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The relationship between scapular position and glenohumeral rotational range of motion in high school baseball players

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Background: Past research indicated that scapular malposition is related to the glenohumeral internal rotation deficit (GIRD). However, there is no research examining the effect of throwing-related pain on this relationship. This study investigated the relationship between scapular position and range of motion (ROM) and compared the difference in this relationship between with and without throwing-related pain.

Methods: Forty male baseball players in high school were recruited for this study. The existence and degree of throwing-related pain were obtained from a questionnaire. Participants were divided into 2 groups according to the presence or absence of the pain. Glenohumeral internal and external rotation ROM (abduction internal rotation angle and abduction external rotation angle [ABER], respectively) were measured using a digital inclinometer. The pectoralis minor muscle length was measured using a vernier caliper and scapula index, which indicated the scapular position, measured using a measuring tape. All these measurements were taken on both dominant and nondominant sides. The GIRD and total motion arc (TMA) deficit were calculated from the ROM measurements. Groups were compared using a mixed-model analysis of variance.

Results: There was a significant interaction between group and ABER dominance. Other variables were not seen as the interaction effect. There was a significant positive correlation between the scapula index and TMA ($r = 0.47$, $P = .02$) and a negative correlation between the scapula index and GIRD ($r = -0.65$, $P < .01$) in the dominant side of the pain group. In addition, in the nondominant side of the pain group, the scapula index and ABER were significantly correlated ($r = 0.43$, $P = .04$).

Conclusions: The results of this study indicate that the scapular position is associated with the glenohumeral ROM in high school baseball players. In addition, this study demonstrated that the scapular internally rotated position was correlated with the GIRD and TMA deficit in high school baseball players who had throwing-related pain. On the other hand, the scapular externally rotated position was correlated with increased ABER, mainly in the pain-free baseball players or on the nondominant side. These results indicated that the scapular position might affect the glenohumeral rotational ROM in high school baseball players.

The ethics committee of Kyoto Tachibana University has approved this study (approval no. 15-04).

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The shoulder joint is the most susceptible to throwing injuries,[12,25,42] such as rotator cuff tear, biceps tendinitis, labrum tear, or internal impingement,[7,8,43,48] for baseball players. Throwing injuries cause a decrease in throwing performance (lack of control, reduction of ball velocity, etc.), withdrawal, or retirement from baseball.[1,15] Therefore, clarifying the causes of throwing injuries is essential for effective prevention or treatment of these injuries.

The throwing motion is one of the body's fastest and most stressful activities, especially in the upper extremity. The maximum humeral internal rotation (IR) velocity in the acceleration phase of the throwing motion reaches approximately 7000°-8000° per second,[14,16] followed by adaptive changes in soft tissue, such as microtrauma and thickening, which occur at the posterior portion of the shoulder. Thomas et al[44] reported that collegiate baseball players had thicker posterior shoulder capsules on the dominant side of their body compared with the nondominant side, and the thickness was associated with glenohumeral internal rotation deficit (GIRD). Therefore, these adaptive changes, such as posterior glenohumeral joint capsule thickness and/or decreased flexibility,[6,44] are thought to cause GIRD.[8,32,47] Another adaptive change is the uniformness of the scapular position between the dominant and nondominant sides of the body, and this is common in overhead athletes.[13,38,44] Oyama et al[38] reported that healthy college-aged overhead athletes, consisting of baseball pitchers, volleyball players, and tennis players, had more scapular internally rotated, anterior tilted, and protraction positions on the dominant side compared with the nondominant side. Hodgins et al[21] reported that the tightness of the pectoralis minor muscle is a cause of the scapular position change. Therefore, each adaptive change has a reason. However, the scapula has a function as a stable base for the upper extremity;[26] therefore, the scapular position change could affect the glenohumeral joint function.

Itami et al[23] reported that increased scapular IR position decreased glenohumeral external rotation range of motion (ROM) because of internal impingement and increased elbow valgus load to compensate for the decreased ROM simulating the acceleration phase of throwing motion. Furthermore, Mihata et al[33] reported that increased scapular IR position increases glenohumeral contact pressure. These 2 studies are cadaveric, but increases in scapular IR position may restrict glenohumeral rotation ROM and cause throwing-related shoulder and elbow injuries.

Previous research has highlighted the relationship between scapular position and glenohumeral ROM. Laudner et al[30] found the relationship between scapular forward posture and glenohumeral horizontal abduction ROM in 40 professional baseball players. It concluded that posterior shoulder tightness (PST) might partially predict excessive forward scapular posture. The relationship between the scapular anterior tilt angle in static posture and glenohumeral IR ROM has been documented.[1] Ribeiro and Pascoal[40] reported that this anterior scapular tilt is observed more in overhead players on the dominant side when engaging in active IR motion of the glenohumeral joint with the arm abducted. However, subjects of this research were healthy, as those who had shoulder pain or throwing-related pain were excluded.

In addition, to our knowledge, there is no research regarding the relationship between the degree of scapular IR and glenohumeral ROM. The increase of scapular IR is one of the adaptive changes with repetitive ball throwing. Then the degree of scapular IR change could affect the glenohumeral ROM as the anterior scapular tilt does. This study investigated the relationship between the scapular position and glenohumeral ROM and examined the differences between with and without throwing-related pain. This study hypothesizes that (1) IR ROM and total motion arc (TMA) are restricted in the pain group, and (2) glenohumeral rotation ROM and TMA are restricted along with increased scapular IR position.

Materials and methods

Research design

We used a case-control study design to assess the relationship between the scapular position and glenohumeral ROM and examined the differences between with and without throwing-related pain. This study was conducted during the winter offseason of the school in which there is no baseball game because it is believed that the game has effects such as ROM restriction and tightness of the muscles on the players. Those effects have resulted in the accuracy of the test, such as glenohumeral ROM, pectoralis minor muscle length, and scapula index.

Participants

An a priori power analysis was calculated using G*Power 3.1.9.7 software. Parameters for power estimates are as follows: $\alpha = 0.05$, $1 - \beta = 0.8$; the size effect was determined by group means and standard deviations from the first 3 participants' data in both groups. An estimate of sample size for the scapula index was 20 in both groups. Forty male high school baseball players were

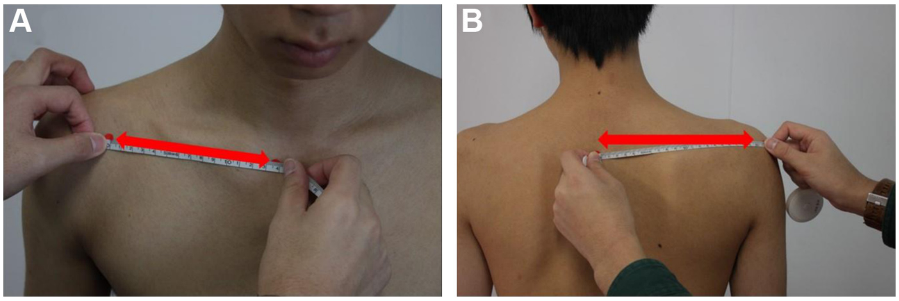

Figure 1 Measurement of the scapula index. (**A**) Measurement of the distance between the sternal notch and the coracoid process. (**B**) Measurement of the distance between the posterolateral corner of the acromion and the thoracic spine.

recruited for this study. The inclusion criteria were male high school baseball players with more than 3 years of playing experience. Exclusion criteria consisted of a record of shoulder or elbow surgery. Before testing, a customized self-administered questionnaire regarding the player's age, height, weight, throwing side (dominant side), duration of baseball playing experience, playing position (pitcher, catcher, infielder, outfielder), and throwing-related pain on the dominant side of the shoulder or elbow at the measurement was completed. The visual analog scale (VAS) was used to determine the degree of throwing-related pain. Participants who had the pain of at least 1 mm of VAS were allocated to the pain group. Twenty-three players (age: 16.4 $\pm$ 0.6 years, height: 170.5 $\pm$ 5.3 cm, weight: 67.6 $\pm$ 8.0 kg) had a throwing-related pain (pain group), and 17 players (age: 16.2 $\pm$ 0.6 years, height: 170.6 $\pm$ 6.0 cm, weight: 69.2 $\pm$ 8.2 kg) had no pain during ball throwing (pain-free group). The pain group consisted of 12 shoulders and 11 elbow pain participants.

Measurements

In this study, all measurements were taken before the daily practice of baseball to minimize the effect of the ball throw. The measurement consists of glenohumeral ROM, pectoralis minor muscle length, and scapular position.

Glenohumeral range of motion

The glenohumeral ROM was evaluated in a supine position with the subject's shoulder abducted at 90°, elbow flexed at 90°, and forearm in a neutral position. A researcher then held the participant's shoulder, placing the thumb on the coracoid process (CP) and the other 4 fingers on the posterior surface of the scapula. In contrast, the other hand secured the participant's wrist and rotated the shoulder internally and externally. During the measurements, 1 more researcher fixed a digital inclinometer with an accuracy of 0.1° (Shinwa Rules, Sanjo, Japan) to the participant's forearm to assess the glenohumeral abduction IR angle (ABIR) and abduction ER angle (ABER). Two physiotherapists performed this measurement for both the dominant and nondominant sides once. The sum of the ABIR and ABER was defined as the TMA. The dominant ABIR was subtracted from the nondominant ABIR to determine the GIRD. The test-retest reliability was preliminarily performed. As a result, 17 healthy shoulders were measured three times in 1 day; the ABIR's intraclass correlation coefficient (1.3) and standard error of mean values were 0.98° and 3.9°, respectively, whereas the ABERs were 0.97° and 4.4°, respectively.

Pectoralis minor muscle length

The pectoralis minor muscle length was defined as the difference between the sternocostal joint of rib 4 (Rib 4) and the CP (Rib 4-CP distance).[4] The validity of this measurement was examined using fresh cadavers and validly revealed the muscle length. Palpation was used to denote Rib 4 and CP. To identify Rib 4, the first sternocostal joint was denoted. Rib 4 was then determined by moving down along the joints individually. Palpation was also used to identify the CP. The distance between Rib 4 and CP, which demonstrated the pectoralis minor muscle length, was measured using a vernier caliper (Shinwa Rules) with an accuracy of 0.01 mm.[41]

The landmarks were palpated and affirmed before the values were obtained to reduce skin movement. Participants were told to sit in a chair without a backrest and preserve a natural but unrounded body position with their upper extremities relaxed. Participants were instructed to sit on a chair without a backrest and maintain a neutral and not too upright or rounded posture with their upper extremities relaxed. The participants were also instructed not to breathe deeply and fix their gaze on a point in front to prevent measurement errors. The foot position was not standardized during the measurements, but all the participants took the sitting position with their hips and knees flexed at 90°. No participants took any abnormal foot positions that affected the measurements. Readings were performed once by a physiotherapist. The intraclass correlation coefficient and standard error of mean values were 0.93 and 0.2 cm, respectively.

Scapular position

An investigator calculated the length from the participant's sternal notch (SN) to the CP (SN-CP distance) while he or she was seated in a neutral sitting position on a chair without a backrest. The span from the posterolateral corner of the acromion (PLA) to the thoracic spine (TS) at the same level was measured to define the PLA-TS distance. The SN-CP and PLA-TS distances were measured using a tape rule (Figure 1). The scapula index, indicating the scapular position due to pectoralis minor tightness, was calculated using the following equation: scapula index = (SN $-$ CP distance/PLA $-$ TS distance) $\times$ 100. The scapula index measures the scapular internally/externally rotated position, which was first proposed by Borstad.[3] The scapula index help measure the scapular position because it is correlated with scapular IR as measured using a 3-dimensional motion capture system. In this measurement, a higher value means the scapula is at a more externally rotated position and vice versa.

Table I Participant demographics

	Pain group (n = 23)	Pain-free group (n = 17*)	*P* value (95% CI)
Age (yr)	16.4 ± 0.6	16.2 ± 0.6	.38 (−0.6 to 0.2)
Height (cm)	170.5 ± 5.3	170.6 ± 6.0	.94 (−3.5 to 3.8)
Weight (kg)	67.6 ± 8.0	69.2 ± 8.2	.55 (−3.7 to 6.8)
Throwing pain (mm)	35.4 ± 28.0	0	**<.01 (−47.6 to −23.3)**
Body site (number)	Shoulder: 12 Elbow: 11		
Playing experience (yr)	7.8 ± 1.8	7.8 ± 2.2	.92 (−1.3 to 1.2)
Position (number)			
Pitcher	6	5	
Catcher	3	0	
Infielder	7	8	
Outfielder	7	6	

95% CI, 95% confidence interval.
Age, height, weight, throwing pain, and playing experience were expressed as mean ± standard deviation.
Bold values indicate statistical significance.
* Two players in the pain-free group play pitcher and infielder.

Data analysis

ABIR, ABER, TMA, Rib4-CP distance, and scapula index were examined using a 2-factor mixed-model analysis of variance in the 2 groups (pain and pain-free groups). Within-subject factor was the dominance of the participants. A statistically significant interaction effect was examined by comparing a simple main effect of the group factor with the dominance factor. Demographic data and GIRD were compared using the unpaired *t*-test between 2 groups. The Pearson correlation coefficient was used to examine the relationship between each group's scapula index, pectoralis minor muscle length, and ROM. All statistical analysis was carried out using SPSS v.20.0 (IBM, Armonk, NY, USA) at a 5% level of error.

Results

Demographic data of participants in both groups are given in Table I. There were no significant differences in age, height, and playing experience between the 2 groups. The mean VAS score of throwing-related pain was 35.4 ± 28.0 in the pain group, and 23 participants (57.5%) had throwing-related pain. There was a significant interaction between group and dominance for ABER regarding each variable. Comparison of the simple main effect by group demonstrated a significant difference in ABER (df = 1; F = 6.28; P = .02). The pain group had a significantly lower ABER than the pain-free group (Table II). In the ABIR, TMA, Rib4-CP distance, and scapula index, interaction effects were not seen, and there was a significant main effect for the dominance.

There was a significant positive correlation between the scapula index and TMA (r = 0.47, P = .02) and a negative correlation between the scapula index and GIRD (r = −0.65, P < .01) in the dominant side of the pain group (Table III). In the nondominant side of the pain group, the scapula index and ABER were significantly correlated (r = 0.43, P = .04) (Table IV). There was no significant correlation between the scapula index and ROM on the

Table II Comparison of each variable between pain group and pain-free group

	df	F ratio	*P* value	Pain group (n = 23)	Pain-free group (n = 17)
ABIR*					
Dominant				26.9 ± 9.1	27.1 ± 8.7
Nondominant				34.8 ± 6.7	36.1 ± 10.6
ABER*,†					
Dominant	1	6.28	**.02**‡	115.6 ± 9.4	122.8 ± 8.3
Nondominant	1	0.26	.62	108.1 ± 9.8	109.6 ± 7.5
TMA					
Dominant				142.6 ± 14.1	150.0 ± 10.4
Nondominant				142.9 ± 10.9	145.7 ± 11.6
GIRD	38		.71	7.9 ± 9.6	9.0 ± 9.1
Rib4-CP*					
Dominant				17.6 ± 1.2	17.7 ± 1.4
Nondominant				18.2 ± 1.4	18.1 ± 1.4
Scapula index*					
Dominant				60.6 ± 3.0	59.1 ± 3.2
Nondominant				62.6 ± 4.9	61.2 ± 3.4

ABIR, abduction internal rotation angle; *ABER*, abduction external rotation angle; *TMA*, total motion arc; *GIRD*, glenohumeral internal rotation deficit; *Rib4-CP*, distance from the sternocostal joint of rib 4 to the coracoid process; *df*, degree of freedom.
Data are expressed as mean ± standard deviation.
The degree of freedom, F ratio, and *P* value were not calculated because there was no statistically significant interaction effect in ABIR, TMA, Rib4-CP, and scapula index.
GIRD was compared using the unpaired *t*-test.
Bold values indicate statistical significance.
* Indicates a statistically significant main effect for dominance.
† Indicates a statistically significant main effect for the group.
‡ Indicates a statistically significant difference between groups. Results are from the mixed-model analysis of variance due to a statistically significant interaction effect between group and dominance.

Table III Correlation matrix between each variable on the dominant side of the pain group

	ABIR	ABER	GIRD	TMA	Rib4-CP
ABER	0.167 (.447)				
GIRD	**−0.746* (<.01)**	−0.26 (.230)			
TMA	**0.754* (<.01)**	**0.773* (<.01)**	**−0.653* (<.01)**		
Rib4-CP	**0.529 (<.01)**	0.253 (.245)	**−0.649* (<.01)**	**0.509† (.013)**	
Scapular index	0.326 (.130)	0.396 (.062)	**−0.649* (<.01)**	**0.473† (.023)**	0.334 (.119)

ABER, abduction external rotation angle; *GIRD*, glenohumeral internal rotation deficit; *TMA*, total motion arc; *Rib4-CP*, distance from the sternocostal joint of rib 4 to the coracoid process; *ABIR*, abduction internal rotation angle.
Data are presented as r value (*P* value).
Bold values indicate statistical significance.
* P < .01.
† *P* < .05.

Table IV Correlation matrix between each variable on the nondominant side of the pain group

	ABIR	ABER	GIRD	TMA	Rib4-CP
ABER	−0.169 (.442)				
GIRD	**0.422* (.045)**	−0.373 (.080)			
TMA	**0.460* (.027)**	**0.798† (<.01)**	−0.078 (.724)		
Rib4-CP	−0.359 (.093)	0.189 (.388)	**−0.652† (<.01)**	−0.050 (.822)	
Scapular index	−0.364 (.088)	**0.428* (.041)**	**−0.627† (<.01)**	0.163 (.457)	**0.560† (<.01)**

ABER, abduction external rotation angle; *GIRD*, glenohumeral internal rotation deficit; *TMA*, total motion arc; *Rib4-CP*, distance from the sternocostal joint of rib 4 to the coracoid process; *ABIR*, abduction internal rotation angle.
Data are presented as r value (*P* value).
Bold values indicate statistical significance.
* *P* < .05.
† *P* < .01.

dominant side in the pain-free group (Table V). However, a trend of nonsignificant correlation between the scapula index and ABER was seen on the nondominant side ($r = 0.48$, $P = .05$) (Table VI).

Discussion

The main findings of this study are as follows: (1) the scapular internally rotated position is associated with GIRD and TMA deficit in the pain group, (2) this association is not seen in the pain-free group, and (3) ABER is significantly decreased in the pain group compared with that in the pain-free group.

The scapula index had been proposed to indicate the scapular internally/externally rotated position, wherein a greater degree of the scapula index indicates that the scapula is at a more externally rotated position. Therefore, the results of this study suggest that the scapular internally rotated position is associated with GIRD and TMA deficit in baseball players who have throwing-related shoulder or elbow pain. The increased scapular internal rotated position or anteriorly tilted position is associated with the glenohumeral ABIR deficit.[27,49] Ribeiro and Pascoal[40] reported a relationship between the scapular anterior tilted position and decreased glenohumeral ROM when the subjects were instructed to move their arm actively. Borich et al[2] reported that the throwing athletes who have the GIRD had a significantly greater scapular anterior tilt during active arm movement than athletes who have no IR ROM deficit. Many researchers had thought that PST or GIRD is a cause of scapular malposition. However, Kibler[26] described that the scapula is a stable base for the upper extremity, and it is possible to assume that the scapular positional change could affect glenohumeral ROM. Itami et al[23] reported that increased scapular internally rotated position significantly decreased glenohumeral rotational ROM because of internal impingement occurrence. Past research reported that the glenohumeral ROM deficit, such as GIRD or TMA deficit, is thought to cause throwing injuries. Therefore, the result of this study suggests that the scapular internally rotated position could be a cause of GIRD or TMA deficit, leading to throwing injuries.

Scapula index and ABER were significantly correlated with the nondominant side of the pain group. In addition, the exact relationship trend was observed on the dominant side of the pain group and the nondominant side of the pain-free group, although not significant ($P = .06$ and .05, respectively). In this study, a rolled towel was not placed under the participants' arms during the measurement of ROM to obtain an adequate glenohumeral horizontal abduction position.[28] Therefore, glenohumeral horizontal

Table V Correlation matrix between each variable on the dominant side of the pain-free group

	ABIR	ABER	GIRD	TMA	Rib4-CP
ABER	−0.25 (.33)				
GIRD	−0.29 (.27)	0.16 (.55)			
TMA	**0.63*** (**<.01**)	**0.59†** (**.01**)	−0.11 (.67)		
Rib4-CP	−0.23 (.39)	**0.49†** (**.04**)	0.15 (.56)	0.21 (.43)	
Scapular index	0.24 (.35)	−0.17 (.51)	−0.14 (.59)	0.05 (.85)	**0.734*** (**<.01**)

ABER, abduction external rotation angle; *GIRD*, glenohumeral internal rotation deficit; *TMA*, total motion arc; *Rib4-CP*, distance from the sternocostal joint of rib 4 to the coracoid process; *ABIR*, abduction internal rotation angle.
Data are presented as r value (P value).
Bold values indicate statistical significance.
* $P < .01$.
† $P < .05$.

Table VI Correlation matrix between each variable on the nondominant side of the pain-free group

	ABIR	ABER	GIRD	TMA	Rib4-CP
ABER	−0.21 (.42)				
GIRD	**0.62*** (**<.01**)	−0.28 (.28)			
TMA	**0.78*** (**<.01**)	0.45 (.06)	0.39 (.13)		
Rib4-CP	0.10 (.71)	0.32 (.22)	0.14 (.59)	0.29 (.26)	
Scapular index	−0.27 (.29)	0.48 (.054)	−0.02 (.95)	0.06 (.82)	0.37 (.15)

ABER, abduction external rotation angle; *GIRD*, glenohumeral internal rotation deficit; *TMA*, total motion arc; *Rib4-CP*, distance from the sternocostal joint of rib 4 to the coracoid process; *ABIR*, abduction internal rotation angle.
Data are presented as r value (P value).
Bold values indicate statistical significance.
* $P < .01$.

abduction is increased relatively when the participant has a more scapular internally rotated position during ABER measurement. Cieminski et al[11] reported that glenohumeral ROM was restricted when horizontal abduction of the glenohumeral joint increased. They concluded that it is caused by increased soft tissue tension surrounding the glenohumeral joint. Soft tissues surrounding the glenohumeral joint, such as ligaments or joint capsules, restrict the glenohumeral movement.[5,29,34] Higuchi et al[19] reported that stretching the pectoralis minor muscle increases the ABIR, scapular externally rotated, and posteriorly tilted positions. In addition, the degree of the scapular externally rotated position change and the extent of the ABIR increase were significantly correlated. Therefore, increasing the scapular externally rotated position would be a useful option to improve the GIRD and/or TMA deficit for the prevention or treatment of throwing injuries.

There was no significant correlation between the scapular internally rotated position and glenohumeral ROM in the pain-free group, although there is a significant correlation in the pain group. One possible explanation for this difference is that baseball players with glenohumeral ROM, which is susceptible to the scapular position, may be prone to throwing injuries. Tyler et al[46] reported that the preseason supraspinatus weakness is associated with increased shoulder or elbow injury risk in high school baseball players. Furthermore, Byram et al[9] reported that the preseason glenohumeral external rotation muscle strength and supraspinatus weakness are associated with throwing-related injury requiring surgical intervention. These reports suggest that the weakness of the shoulder muscles is a cause of throwing injuries. Huston and Wojtys[22] reported that collegiate athletes had significantly lower joint laxity than noncollegiate athletes. Lower ABER in the pain group obtained in this study may partially indicate the tightness of the shoulder muscles. It may be possible that the participants in the pain group had less muscle strength surrounding the shoulder, leading to much severe muscle tightness induced by repetitive throwing motion. The tightness increases depending on the scapular position to the glenohumeral ROM. However, this study did not evaluate muscle strength and joint laxity, and the theory mentioned above is just speculation. Moreover, the reason why the relationship between the scapular internally rotated position and ABER was seen only for the pain group remains unclear. Further research is needed to determine which factor increases the dependence on the scapular position for the glenohumeral ROM.

In this study, ABER was significantly reduced in the pain group compared with the pain-free group. It has been reported that decreased ABER is associated with shoulder and elbow injuries in baseball players.[10,18,35] Sufficient

ABER for throwing motion is necessary to create IR velocity[20,31] because the maximum IR velocity in the acceleration phase of throwing reaches more than 7000°-8000° per second.[14,16] Furthermore, sufficient ABER decreased elbow valgus stress during throwing motion.[39] Excess IR force for the glenohumeral joint, which is thought to cause throwing-related pain, would be created to compensate for the decreased ABER during throwing. Therefore, interventions aiming to increase the ABER would be beneficial to prevent or treat throwing injuries.

Garrison et al[17] compared high school and collegiate baseball players with and without ulnar collateral ligament tear and reported that players without ulnar collateral ligament tear have 119.7° ± 11.8° in ER ROM and 20.9° ± 6.1° in IR ROM in their dominant shoulder. These results are similar to this study, and it is suggested that the results in this study would be a normative value in high school baseball players. Regarding the scapular position, Borstad[3] reported that the scapula index with the shorter and longer pectoralis minor muscle is 61.3 ± 0.9 and 65.5 ± 1.2, respectively. In this study, the scapula index in the dominant shoulder was 60.6 ± 3.0 in the pain group and 59.1 ± 3.2 in the pain-free group. The results of the scapula index in this study are also similar to the values of Borstad's[3] study. Although a normative value of the scapula index is not established yet, the scapula index obtained in this study would not be considered an outlier.

Several limitations exist in this study. First, the participants of this study were recruited from a local high school baseball team. Therefore, the results of this study do not apply to other sports or age groups. Participants of this study had approximately 7-8 years of baseball experience. This means they started their baseball career when they were around 8 years old. In addition, they have been practicing baseball for 6 days per week. This duration and frequency of exposure to baseball are typical for Japanese baseball players; therefore, the results of this study would not differ from general Japanese high school baseball players. Second, the scapular position was defined only by the scapula index. Anterior/posterior tilting and upward/downward rotation of the scapular position were not measured in this study. However, whether these movements negatively affect the glenohumeral joint is controversial. Muraki et al[36] reported that the increased scapular anterior tilt did not increase the subacromial contact pressure during humeral elevation. Karduna et al[24] reported that the increased scapular upward rotation decreased the subacromial space. Increased subacromial contact pressure or reduced subacromial space is thought to cause shoulder injuries. Therefore, the results of these studies suggested that the impact of the scapular anterior/posterior tilt and upward/downward rotation for shoulder injuries may be more restrictive than is commonly believed. Third, PST and retrotorsion of the humeral head, which are thought to affect the glenohumeral ROM,[37,45] were not measured. Therefore, how much the scapular IR position affects ROM in the dominant side of the baseball players is unclear. Finally, participants were divided by their complaints of throwing-related pain. Further prospective studies with large sample sizes and detecting the cause of throwing-related pain are warranted to address the effect of scapular function on throwing injuries.

Conclusion

This study examined the relationship between the scapular position and glenohumeral ROM and compared this relationship with and without throwing-related pain. Scapular IR position correlated with GIRD and TMA deficit in the players who had throwing-related pain. In addition, the same trend of this correlation was seen in players without throwing-related pain, although it was not statistically significant. These results suggest that the glenohumeral ROM would be much more susceptible to restriction with increased scapular IR position, especially in throwing-related pain players. The restriction of the glenohumeral ROM is thought to be a cause of throwing injuries. It is believed that increasing the scapular external rotation position would be necessary to prevent and treat throwing injuries.

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