

# Asymptomatic Medial Elbow Ultrasound Abnormality in Youth Baseball Players Is an Independent Risk Factor for Elbow Injury

## A Prospective Cohort Study

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**Background:** Youth baseball players who experience elbow pain during the season frequently exhibit radiographic elbow abnormalities. However, it is unknown whether asymptomatic elbow abnormalities are risk factors for in-season elbow injuries.

**Purpose:** To determine whether the preseason presence of asymptomatic medial epicondyle apophysitis is a risk factor for in-season elbow injuries in youth baseball players.

**Study Design:** Cohort study; Level of evidence, 2.

**Methods:** Youth baseball players (N = 210; age range, 7-12 years) with no pain or history of injury in their throwing arms underwent preseason evaluations that included shoulder and elbow range of motion measurements, shoulder muscle strength testing, and ultrasound elbow scans with a multifrequency 13-MHz linear array transducer. Over 1 year of play, the players and their parents maintained daily elbow pain diaries. Elbow injuries were defined as medial elbow symptoms that prevented ball throwing for  $\geq 8$  days.

**Results:** The preseason ultrasound evaluation revealed medial epicondyle apophysitis in 59 players. In the year following, elbow injuries occurred in 17 (28.8%) players with preseason medial epicondyle apophysitis and 18 (11.9%) players without apophysitis. Independent predictors of elbow injuries were preseason medial epicondyle apophysitis (odds ratio [OR], 2.488; 95% confidence interval [CI], 1.152-5.376;  $P = .02$ ) and deficits of abduction (ABD) and external rotation of the dominant shoulder (OR, 0.963; 95% CI, 0.936-0.992;  $P = .012$ ).

**Conclusion:** Asymptomatic medial epicondyle apophysitis and ABD and external rotation deficits in the dominant shoulder were risk factors for elbow injuries in 7- to 12-year-old youth baseball players. These findings may aid in the design of programs to prevent elbow injuries in this population.

**Keywords:** baseball; elbow; medial epicondyle apophysitis; imaging; diagnostic ultrasonography; injury prevention

Youth baseball players always face a high risk of elbow injuries.<sup>5,8,10,22,23</sup> Cumulative and repeated microtrauma from elementary or junior high school is believed to cause baseball-related elbow injuries in high school and college players.<sup>10</sup> Repeated microtrauma and high forces to the medial elbow joint during throwing are related to medial epicondyle apophysitis or anterior bundle of ulnar

collateral ligament (UCL) injury and may lead to osteochondritis dissecans of the humeral capitellum.

The risk factors for a baseball-related elbow injury have been investigated by Lyman et al<sup>10,11</sup> and Harada et al<sup>5</sup> and include the following: large number of pitches per season, older age, taller height, pitcher position, daily training, deficits in shoulder abducted external rotation (ABER), and greater shoulder external and internal rotation muscle strength. However, Harada et al<sup>5</sup> enrolled players who had elbow pain prior to the beginning of the study. It is necessary to investigate the risk factors for elbow injuries in youth baseball players without prior elbow pain. To address

The Orthopaedic Journal of Sports Medicine, 9(4), 2325967120986791  
DOI: 10.1177/2325967120986791  
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this issue, Matsuura et al<sup>12</sup> prospectively observed 449 baseball players aged 7 to 12 years without a history of elbow pain for 1 season to investigate the risk factors for baseball-related elbow injury. Those investigators demonstrated that approximately 30% of players experienced elbow pain during the season. Radiographic abnormalities were concomitant in approximately 60% of players with elbow pain. The risk factors for elbow pain were being an older age, being a pitcher, being a catcher, and playing >100 games per year.<sup>12</sup>

In the Matsuura et al<sup>12</sup> study, the players did not undergo preseason imaging screening and underwent radiographic evaluation only after the development of elbow pain. Thus, it is unknown whether the abnormalities detected on radiographs happened during the season and whether a relationship exists between the radiographic abnormalities and elbow pain. Recent magnetic resonance imaging (MRI) studies demonstrated that abnormalities were found in 35% of baseball players aged 10 to 13 years who were asymptomatic at a preseason evaluation,<sup>14</sup> and 58% had dominant-arm MRI pathology at the completion of a 3-year follow-up.<sup>7</sup> Although MRI has a high diagnostic ability, as indicated by these studies,<sup>7,14</sup> the number of participants evaluated was limited because of the cost of MRI. To reduce the participants' selection bias and determine the relationship between asymptomatic elbow abnormality and throwing-related injury, more participants need to be evaluated.

Ultrasonography has recently been used to detect noninvasive baseball-related elbow lesions, such as medial epicondyle apophysitis, anterior bundle of UCL injury, and osteochondritis dissecans of the humeral capitellum. A previous study<sup>5</sup> reported that among baseball players aged 9 to 12 years, medial epicondylar fragmentation and osteochondritis dissecans were detected with ultrasonography at prevalences of 19.7% and 0.7%, respectively. Sakata et al<sup>17</sup> reported that the incidence of initial medial epicondyle abnormalities detected with ultrasonography was 22.1% among asymptomatic baseball players aged 6 to 12 years. There is still limited evidence of a causal effect between imaging abnormalities and symptoms.

To shed light on this issue, prospective studies of players without prior elbow pain who have undergone an initial preseason elbow imaging screening are necessary to determine whether elbow abnormalities seen on ultrasonography may be a risk factor for elbow injury. In youth baseball players, medial epicondyle abnormalities occur more frequently than osteochondritis dissecans of the humeral capitellum. Therefore, we conducted the present study to screen all youth baseball players using

ultrasonography before the season and to clarify whether the presence of asymptomatic medial epicondylar apophysitis in the preseason affects the incidence of elbow injury during the season. We hypothesized that youth baseball players with asymptomatic medial epicondyle abnormalities would have a greater risk of developing elbow injuries.

## METHODS

### Participants

For the current study, we recruited youth baseball players who belonged to a competitive baseball league; they were aged 7 to 12 years when we performed preseason medical checkups in 2018. Based on the inclusion criteria used in previous studies,<sup>18,19</sup> we included players if they had participated in annual medical checkups for 2 consecutive years (ie, in 2018 and 2019); had participated in preseason practice as an active player at the first medical checkups; and had no restrictions in baseball activities, such as throwing, running, and batting, at the first medical checkup. The exclusion criteria<sup>18,19</sup> were history of elbow pain on the dominant side at the first medical checkup; prior injuries (eg, fracture) of the throwing arm; and inability to play baseball because of foot, ankle, knee, hip, spine, shoulder, or elbow problems at the first medical checkup. To reduce confounding factors, we excluded players with a history of medial elbow pain, which is a risk factor for future elbow injury in youth baseball players.<sup>1</sup> This study received ethics approval from our institution, and informed consent was obtained from the participants' parents prior to enrollment.

### Preseason Medical Examination

As in previous reports,<sup>18,19</sup> preseason medical checkups in the current study were performed as the baseline medical examinations. The aim of preseason medical checkups was to evaluate the preseason condition of the participants' shoulders and elbows. To avoid confirmation bias, the examiners were not aware of the participants' hand dominance. We evaluated height, weight, shoulder and elbow range of motion (ROM), shoulder muscle strength, and ultrasound scan of the elbow.

### Elbow and Shoulder ROM Measurement

Drawing on procedures used in previous studies,<sup>18,19</sup> we used a digital protractor (iGaging) to bilaterally measure

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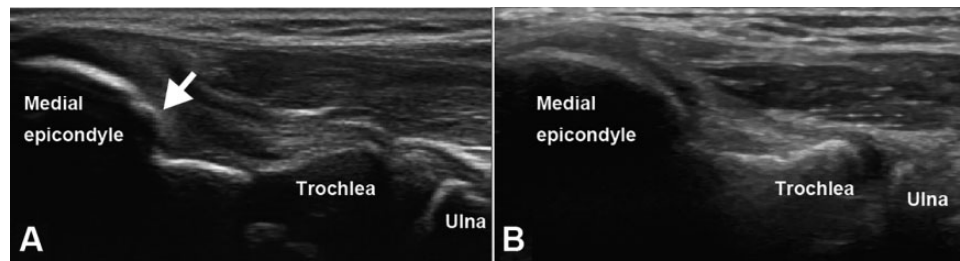
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Final revision submitted November 26, 2020; accepted December 9, 2020.

One or more of the authors has declared the following potential conflict of interest or source of funding: This research was partly supported by grants from the Japan Sports Medicine Foundation 2012 and Kozuki Foundation 2012 (to H.S.) and a grant from the Japanese Orthopedic Society for Sports Medicine (to T.I.). AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.

Ethical approval for this study was obtained from the institutional review board of Gunma University Hospital (ID No. 1003).



**Figure 1.** Longitudinal ultrasound images of the medial elbow joint. (A) Medial epicondyle apophysitis. The arrow indicates fragmentation of the medial epicondyle. (B) No apophysitis.

passive elbow ROM of flexion and extension, passive shoulder ROM of horizontal adduction (HA), and 90° ABER and abducted internal rotation (ABIR). All ROMs were measured with the participant in the supine position. The intrarater validity and reliability of ROM measurements using a digital protractor have been previously established.<sup>19</sup>

When measuring passive HA, the examiner stabilized the axillary border of the scapula and another examiner placed a digital protractor on the humerus. When measuring passive ABER and ABIR, the examiner stabilized the scapula by applying a posterior force to the coracoid process and another orthopaedic surgeon placed a digital protractor on the forearm. The total arc was calculated for the dominant and nondominant shoulders by adding the ABER and ABIR for each shoulder. The difference in each measurement was calculated as the ROM of the dominant side minus the ROM of the nondominant side.

### Shoulder Strength Measurement

According to the procedure used in previous studies,<sup>18,19</sup> orthopaedic surgeons used the PowerTrack II Commander hand-held dynamometer (J-Tech Medical) to measure seated abduction (ABD), prone internal rotation (PIR) strength, and prone external rotation (PER) strength of both shoulders. The intrarater validity and reliability of shoulder strength measurements using handheld dynamometers have been established in a previous study.<sup>19</sup>

To measure ABD strength, the participant was asked to sit on an examination table with his or her back against the wall, abduct the humerus to 90° in the coronal plane, and then horizontally adduct the humerus to 45° with the forearm in neutral position. The dynamometer was placed 5 cm proximal to the proximal wrist extension crease as the participant raised his or her arm perpendicular to the floor with maximum effort. The PIR and PER strengths were measured with the participant in the prone position with humeral ABD of 90° and elbow flexion of 90°. The examiner then stabilized the humerus and set the arm in a neutral position. The participant was asked to rotate the arm externally or internally with maximum power against the dynamometer. For the measurement of PIR strength, the dynamometer was placed on the volar side of the forearm, 5 cm proximal to the proximal wrist flexion crease. When PER strength was measured, the dynamometer was placed

on the dorsal side of the forearm, 5 cm proximal to the proximal wrist extension crease. Each measurement was repeated 3 times, and the median value was calculated for each participant. In addition, the dominant-to-nondominant ratios of ABD, PER strength, and PIR strength and the ratio of PER strength to PIR strength in the dominant arm were calculated for each participant.

### Ultrasonography of the Elbow Joint on the Dominant Side

Ultrasound evaluation of the elbow joint has been established in previous studies.<sup>20,21</sup> To detect any elbow abnormality,<sup>5,6,25</sup> ultrasound images were obtained using a multifrequency 13-MHz linear array transducer (MyLabfive; Hitachi Medical) by 3 orthopaedic surgeons (T.T., T. Kuboi, and H.S.) who had >15 years of experience in musculoskeletal ultrasonography. We defined fragmentation of the medial epicondyle apophysitis as discontinuity of the medial epicondyle (Figure 1).<sup>6</sup> In addition, we defined osteochondritis dissecans of the capitellum as an irregularity of the subchondral bone of the capitellum.<sup>24</sup> The decision was made by consensus. When decisions were divided among the 3 examiners, discussion was continued to reach a consensus. Only the symptomatic players were informed of the ultrasound findings, because these players may have needed additional examinations.

To test whether preseason asymptomatic medial epicondyle apophysitis affected the incidence of elbow injury during the season, the participants were divided into 2 groups: the asymptomatic medial epicondyle apophysitis group and the no-apophysitis group.

### Injury Tracking

From the player's viewpoint, we defined elbow injury as an inability to throw for  $\geq 8$  days because of medial elbow symptoms.<sup>16,18,19</sup>

Injuries that occurred by other mechanisms, such as being hit by a ball, colliding with another player, or incurring a trauma from a fall, were excluded from the statistical analysis. To avoid recall bias, participants and their parents were asked to complete a self-recorded questionnaire every day regarding the presence of medial elbow pain, limitations to pitching caused by medial elbow pain, and the presence of other injuries and to submit their

questionnaire results to us every month. Furthermore, to verify that participants were completing the daily questionnaires accurately, we called them once or twice each month for confirmation.

### Statistical Analysis

All statistical tests were 2-sided with a significance level of  $P = .05$ . Baseline characteristics as well as the results of univariate analyses in continuous variables are presented as the mean  $\pm$  standard deviation. Group differences in baseline characteristics between the apophysitis and no-apophysitis groups were evaluated using the Mann-Whitney  $U$  test for contentious data and the chi-square test for categorical data. To confirm whether asymptomatic medial epicondyle apophysitis was a risk factor for elbow injuries and to calculate the odds ratio (OR) and 95% CI, a logistic regression analysis was conducted, after adjustment for significant variables determined from univariate analyses. Variables for the model were selected, based on the results of univariate analyses ( $P < .1$ ).<sup>13</sup> To avoid multicollinearity, Pearson correlation coefficients were calculated for the candidates of explanatory variables, and significantly correlated variables were then removed.

A previous statistical power analysis for the logistic regression analysis indicated that 70 participants would be needed to detect statistical significance, based on a statistical power of 80% at an  $\alpha$  level of .05 (ie, assumptive incidence rate, 20%; OR, 2.5).<sup>27</sup> To confirm the statistical power of the logistic regression analysis, we conducted a post hoc power analysis using G\*Power Version 3.1.9.4 (Heinrich Heine University).<sup>4</sup> All other statistical analyses were conducted with SPSS Statistics Version 25 (IBM).

## RESULTS

### Participants

In total, 229 baseball players participated in annual medical checkups for 2 consecutive years. We excluded 19 players because of a history of elbow pain. Thus, 210 youth baseball players were enrolled in this study.

### Results of Preseason Examination

**Ultrasound Findings.** We found that 59 players had ultrasound evidence of medial epicondyle apophysitis in the dominant elbow at the time of preseason screening. During the 1-year observation period, elbow injury occurred in 17 of 59 (28.8%) players in the apophysitis group and 18 of 151 (11.9%) players in the no-apophysitis group ( $P = .003$ ,  $\chi^2$  test).

**Baseline Characteristics, ROM, and Muscle Strength.** The results of the preseason screening measurements are shown in Table 1. No significant differences existed between the apophysitis and no-apophysitis groups in age, height, weight, or playing position. On the dominant side, the ABER and the total arc were significantly lower in the

TABLE 1  
Characteristic Data and Changes in the Medial Elbow Joint Space in Each Condition<sup>a</sup>

Variable	Medial Epicondyle Apophysitis (n = 59)	No Apophysitis (n = 151)	P
Baseline characteristics			
Age, y	10.4 $\pm$ 1.2	10.3 $\pm$ 1.2	.949
Height, cm	143.1 $\pm$ 9.8	141.0 $\pm$ 9.3	.154
Weight, kg	35.8 $\pm$ 8.4	35.2 $\pm$ 8.5	.641
Position played, n			.142
Pitcher	10	18	
Catcher	10	14	
Fielder	39	119	
Findings on ultrasonography			
Capitellum on dominant side, n			.549
Normal	57	148	
Abnormal	2	3	
Elbow and shoulder ROM, deg			
Elbow extension	6.0 $\pm$ 6.7	6.7 $\pm$ 5.6	.413
Elbow flexion	140.7 $\pm$ 5.8	139.7 $\pm$ 6.2	.295
ABER on dominant side	112.0 $\pm$ 15.1	118.7 $\pm$ 13.2	.002 <sup>b</sup>
Difference in ABER	6.7 $\pm$ 12.0	6.9 $\pm$ 12.1	.949
ABIR on dominant side	44.7 $\pm$ 15.0	47.0 $\pm$ 13.1	.261
Difference in ABIR	-8.6 $\pm$ 12.6	-6.4 $\pm$ 14.4	.294
Total arc on dominant side	156.7 $\pm$ 22.8	165.7 $\pm$ 19.9	.005 <sup>b</sup>
Difference in total arc	-1.9 $\pm$ 14.4	0.5 $\pm$ 16.7	.338
HA on dominant side	19.6 $\pm$ 10.1	20.6 $\pm$ 10.7	.527
Difference in HA	-9.0 $\pm$ 9.2	-9.2 $\pm$ 10.3	.917
Shoulder strength			
ABD on dominant side, kg	8.9 $\pm$ 3.8	7.0 $\pm$ 2.9	.001 <sup>b</sup>
ABD ratio	1.0 $\pm$ 0.1	1.0 $\pm$ 0.2	.893
PER on dominant side, kg	13.0 $\pm$ 5.1	11.0 $\pm$ 4.4	.006 <sup>b</sup>
PER ratio	1.1 $\pm$ 0.2	1.1 $\pm$ 0.2	.825
PIR on dominant side, kg	14.6 $\pm$ 7.0	11.8 $\pm$ 5.2	.006 <sup>b</sup>
PIR ratio	1.0 $\pm$ 0.2	1.1 $\pm$ 1.1	.631
PER/PIR ratio	0.9 $\pm$ 0.2	1.0 $\pm$ 0.2	.300

<sup>a</sup>Continuous variables are presented as mean  $\pm$  SD. ABD, abduction; ABER, abducted external rotation; ABIR, abducted internal rotation; HA, horizontal adduction; PER, prone external rotation; PIR, prone internal rotation; ROM, range of motion.

<sup>b</sup>Statistically significant difference between groups ( $P < .05$ ).

apophysitis group versus the no-apophysitis group (ABER: 112.0°  $\pm$  15.1° vs 118.7°  $\pm$  13.2°, respectively;  $P = .002$ ; total arc: 156.7°  $\pm$  22.8° vs 165.7°  $\pm$  19.9°, respectively;  $P = .005$ ). Shoulder strength on the dominant side, based on ABD, PER, and PIR, was significantly greater in the apophysitis group versus the no-apophysitis group (ABD: 8.9  $\pm$  3.8 vs 7.0  $\pm$  2.9 kg, respectively;  $P = .001$ ; PER: 13.0  $\pm$  5.1 vs 11.0  $\pm$  4.4 kg, respectively;  $P = .006$ ; PIR: 14.6  $\pm$  7.0 vs 11.8  $\pm$  5.2 kg, respectively;  $P = .006$ ). No significant differences in the remaining variables were found between the groups.

### Logistic Regression Analysis

Based on the results of univariate analyses ( $P < .1$ ), the candidate explanatory variables for the logistic regression were ABER ROM, total arc ROM, ABD strength, PER

TABLE 2  
Results of Logistic Regression Analysis

	Odds Ratio (95% CI)	P
Medial epicondyle apophysitis	2.488 (1.152-5.376)	.020 <sup>a</sup>
Abducted external rotation on the dominant side	0.963 (0.936-0.992)	.012 <sup>a</sup>

<sup>a</sup>Statistically significant difference between groups ( $P < .05$ ).

strength, and PIR strength of the dominant shoulder. To avoid multicollinearity, Pearson correlation coefficients showed that the total arc ROM of the dominant shoulder was significantly correlated with ABER ROM of the dominant shoulder ( $r = 0.769$ ,  $P < .01$ ) and that the strength of ABD of the dominant shoulder was significantly correlated with the strength of the PER and the PIR of the dominant shoulder ( $r = 0.885$ ,  $P < .01$ , and  $r = 0.865$ ,  $P < .01$ , respectively). The total arc ROM and the PER strength and PIR strength of the dominant shoulder were removed from the explanatory variables.

Logistic regression analysis showed that medial epicondyle apophysitis was a significant independent risk factor for elbow injuries (OR, 2.488; 95% CI, 1.152-5.376;  $P = .02$ ) after adjustment for the effect of ABER on the dominant side, which was also a significant independent risk factor (OR, 0.963; 95% CI, 0.936-0.992;  $P = .012$ ) (Table 2). These results demonstrated that in comparison with players with no medial epicondyle apophysitis, players with preseason ultrasound findings of apophysitis had an approximately 2.5 times higher risk for elbow injury in the following season. Pitchers with asymptomatic medial epicondyle apophysitis had a 22% risk reduction (adjusted OR, 0.780) if they had an improvement of 6.7° in ABER on the dominant side.

### Post Hoc Power Analysis

The post hoc power analysis of the logistic regression analysis indicated that the power of the analysis in the present study was 1.00. This result indicated that the sample size in the present study was sufficient to test the aim of our study.

### DISCUSSION

In this study, we aimed to determine whether the preseason presence of asymptomatic medial epicondyle apophysitis was a risk factor for in-season elbow injuries in youth baseball players. The most important finding of the present study was that medial epicondyle apophysitis was a significant independent risk factor for elbow injuries. A deficit of ABER on the dominant side was also an independent factor (apophysitis group,  $112.0^\circ \pm 15.1^\circ$ ; no-apophysitis group,  $118.7^\circ \pm 13.2^\circ$ ). The risks for elbow injury in the following season were approximately 2.5 times higher if ultrasonography revealed the presence of medial epicondyle apophysitis than if ultrasonography revealed no injury. A risk reduction

of 22% occurred when the ROM ABER on the dominant side of players with apophysitis improved to the same ROM ABER on the dominant side of players in the no-apophysitis group. Furthermore, these results were supported by a post hoc power of 100%.

### Medial Epicondyle Apophysitis

Studies on asymptomatic medial epicondyle abnormality are limited. Pennock et al<sup>14</sup> prospectively investigated 26 asymptomatic Little League players, aged 10 to 13 years, and demonstrated that abnormal elbow findings on MRI were significantly associated with year-round playing (playing  $\geq 8$  months a year) and working with a private coach. Furthermore, those investigators reported a significant association between a history of pain and year-round play, but there was no significant correlation between abnormal MRI findings and playing position, baseball experience, history of elbow pain, or compliance with throwing guidelines. The authors additionally investigated the same participants in the next season and reported that 48% had MRI abnormalities in the dominant elbow and 28% experienced arm pain during the season.<sup>15</sup> In that study, year-round playing was a significant risk factor for postseason elbow MRI abnormalities, and no significant association was observed between postseason elbow MRI abnormalities and number of games, position, pitch counts, pitch innings, pitch types, private coaching, or any physical examination findings, including ROMs of the shoulder and elbow.

Lee et al<sup>9</sup> demonstrated that a medial epicondylar lesion was detected with ultrasonography in 7.0% of all baseball players aged 12 to 18 years and that a medial epicondylar lesion was significantly associated with a deficit in shoulder ABER. Matsuura et al<sup>12</sup> reported that approximately 60% of youth baseball players who experienced elbow pain during the season already had radiographic abnormalities such as osteochondritis dissecans of the capitellum and medial epicondylar fragmentation. Those investigators conducted postseason radiographic examinations (ie, after the incidence of elbow pain during the season) for only the players who experienced elbow pain during the baseball season. Harada et al<sup>5</sup> prospectively observed all baseball players aged 9 to 12 years and demonstrated that medial epicondylar fragmentation and osteochondritis dissecans were detected by ultrasonography in 19.7% and 0.7% of players, respectively. Harada et al used ultrasonography only to identify elbow injury rather than to determine the candidate risk factors. In a prospective study to detect physical risk factors for medial elbow injury in junior baseball players, Sakata et al<sup>17</sup> defined medial elbow injury as medial elbow pain when throwing and abnormal ultrasound findings or elbow pain in the clinical assessment, which were evaluated during the season. They also used ultrasonography only to identify elbow injury rather than to determine candidate risk factors.

The existence of imaging abnormalities in asymptomatic elbows has not been evaluated in previous studies. In the present study, we clarified that asymptomatic medial epicondyle apophysitis was a significant independent risk factor for elbow injuries during the season

among 7- to 12-year-old youth baseball players who had no prior elbow pain at preseason, and we demonstrated that the presence of asymptomatic medial epicondyle apophysitis increased risk of the elbow injury by 2.5 times compared with elbows without apophysitis. Based on our results, we cannot determine why asymptomatic medial epicondyle apophysitis increases the risk of elbow injury. However, a few potential explanations exist. One key finding was that the shoulder ABER deficit was also an independent, significant risk factor for elbow injury. Asymptomatic medial epicondyle apophysitis itself was a risk factor, although other factors such as worsening physical conditions may work together with asymptomatic medial epicondyle apophysitis and may then evoke elbow pain. Thus, asymptomatic medial epicondyle apophysitis may coexist without any elbow pain under specific physical conditions, such as sufficient mobility and strength in the shoulder, scapula, trunk, hip, and ankle, because players who had asymptomatic medial epicondyle apophysitis were able to play without any elbow problem until the elbow pain occurred. Therefore, specific physical conditions should be identified to prevent baseball players from being in a situation that precludes throwing. Another potential explanation is that ultrasound findings seem to predate the clinical symptoms. This might be because players ignore symptoms until they are sufficiently severe enough to limit throwing ability.

It is also important to note that 71.9% of players with positive findings on ultrasonography did not develop pain. Future research may help identify other factors that contribute to the development of symptoms in certain players.

### Elbow Injury and Deficit in Shoulder ABER and Total Arc

Camp et al<sup>3</sup> demonstrated that a preseason shoulder ABER deficit was an independent risk factor for elbow injuries during the upcoming season in professional baseball players. Harada et al<sup>5</sup> reported that a deficit in shoulder ABER (OR, 1.98) was a risk factor for elbow injury among young baseball players. However, Wilk et al<sup>26</sup> demonstrated that neither an ABER deficit nor an ABIR deficit was correlated with elbow injuries in professional baseball pitchers. Those investigators also reported that professional baseball pitchers whose shoulders had a deficit of  $>5^\circ$  in total rotation on the dominant side had a 2.6 times greater risk for elbow injury. In the present study, decreased ABER on the dominant side was a significant independent risk factor (OR, 0.963). To compare with previous studies,<sup>5,26</sup> we calculated the OR in the present study. The calculated OR was 1.203 when a  $5^\circ$  decrease in the ABER existed. The effect of elbow injury on the deficit of ABER in the present study was smaller than that reported in previous studies.<sup>5,26</sup> This finding may have been due to differences in the maturity of participants and their performance level. The results in the present study indicated that correcting ABER deficits may reduce the risk of elbow injury in players with abnormalities on

ultrasonography. Thus, it is necessary to investigate in future studies whether conditioning and training, such as shoulder stretching to improve ABER deficits, reduces risk for elbow injury.

### Shoulder Strength and Elbow Injury

Harada et al<sup>5</sup> found that greater shoulder muscle strength, which was evaluated with the participant seated (external rotation  $>80$  N [8.2 kg] and internal rotation  $>100$  N [10.2 kg]), was a risk factor for elbow injury. In professional baseball pitchers, PER strength was significantly associated with throwing-related injuries requiring surgical intervention.<sup>2</sup> In high school baseball pitchers, Shitara et al<sup>18</sup> demonstrated that the ratio of PER on the dominant side versus the nondominant side was an independent risk factor for shoulder and elbow injury. In the present study, greater ABD, PER, and PIR values were significantly associated with elbow injury in the univariate analysis but were not independent risk factors. These results are in partial agreement with the findings of Harada et al,<sup>5</sup> although the position in which players were measured differed (seated in the Harada study vs prone in the current study). The contrasting results between young baseball players and high school and professional baseball pitchers may be caused by whether the growth plate on the medial elbow joint was open or closed.

Because the majority of players with abnormalities on ultrasonography did not experience elbow injury, the factors that change asymptomatic medial epicondyle apophysitis to symptomatic medial epicondyle apophysitis should be investigated in the future. Identifying other associated risk factors is important to determine which players need closer monitoring and to design injury prevention programs for baseball-related injuries. Further, certain players with higher risk factors for elbow injury based on position (pitchers and catchers), throwing volume, or higher velocity should undergo preseason ultrasonography. Moreover, if medial epicondylar abnormalities are identified, these players should be kept on a strict pitch count program.

### Limitations

This study had some limitations. First, we did not analyze which risk factors (eg, playing for multiple teams, pitch velocity, and arm fatigue) exacerbate asymptomatic medial epicondyle apophysitis to the level of a symptomatic elbow problem. Studies focusing on only athletes who have asymptomatic medial epicondyle apophysitis without any prior elbow pain will be required to address this issue. Second, we did not perform ultrasonography after the onset of pain to determine whether players with no injury on ultrasonography developed abnormalities or whether there were changes in the abnormalities of players with preseason findings. Third, the progression of medial epicondyle apophysitis was not evaluated because qualitative assessment was applied in this study. However, we did evaluate the medial epicondyle when the participants returned for their medical checkup at the beginning of the next season, and we confirmed that no

severe problems existed that needed an intervention such as surgery. To address this issue, severity grading should be used for the evaluation of medial epicondyle apophysitis. Fourth, we did not evaluate external load, such as the number of innings participants had played and how much training they had or how many hours they spent in competition. In the future, a comprehensive study should be performed to examine independent variables that may affect elbow injuries (eg, innings pitched per game, showcase participation, games per year, training days per week, pitch type, shoulder external rotation, shoulder total ROM, weight, months of pitching per year, innings or pitches per year, catching, shoulder HA, and glenohumeral internal rotation deficit). Fifth, the precise cause of elbow injury was unclear (medial epicondylar pathology, UCL injury, or other) because we did not evaluate the elbow when the injury occurred. To investigate the cause of medial elbow pain, an imaging evaluation will be required in real time.

## CONCLUSION

We demonstrated that medial epicondyle apophysitis was a significant independent risk factor for elbow injuries in baseball players aged 7 to 12 years. A deficit in ABER on the dominant side was also a significant independent risk factor. The risks for the elbow injury in the following season were calculated as approximately 2.5 times higher in players with medial epicondyle apophysitis than in players without apophysitis. This prospective study is the first to provide evidence that asymptomatic medial epicondyle apophysitis is a significant independent risk factor for elbow injury in this study population.

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## ACKNOWLEDGMENT

We thank the personnel, players, coaches, and staff of the Gunma High School Baseball Federation for their assistance and cooperation in this study. We also thank Kureha Special Laboratory and the Japan Institute of Statistical Technology for assistance with the statistical analysis. Finally, we thank Editage for its English-language editing.

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