 20 pitches, there was no significant interaction between condition for pitch count or main effect. With regard to comfort of the elbow brace, 8 players reported "no change" while 17 players reported "less ability to throw." All pitches were more than 70% of the mean ball velocity of the first 20 pitches.

DISCUSSION

In a previous study of elbow injury in young baseball players (age range, 9.5-12.0 years), Hang et al[16] showed that 52% of players had medial elbow pain and 57% had separation of the medial epicondyle. Likewise, Harada et al[20] showed that 45% of baseball players (age range, 15-17 years) had elbow pain and that 17% of players had a sonographically determined medial elbow joint space gapping. In 2005, the Japanese Society of Clinical Sports Medicine[22] reported that 50% of all elementary school–aged players have elbow pain, with 20% of all players having radiographic bone abnormalities. In junior high school students, 46% of baseball players have elbow pain, and in high school students, approximately half of players have a history of injury and have consulted a sports doctor about their elbow pain.[22] It can therefore be seen that elbow pain is a major problem among young baseball players that requires further attention. Therefore, we advocate for the prevention of the burden of the elbow among young baseball players.

According to the results of our study, throwing without an elbow brace induces widening of the elbow medial joint space after 60 pitches. This indicates that throwing more than 60 pitches without an elbow brace may lead to

increased medial elbow joint space gapping, as measured by gravity stress ultrasound. Kirkley et al[26] showed that repetitive loading exercise contributes to an increase in translation at the joint. Pitching-generated repetitive valgus stress in the elbow is considered to correspond to the repetitive loading exercise. In our study, repetitive valgus stress of the elbow during repetitive throwing contributed to an increase in medial elbow joint space gapping.

The National High School Baseball Tournament (Koshien) is the highest-level baseball tournament among high school baseball players in Japan. To become a champion in the Koshien tournament, it is necessary to win at least 5 consecutive games in 14 days.[27] Because of the pressure to succeed in this tournament, teams often rely on a specific pitcher for all of their games unless there is an injury. Assuming the 100 pitches per game recommended by the Japanese Society of Clinical Sports Medicine, a pitcher usually has to pitch 500 balls in 14 days at this tournament. This demanding schedule is not specific to the Koshien tournament but is the same for other local tournaments in each prefecture of Japan. Therefore, overuse of the elbow is quite common among baseball players during intense practice and game schedules.

Baseball elbow screening using ultrasound has been tested in various locations as a means of preventing elbow injury,[18] but its effectiveness is not known. Although baseball elbow screening is a possible method of detecting early elbow injury, it is not likely to prevent elbow injury. Pitching limitations have been recommended to reduce elbow injury,[22] but the number of elbow injuries has not decreased in recent years. In fact, the number of elbow-injured players who require surgery to the medial elbow joint has increased.[6]

We suggest that elbow bracing may reduce mechanical stress on the elbow by reducing medial elbow joint space gapping. The results of our study showed that medial elbow joint space gapping when wearing an elbow brace was unchanged after 100 repeated pitches. Furthermore, the medial elbow joint space gapping when wearing an elbow brace was significantly less when compared with not wearing an elbow brace after 60 pitches. These results may indicate that using an elbow brace for repetitive throwing is a means of protecting the thrower's elbow. The elbow brace used in this study is designed to control lateral instability by aluminum hinges built into both sides of the brace overlying the elbow joint. In addition, valgus instability is controlled by straps with 3 points of fixation to suppress valgus stress. A study of a brace with similar makeup showed that it applies valgus moment to the knee joint and reduces the varus moment to the joint in action.[37] In the current study, the varus brace is designed to apply a varus moment to the elbow joint and potentially reduce the valgus moment to the elbow joint during repetitive throwing. The current results indicate that the use of an elbow brace can decrease the medial elbow joint space gapping seen during repetitive throwing.

With regard to pitching performance, these results indicate that pitching performance, including ball velocity and accuracy of pitching, can be maintained even when wearing an elbow brace.

With regard to the comfort of the elbow brace, 68% of participants (n = 17) reported some difficulty with pitching when wearing the elbow brace. Some factors such as hinge structure, straps, and brace materials may have an impact on comfort, and refinement of the brace in this regard may improve brace comfort. The weight of the brace (120-132 g) is also a factor that needs to be considered and may affect the comfort and smooth movement of the arm during the throwing motion.

Currently, the use of an elbow brace is prohibited in baseball games because it is thought that a brace may influence performance in baseball pitchers. In spite of this, we believe that an elbow brace has the potential to reduce elbow injuries in adolescent baseball pitchers. Therefore, we recommend that the governing institutions allow a clinical study to be undertaken to see whether elbow braces can decrease injury rates in adolescent pitchers.

There are a number of limitations to this study. First, it is not possible to directly correlate decreased elbow injury with reduced medial elbow joint space gapping. To determine this, it is necessary to conduct a longitudinal study with throwers wearing a brace matched with a control group to determine whether wearing a brace can decrease the incidence of medial elbow injuries in this population. Second, the elbow brace was uncomfortable in more than half of the players. Future studies should look at improving the elbow brace configuration. Third, the measurements using ultrasound were not blinded as to brace use. Last, participants of this study included only a narrow age range of baseball players (16.6 ± 0.7 years). It is necessary to widen the age range of participants in further studies.

CONCLUSION

We investigated the effects of elbow bracing as a way to reduce stress on the elbow during repetitive throwing in adolescent baseball players. According to the results of our study, it is apparent that throwing without an elbow brace for more than 60 pitches induces an increase in medial elbow joint space gapping, as determined by gravity stress ultrasound. During repetitive throwing with an elbow brace, the medial elbow joint space gapping was not significantly different after 100 repeated throwing actions. Wearing an elbow brace significantly reduced medial elbow joint space gapping when compared with not wearing an elbow brace after 60 pitches. With regard to pitching performance, there was no significant difference for ball velocity and accuracy of pitching between the elbow brace condition and control. Regarding comfort of the elbow brace, more than half of players reported the brace as uncomfortable. Future studies are needed to demonstrate whether a brace will reduce elbow injuries in adolescent patients.

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