



Increased medial laxity of the elbow in preadolescent baseball players with or without medial elbow apophysitis



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Background: Medial elbow apophysitis is a traction apophysitis observed in the medial epicondyle of the elbow in preadolescent baseball players. The purpose of this study was to determine the relationship between medial elbow apophysitis and elbow valgus instability in preadolescent baseball players.

Methods: The participants were classified into a control group and an injury group; the injury group included participants diagnosed with a medial elbow injury (inclusion criteria were only symptoms of the elbow joint or positive findings on physical examinations, or both). Elbow valgus instability was assessed by measuring the differences in ulnohumeral joint gapping width, with and without gravity stress induced by weight loading of the forearm using ultrasonography.

Results: The control and injury groups consisted of 81 and 23 preadolescent baseball players, respectively. In the throwing elbow, valgus instability in the injury group was significantly greater than that in the control group (1.07 vs. 0.57 mm, $P = .001$). In the non-throwing elbow, valgus instability in the injury group was significantly greater than that in the control group (0.57 vs. 0.37 mm, $P = .011$). The area under the curve for valgus instability of the throwing elbow was 0.89 mm (95% confidence interval, 0.64–0.77), and the cut-off value for elbow pain appearance was 0.80 mm.

Conclusion: The increased elbow valgus instability in the injury group was associated with a medial elbow injury. For the elbow valgus instability of the non-throwing side in the injury group, we considered that players with medial elbow apophysitis inherently have elbow laxity.

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Elbow injuries in adolescent baseball players are common and account for more than 30% of baseball-related injuries.^{14,19} The medial elbow injury in young baseball players has classically been termed “Little League Elbow” and is classified as an apophysitis and ulnar collateral ligament (UCL) injury.^{2,3,7,8} Medial elbow apophysitis is a more frequent cause of medial elbow injury in young athletes than a UCL injury. Medial elbow apophysitis is a traction apophysitis observed in the medial epicondyle of the elbow in

patients aged 9 to 12 years and is caused by repeated throwing movements.^{2,26,31} Moreover, throwing intensity, season length, and single-sport participation at younger ages are all considered environmental factors affecting the increased incidence of medial elbow apophysitis.² In patients with medial elbow apophysitis, the occurrence of secondary osteophyte formation caused by the loose body in the elbow, fragmentation, and UCL injury is possible in the future.

Medial elbow injuries have been reported to occur owing to valgus stress induced during the late cocking and acceleration phases of baseball pitching.¹² Valgus moments during throwing have been estimated to be of 50 to 120 Nm and are resisted by soft tissues in the medial epicondyle.^{9,33} The UCL is the main medial elbow stabilizer against valgus loads. Furthermore, during a

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throwing movement, valgus stress is one of the mechanical causes of medial elbow apophysitis in throwing movement in preadolescent baseball players.

Measurement of the valgus instability of the elbow has been established as an examination for UCL injuries.^{2,17} Magnetic resonance arthrography has been shown to improve the diagnosis of partial undersurface tears and small full-thickness perforations of the UCL.^{13,15,28} However, magnetic resonance arthrography is not always available as an imaging technique to diagnose a UCL injury because of its cost. Magnetic resonance arthrography is usually used to evaluate the magnitude of a UCL injury rather than the elbow joint; the UCL plays the main function in elbow stability. Stress imaging using radiography is performed as one of the examinations for valgus instability, and the same method using ultrasonography, which is a useful and less-invasive technique, has been used recently.^{10,18,30,32} The validity and reliability of stress imaging using ultrasonography are slightly similar to those of stress imaging using radiography. Lee et al showed that the ulnohumeral distance of the uninjured elbow was 4.0 ± 0.7 mm and 4.7 ± 0.6 mm in the unloaded (gravity only) and loaded conditions (5 lb), respectively, using stress radiographs. These medial elbow-gapping measurements are within 1 standard deviation of the mean measurements obtained on stress sonography with a similar experimental protocol. In addition, Bica et al measured the reliability of the ulnohumeral joint gapping using ultrasonography and demonstrated an excellent level of precision with an intraclass coefficient of 0.51 to 0.97 and a standard error of less than 0.5 mm.⁵

A previous study showed that elbow valgus instability of adolescent baseball players with medial elbow injury is more than that of those without medial elbow injury.²⁷ However, this is unclear in preadolescent baseball players. Supposedly, if the relationship between elbow valgus instability and medial elbow apophysitis is identified, it is important to demonstrate whether preadolescent baseball players have elbow valgus instability. This study aimed to determine the relationship between medial elbow apophysitis and elbow valgus instability in preadolescent baseball players.

Material and methods

Participants

In total, 132 male Japanese baseball players aged 9 to 12 years participated in this study. All the participants belonged to the Japan rubber baseball association. The exclusion criteria for this study were a history of elbow or shoulder surgery, elbow or shoulder injury in the past six months, untreated symptomatic elbow pain, current lateral and posterior elbow pain, and a history of elbow pain. The participants were classified into two groups as follows: a control group and an injury group (Inclusion criteria were only symptoms of the medial elbow joint, positive findings on physical examinations, or both.). Participants and their parents provided written informed consent before participation, and the study protocol was approved by our institution's ethics committee (approval number [2015-032]).

Procedure

We used a self-administered questionnaire for this study. We surveyed the participants' age, height, weight, body mass index, throwing side, years of baseball experience, playing position, and whether they experienced elbow pain at rest or throwing. If the participant reported having elbow pain, we evaluated the position of the pain in the elbow joint in detail, such as medial, lateral, or posterior. Furthermore, we similarly surveyed any history of elbow pain experienced during baseball.

Diagnosis of medial elbow injury

In total, 15 staff members participated in the examination of this study. Physical findings of the elbow joint were examined by four orthopedic surgeons. We determined the presence or absence of tenderness in the medial epicondyle and the Milking sign as positive findings of medial elbow injury. Similarly, we checked for any tenderness of the radiocapitellar joint and the olecranon as positive findings of lateral and posterior elbow injuries.

Elbow valgus instability assessment

Elbow valgus instability assessments were performed as described by Sasaki et al.²⁹ They assessed medial elbow instability in baseball players aged 19 to 24 years and detected significant medial elbow joint gapping width of the throwing side using their methodology. Elbow valgus instability was assessed by measuring the differences in ulnohumeral joint gapping width, with and without gravity stress induced by weight loading of the forearm when the elbow was placed at 90 degrees of flexion. Ulnohumeral joint gapping width was measured using ultrasonography (SonoSite M-turbo; FUJIFILM SonoSite, Inc., Bothell, WA, USA) and a probe (HFL50x/15-6 Hz). In addition, we measured ulnohumeral joint gapping width, defined as the distance from the trochlea of the humerus to the coronoid process of the ulna on ultrasonographic images, using ImageJ ver. 1.48 (National Institutes of Health, Bethesda, MD, USA). Participants were laid in a supine position at rest with a shoulder abduction of 90 degrees and an external rotation of 90 degrees, an elbow flexion of 90 degrees, and a forearm pronation-supination of 0 degrees. To measure nongravity stress at the medial elbow, each participant placed their whole arm on the bed, and to measure gravity stress at the medial elbow, each participant placed only their upper arm on the bed (Fig. 1, A and B).⁵

We applied the ultrasonography probe to the ulna from the medial epicondyle, in line with the direction of the UCL, and selected the image wherein the articular surface of the trochlea humerus and ulna was visible and the fibrillar pattern of the UCL was most clearly reflected (Fig. 1, C and D).²² We measured the ulnohumeral joint gapping width with and without gravity stress. The joint gapping was calculated as the difference between gravity stress and nongravity stress (elbow valgus instability). Images were collected and measured by a single proficient physiotherapist with 25 years of experience, who served as the sonographer.

The intraclass coefficient [1,1] of the elbow valgus instability using ultrasonography was 9.05 in the preliminary experiment.

Statistical analysis

The statistical analysis was performed using a paired t-test and the χ^2 test to compare background factors and elbow valgus instability between the injury and control groups. Receiver operating curve analysis was used to determine cutoff scores of the elbow pain appearance in relation to the area under the curve, sensitivity, and specificity. The statistical package for social science version 23 (SPSS; IBM Inc., Armonk, NY, USA) was used for all statistical analyses, and the level of significance was set to 5%.

Power analysis

The sample size was calculated using the sample size and power calculation software (G*Power, version 3.1.9.4; Heinrich–Heine–Universität Düsseldorf, Düsseldorf, Germany [<http://www.gpower.hhu.de/>]) before enrolling participants. The conditions for determining the sample size were moderate effect size, α err probability of 0.05, and power ($1 - \beta$ err probability) of

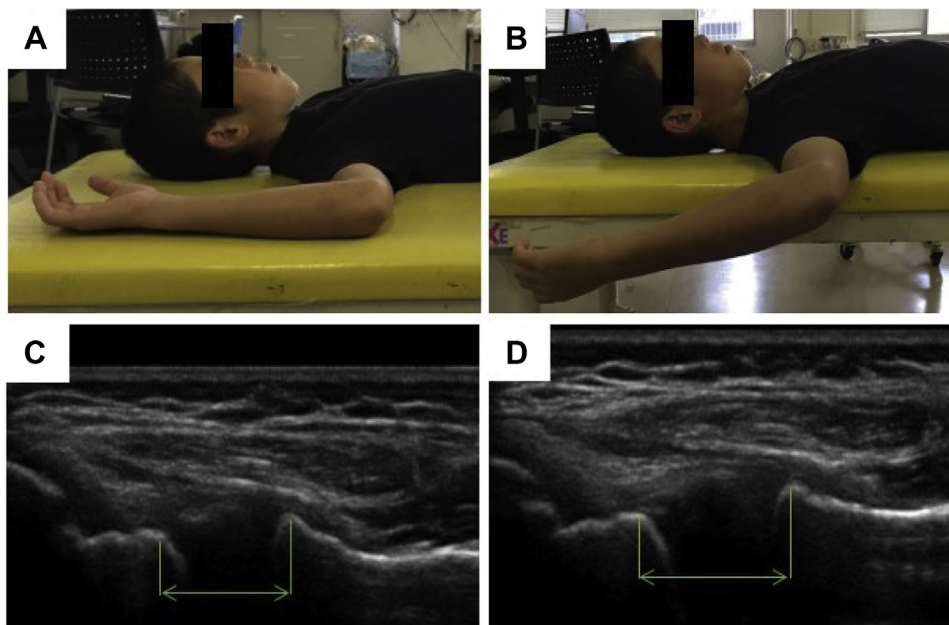


Figure 1 Measurement position of participants and the ultrasonographic images with and without gravity stress. (A) The position for nongravity stress. (B) The position for gravity stress. (C) The image under nongravity stress (indicated by green arrows). (D) The image under gravity stress (indicated by green arrows).

0.8. The power analysis results showed that 51 participants are required in each group (102 participants in total) to detect statistical differences between the control and injury groups.

Results

Of the 132 participants, 12 with lateral or posterior elbow pain and 16 with a history of elbow pain were excluded from this study; in total, 104 participants were included in this analysis. Of the 104 participants, 23 had medial elbow injury (injury group), and 81 did not (control group). In the injury group, eight, nine, and six patients had positive findings of the medial elbow tenderness, the Milking sign, and both findings, respectively (Fig. 2). The characteristics of the participants are highlighted in Table I. There were no significant differences in the characteristics of the participants.

Table II shows the data obtained on elbow valgus instability in both groups, alongside the statistical analysis comparing both groups. Throwing elbow valgus instability was significantly greater in the injury group than that in the control group (1.09 ± 0.32 mm vs. 0.57 ± 0.30 mm). Nonthrowing elbow valgus instability was significantly greater in the injury group than that in the control group (0.57 ± 0.34 mm vs. 0.37 ± 0.30 mm).

The area under the curve value for valgus instability of the throwing elbow was 0.89 (95% confidence interval, 0.64–0.77), and the cutoff value of elbow pain appearance was 0.80 mm (Fig. 3).

Discussion

Our results showed that the valgus instability of the throwing elbow in the injury group was significantly greater than that in the control group. Concerning the nonthrowing elbow, the valgus instability in the injury group was significantly greater than that in the control group. Considering the age of the participants, it was shown that increased elbow valgus instability in the injury group was associated with medial elbow apophysitis. Because elbow valgus instability of the nonthrowing side in the injury group was higher than that in the control group, it was suggested that the

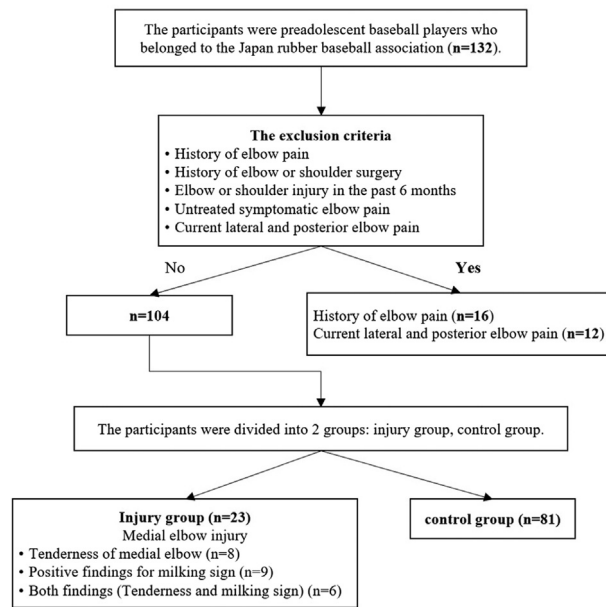


Figure 2 Flowchart of the procedure for classifying the participants into two groups: an injury group and a control group.

preadolescent players with medial elbow injury inherently have elbow laxity.

Previous studies showed that elbow valgus instability in adult baseball players increased owing to the valgus stress induced by throwing movements, and it was reported that elbow valgus instability on the throwing side was higher than that observed on the nonthrowing side.^{1,11,25} In other studies, the elbow valgus instability in adolescent baseball players similarly increased owing to the valgus stress induced by throwing movements. As immature elbow joints are weaker than those of adolescents or adults owing to the growth form of the joint, preadolescent baseball players are supposedly more likely to experience elbow injuries.^{4,24} Moreover,

Table I
Characteristics of participants.

Characteristics	Control group (n = 81)	Injury group (n = 23)	P value
Age (yr)	10.9 ± 0.77	10.6 ± 0.94	.252
Height (m)	1.45 ± 0.79	1.42 ± 0.76	.381
Weight (kg)	37.9 ± 9.47	39.3 ± 8.22	.596
BMI (kg/m ²)	17.9 ± 3.45	19.0 ± 2.25	.162
Throwing side			.602
Right, % (n)	93.8 (76)	95.6 (22)	
Left, % (n)	6.17 (5)	4.34 (1)	
Experience year (year)	1.45 ± 0.79	1.45 ± 0.79	.343
Position			.067
Pitcher, % (n)	40.7 (33)	39.1 (9)	
Catcher, % (n)	18.5 (15)	26.0 (6)	
Fielder, % (n)	40.7 (33)	34.7 (8)	

BMI, body mass index.
Values are presented as mean ± standard deviation.

Table II
Increased medial laxity of the elbow in both the control group and injury group.

Values of the elbow valgus stress	Control group (n = 81)	Injury group (n = 23)	P value
Throwing side			
Non gravity stress (mm)	12.36 ± 2.42	12.48 ± 1.79	.797
Gravity stress (mm)	12.93 ± 2.43	13.58 ± 1.84	.176
Elbow valgus instability (mm)	0.57 ± 0.30	1.09 ± 0.32	.001*
Nonthrowing side			
Nongravity stress (mm)	11.89 ± 2.29	12.24 ± 1.53	.392
Gravity stress (mm)	12.25 ± 2.29	12.81 ± 1.68	.201
Elbow valgus instability (mm)	0.37 ± 0.30	0.57 ± 0.34	.011*

Values are presented as mean ± standard deviation.
Elbow valgus instability: Gravity stress – nongravity stress.
*Significant difference ($P < .05$).

it has been revealed that elbow valgus instability of adolescent baseball players with medial elbow injury is higher than that of adolescent baseball players without medial elbow injury.

The evaluation of elbow valgus instability was performed by measuring from the trochlea of the humerus (the proximal landmark) to the coronoid process of the ulna (the distal landmark) using ultrasonography. Ultrasonography was performed such that the same landmark (the trochlea of the humerus, coronoid process of the ulna, and the UCL) would be indicated on single images taken both with and without gravity stress. In preadolescent baseball players, the ulnohumeral joint gapping width is overestimated than that in previous studies in adult or adolescent baseball players. This is because the bone forming the joint is immature and the amount of cartilage relative to the bone is large.^{21,23} Furthermore, as the period of peak growth is different among individuals, it is impossible to compare the absolute values of ulnohumeral joint gapping width, including the cartilage width. Therefore, we did not use the absolute value of the ulnohumeral joint gapping width; rather, the differential values between the presence and absence of gravity stress were used. The method used in this study had high intra-inspector reliability in the preliminary experiments, as in a previous study.⁵ It was suggested that the evaluation of elbow valgus instability by this method, as used for adult or adolescent baseball players, is equally useful for preadolescent baseball players. However, as preadolescent baseball players have epiphyseal cartilage in the elbow joint, careful measurement is required, unlike for adults.

This study showed that, on the throwing side, elbow valgus instability of preadolescent baseball players with medial elbow injury was significantly greater than that of players without medial elbow injury. Many of the medial elbow injuries in preadolescent baseball players were disorders of the epiphyseal cartilage and epiphyseal lines. In contrast, many of the medial elbow injuries in

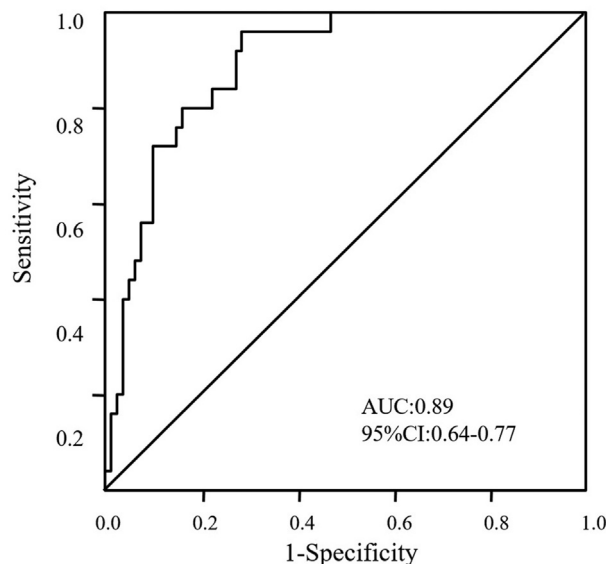


Figure 3 Receiver operating characteristic curve and AUC of valgus elbow instability on the throwing side. AUC, area under the curve, 95% CI, 95% confidence interval.

adolescent baseball players were disorders of the soft tissues, such as the UCL.¹⁶ Several preadolescent baseball players had a secondary ossification nucleus of the elbow, signifying immature bone formation. The period of appearance of the secondary ossification nucleus of the medial epicondyle is between the ages of six and nine years, and the closing period of the epiphyseal line in the medial epicondyle is between the ages of 13 to 16 years.^{6,23} Thus, players aged 9 to 12 years have epiphyseal cartilage in the elbow and are vulnerable to mechanical stress because epiphyseal cartilage has only approximately 20% of the strength compared with the ligament tissue.

As the robustness of epiphyseal cartilage against tensile insult is weaker than that of the ligament, the cause of an increasing ulnohumeral gapping width may differ between adolescents and preadolescents, and medial elbow injuries in preadolescent baseball players may be more serious owing to epiphyseal cartilage injury. Furthermore, the finding that increased medial laxity of the elbow is associated with medial elbow injury may indicate a progression to the future disability of the elbow. Although we initially believed that participants would have shown similar levels of valgus instability, the damaged parts of the elbow are different between adolescents and preadolescents because participants in this study had a similar onset mechanism for medial elbow injury. The cutoff value of valgus elbow instability in this study was 0.8 mm, which was lower than the mean values in the previous studies for adult participants.³⁰ Although this study revealed a relationship between the onset of medial elbow injury and elbow valgus instability values, participants with increased medial laxity of the elbow may experience future throwing disorders, such as UCL injuries. The study results may be one of the indicators for preventing medial elbow injury; however, further data should be accumulated for clinical application. If a field player has a large elbow valgus instability, the elbow joint deficit should be identified as a risk factor by motion analysis using biomechanical analysis in addition to the rest period. However, there is currently insufficient evidence regarding the relationship between elbow valgus instability and pitching motion in field players.

In this study, we similarly investigated elbow valgus instability of the nonthrowing side and the throwing side. The increased medial laxity of the elbow of the nonthrowing side in preadolescent

baseball players with medial elbow injury was significantly higher than that in preadolescent baseball players without medial elbow injury. If it is assumed that the nonthrowing side of the elbow is not affected by the throwing movement, it is likely that the elbows of preadolescent baseball players with injuries have inherent laxity. Preadolescent baseball players with elbow instability of the nonthrowing side may not be allowed to play in positions with a high number of pitches, such as pitchers and catchers, until their body matures or the epiphyseal cartilage of the elbow joint is closed.²⁰

A potential limitation of this study is that it remains unclear whether increased or inherently large levels of medial laxity are the cause of medial elbow injury because this was a cross-sectional study. In this study, the power analysis revealed that a sample size of 51 cases was required for each group; however, the injury group had a sample size of 23 cases, resulting in a shortage of 28 cases. Therefore, future studies involving a larger sample size for the injury group are warranted. In addition, female baseball players were not included among the study participants, and the accuracy of the physical examination performed by the four doctors is unclear. Moreover, the cutoff values in this study could not predict the onset of medial elbow injury in the participants. To clarify these issues, it is necessary to perform a longitudinal study of male and female preadolescent baseball players before the onset of medial elbow injury.

Conclusion

Preadolescent baseball players were examined for increased medial laxity of the elbow joint in this study. Our study revealed that elbow valgus instability (increased medial laxity of the elbow) is a reliable finding in preadolescent baseball players as well as adult or adolescent baseball players, as demonstrated in previous studies.

We compared elbow valgus instability in preadolescent baseball players with and without medial elbow injury. The increased elbow valgus instability in the injury group was associated with medial elbow injury. The cutoff value of valgus elbow instability in this study was 0.8 mm. Preadolescent baseball players with increased medial laxity of the elbow should be placed on an extended pitch interval or a rest period to prevent medial elbow injury.

For the elbow valgus instability of the nonthrowing side in the injury group, we considered that players with medial elbow apophysitis-matched age inherently have elbow laxity. Considering the age of the participants, medial elbow apophysitis appears to be associated with increased elbow valgus instability, particularly in the injured elbow. However, in players with apophysitis, even the uninjured elbow appears to have valgus instability, suggesting that the inherent laxity in these players is a possible etiology for their medial apophysitis.

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