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Shoulder ranges of motion and humeral torsions of injured baseball players have different characteristics depending on their pitching sides

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A R T I C L E I N F O

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Level of evidence: Level III; Cross-Sectional Design; Epidemiology Study

Background: Right- and left-side throwers in baseball may have different shoulder conditions and throwing biomechanics. This study aimed to compare the passive range of motion, humeral torsion, and clinical findings between right- and left-handed throwers who sustained throwing shoulder injuries and confirm the differences in the characteristics between throwing sides.

Methods: A total of 52 pitchers diagnosed with throwing shoulder injuries were included in this study: 27 patients were right-side throwers (R group), and 25 were left-side throwers (L group). We measured the bilateral passive external and internal rotation angles in abduction position (ABIR) and total arc at their first visit. To assess posterior shoulder tightness, the internal rotation angles in forward flexion (FIR), and the abduction angle (AA) and horizontal flexion angle (HFA) without scapula motion were measured. The bilateral humeral torsion angles were also measured using ultrasonography. These values were compared between the participants' throwing and non-throwing sides and between the R and L groups' throwing sides. Furthermore, several physical findings in the shoulders were assessed, and the positive ratio was compared between the R and L groups.

Results: On comparing the throwing and non-throwing sides, the R group had significantly greater external rotation angles in the abduction position and humeral torsion angle, and smaller ABIR, total arc, FIR, AA, and HFA in the throwing side, while the L group showed no significant differences, except for a smaller ABIR and larger HFA in the throwing side. On comparing the throwing side between the R and L groups, the R group had a smaller FIR, AA, and FHA than the L group. Regarding the physical findings, the posterior jerk test, Kim test, anterior and posterior drawer sign, sulcus sign, and scapular winging in the L group were significantly more positive than in the R group.

Conclusion: The range of motion and humeral torsions differed between the left- and right-side throwers, as did the pathology between their throwing sides. Clinicians should consider the possibility that the pathological condition differs between left- and right-side throwers.

Baseball is one of the most popular sports not only in North and Latin America but also in Eastern Asia. Baseball includes various actions such as hitting, catching, and throwing the ball. In particular, the throwing action is an extraordinary motion in which the upper limb shifts from an excessive external rotation (ER) to an internal rotation (IR) within a short time during throwing. It has been reported that the range of motion (ROM) of the shoulder joint changes because of repeated throwing motions.[1,10] Jobe reported that baseball players have a larger ER angle and smaller IR angle in the dominant shoulder than in the nondominant shoulder.[10] Reagan et al reported a correlation between increased humeral torsion and ROM change and ER increase and IR decrease.[21] Some reports have stated that the laxity of the anterior capsule and tightness of the posterior capsule are related to these ROM changes.[11,20] Conversely, Burkhart et al reported that players with an excessive glenohumeral IR deficit (GIRD) were predisposed to sustaining throwing injuries, such as type II superior labrum anterior to posterior lesions.[3,4] Morgan et al reported that posterior shoulder

This retrospective study was approved by our institutional review board (permission number: E-2020).

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tightness caused increased postero-superior translation of the humeral head at the late cocking phase and that translation caused internal impingement followed by superior labrum anterior to posterior lesions.[16] However, since the dominant and nondominant throwing sides were compared, right- and left-handed players were mixed in these studies. Few studies have compared ROM and humeral torsion between right- and left-side throwers.[24,25]

In recent years, it has been noted that right-side throwers and left-side throwers in baseball may have different humeral torsions[24,25] and pitching biomechanics.[23,26] If some shoulder ROM or anatomical differences did exist between right- and left-side throwers, the reliability of the previous studies that involved both throwing sides would be expected to decrease. In addition, the pathogenesis of the throwing shoulder injury may differ between the dominant sides. The purpose of this study was to evaluate the differences in several aspects related to shoulder ROM and humeral torsion, as well as the cause of throwing shoulder disorders, and to subsequently compare throwing sides.

Materials and methods

This descriptive epidemiological study was approved by our institutional review board (E-2020). Fifty-two adult patients who were seen at our department for a diagnosis of a chronic throwing shoulder injury were included in the current study. Patients diagnosed with little league shoulders or with acute trauma injuries from playing baseball were excluded. Twenty-seven patients were right-side throwers (R group), and 25 patients were left-side throwers (L group). All players were male pitchers in this study. The average age at consultation was 19.4 ± 2.7 (range 16-24) years in the R group and 20.8 ± 6.9 (range 16-42) years in the L group. The average accumulated baseball experience was 10.6 ± 3.0 (range 6-16) years in the R group and 12.3 ± 6.9 (range 5-33) years in the L group. A summary description of hitting sides or play levels for these groups is shown in Table I. All the patients had improved their symptoms by conservative treatment, such as injection or rehabilitation, and did not undergo any surgical treatments. Therefore, exact structural diagnoses were not demonstrated despite some labrum disorders observed by ultrasonographic examination or magnetic resonance imaging.

For all patients, the ROMs in ER and IR in a 90° abduction position (ABER and ABIR, respectively) were measured using a digital goniometer in the supine position by immobilizing the entire scapula using the examiner's hand (Fig. 1, *A* and *B*) and the total arc (TA) was calculated by adding ABER and ABIR. In addition, IR in 90° anterior flexion (FIR) was measured to assess the posterior tightness of the shoulder in the same fixed scapula position (Fig. 2). Furthermore, the abduction angle (AA) and horizontal flexion angle (HFA) while fixing the lateral border of the scapula with the examiner's hand were quantitatively measured based on the guidelines set forth by Mifune et al[15] (Fig. 3, *A* and *B*). These values are useful for assessing the motion of the glenohumeral joint, excluding that of the scapula, to assess posterior tightness. Each measurement was performed twice, and the mean values were calculated.

Measurement of humeral torsion

The humeral torsion angle (HTA) was measured in the same manner as described in Yamamoto et al.[28] The patients were laid in the supine position with 90° of shoulder abduction and elbow flexion. A high-frequency linear probe of an ultrasound device (Noblus, Hitachi, Ltd., Tokyo, Japan) was applied at the bicipital groove of the proximal humerus along the short axis, and the examiner rotated the humerus and adjusted the ultrasonographic image such that the tangent line connecting the greater and lesser tuberosity was horizontal (Fig. 4*A*). HTA was defined as the angle between the horizontal plane and the patients' forearm axis, and the other examiner measured the HTA using a goniometer (Fig. 4*B*). The larger the HTA, the greater the actual humeral torsion. To determine the intraobserver reliability, 1 orthopedic surgeon unaware of the participants' dominant sides evaluated the FIR, AA, HFA, and HTA of 30 healthy volunteers twice on separate occasions. Moreover, to determine interobserver reliability, 2 orthopedic surgeons unaware of the patients' dominant sides evaluated the HTA of the same shoulders and compared them.

Physical findings

We conducted various clinical tests on all the patients at their first visit to our clinic to determine the cause of the shoulder pain during throwing. Physical findings, such as from the crank test[14] for detecting internal impingement, Neer test,[17] Hawkins test,[9] and Ellman test[7] for detecting subacromial impingement, posterior jerk test,[2] Kim test[13] for detecting posterior or postero-inferior instability, anterior and posterior drawer sign (PDS), sulcus sign[18] for detecting multidirectional instability, and scapular winging findings[4] for detecting scapular dyskinesis, were examined.

Evaluation

We compared the ROM-related items between the throwing and non-throwing sides for the R and L groups, respectively. In addition, we compared not only the ROM-related items of the throwing sides between the R and L groups but also those of the right and left sides between the R and L groups, respectively. Furthermore, we compared the positive ratio of the physical findings between the R and L groups.

Statistical analyses

Regarding patient demographic data, we performed statistical analyses using the chi-square test and Fisher exact test. Comparison between the right and left sides for the R and L groups was

Table I
Demographic data of the R and the L groups.

	Number	Age at their first visit	Baseball experience	Hitting side	Play level
R group	27	19.4 ± 2.7	10.6 ± 3.0	Right 22 Left 5	C 21 P 6
L group	25	20.8 ± 6.9	12.3 ± 6.9	Left 25	A 4 C 17 P 4
P value		.68	.85	.02*	.09

R group, right-side throwers; *L group*, left-side throwers; *C*, competitive, *P*, professional; *A*, amateur.
* Statistically significant ($P < .05$).

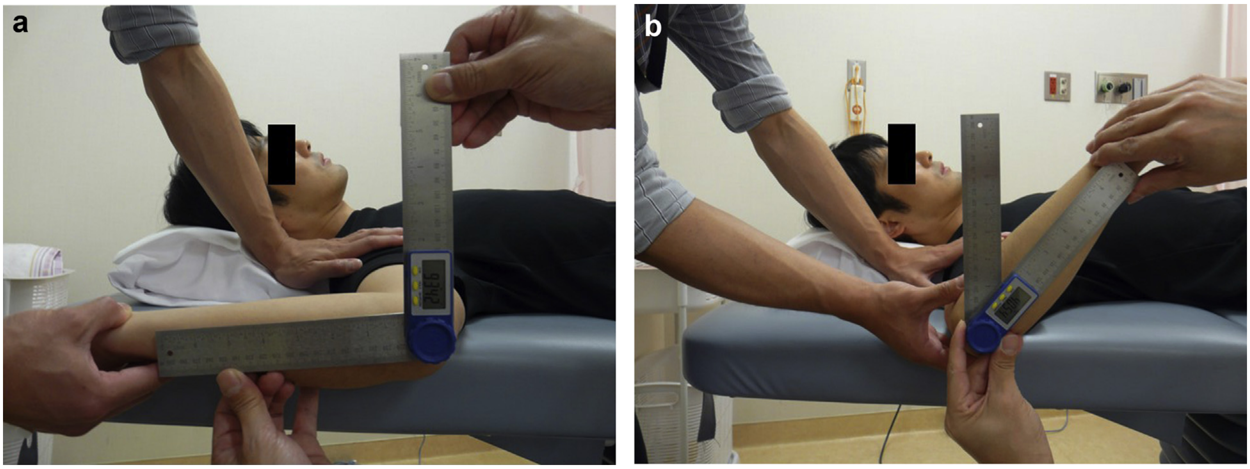

Figure 1 Images representing the measurement of ABER and ABIR at 90° in a fixed scapula position. (**a**) ABER, (**b**) ABIR. *ABER*, external rotation angle in abduction position; *ABIR*, internal rotation angle in abduction position.

Figure 2 Image representing the measurement of 90° FIR in a fixed scapula position. *FIR*, internal rotation angle in forward flexion.

performed using the Wilcoxon signed-rank test. In addition, the Mann-Whitney U test was used for the comparison between the R and L groups, and the chi-square test was used to compare the positive ratio of the physical findings between the 2 groups. $P < .05$ was set as reflective of a significant difference.

Results

Intraobserver reliability and interobserver reliability of FIR, AA, HFA, and HTA

Regarding FIR, AA, and HFA, the intraclass correlation coefficient (ICC) with 95% confidence interval and minimum detectable change values for intraobserver reliability were 0.932 (0.864-0.967), 0.957 (0.912-0.979), and 0.974 (0.946-0.988) and 1.60°, 2.82°, and 2.07°, respectively. The ICC with 95% confidence interval and minimum detectable change values for interobserver reliability were 0.907 (0.837-0.951), 0.953 (0.915-0.976), and 0.969 (0.944-0.984) and 1.94°, 3.17°, and 2.47°, respectively.

Regarding HTA, the ICC with 95% confidence interval and minimum detectable change values for intraobserver reliability were 0.986 (0.948-0.999) and 2.70°. The ICC with 95% confidence interval and minimum detectable change values for interobserver reliability were 0.958 (0.893-0.992) and 3.60°.

Comparison of the throwing and non-throwing sides for the R and L groups

In the R group, the ABER in the throwing side had significantly greater angles, and the ABIR in the throwing side had significantly lower angles than those in the non-throwing side (throwing side vs. non-throwing side; ABER: 103.3 ± 8.1° vs. 98.0 ± 7.9°, $P = .004$, ABIR: 45.2 ± 10.6° vs. 56.0 ± 10.0°, $P < .001$, respectively). The TA in the throwing side had significantly lower angles than that in the non-throwing side (throwing side vs. non-throwing side; 148.5 ± 12.2° vs. 153.9 ± 13.0°, $P = .01$). The FIR, AA, and HFA in the throwing side had significantly lower angles than those in the non-throwing side (throwing side vs. non-throwing side; FIR: 21.1 ± 9.5° vs. 35.0 ± 8.3°, $P < .001$, AA: 140.0 ± 9.0° vs. 157.2 ± 7.3°, $P < .001$, HFA: 97.4 ± 11.4° vs. 127.5 ± 8.5°, $P < .001$, respectively). The HTA in the throwing side had significantly greater angles than that in the non-throwing side (throwing side vs. non-throwing side; 86.4 ± 18.9° vs. 72.7 ± 14.4°, $P = .003$).

Conversely, the ABER and TA in the L group showed no significant differences, except for the ABIR between the throwing and non-throwing sides (throwing side vs. non-throwing side; ABER: 102.5 ± 11.8° vs. 99.4 ± 7.6°, $P = .13$, TA: 151.5 ± 13.8° vs. 154.9 ± 11.8°, $P = .31$, respectively). The ABIR in the throwing side had significantly lower angles than that in the non-throwing side (throwing side vs. non-throwing side; 49.0 ± 9.6° vs. 55.5 ± 10.4°, $P = .01$). In the posterior tightness parameter, the FIR and AA had no significant differences between throwing sides (throwing side vs. non-throwing side; FIR: 32.4 ± 8.5° vs. 33.0 ± 7.3°, $P = .75$, AA: 151.2 ± 10.5° vs. 149.6 ± 10.4°, $P = .72$, respectively). The HFA in the throwing side, however, was significantly higher than that in the non-throwing side (throwing side vs. non-throwing side; 125.0 ± 10.5° vs. 113.9 ± 9.3°, $P = .002$). The HTA in the L group was not significantly different between throwing sides (throwing side vs. non-throwing side; 79.0 ± 25.0° vs. 73.6 ± 20.7°, $P = .40$). These results are summarized in Table II.

Comparison of the throwing sides between the R and L groups

Compared with each throwing side, the ABER, ABIR, and TA did not show significant differences between the R and L groups (R group vs. L group; ABER: 103.3 ± 8.1° vs. 102.5 ± 11.8°, $P = .99$,

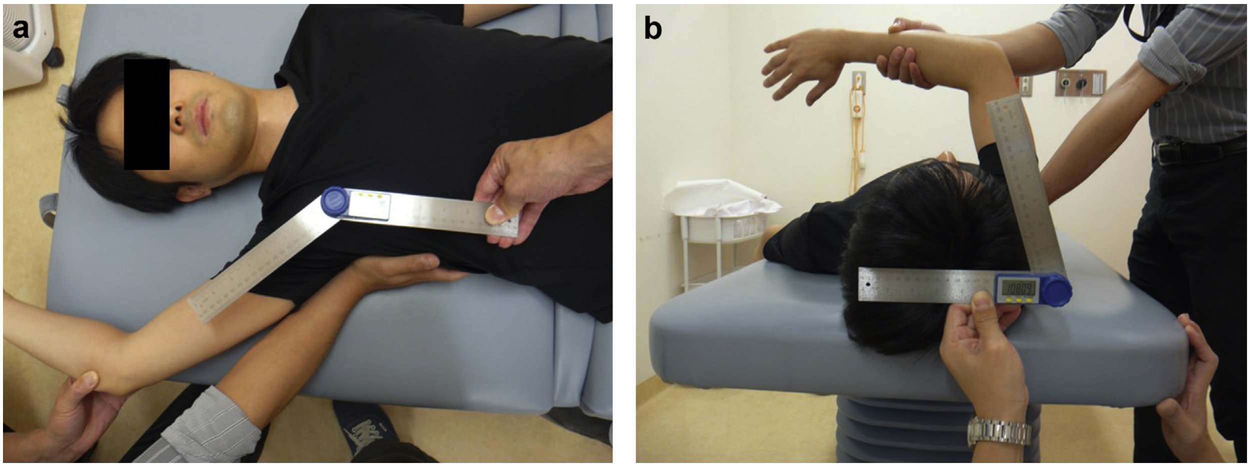

Figure 3 Images representing the measurement of the AA and HFA in a fixed scapula position. (**a**) AA, (**b**) HFA. *AA*, abduction angle; *HFA*, horizontal flexion angle.

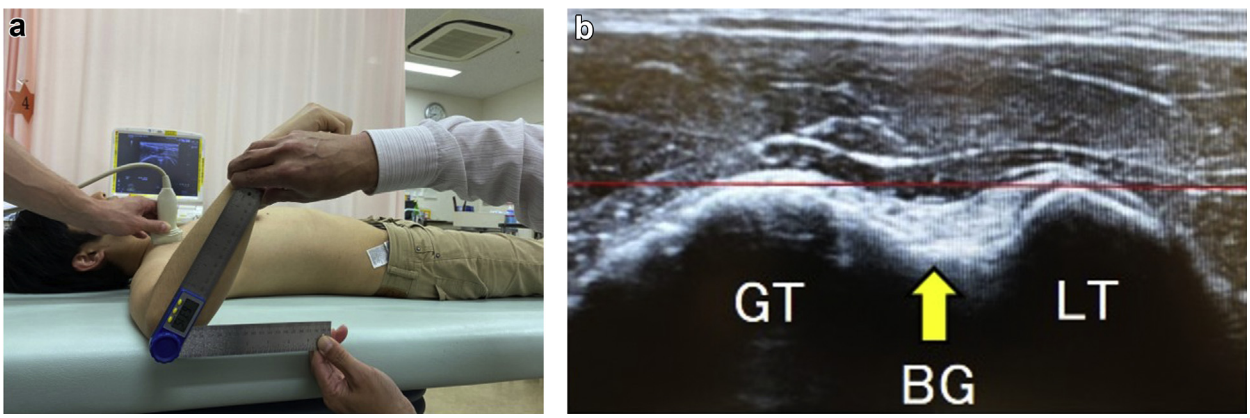

Figure 4 Images representing the measurement of the humeral torsion angle with ultrasonography. (**a**) A probe was applied at the bicipital groove of the proximal humerus along the short axis, and the examiner rotated the humerus. (**b**) The ultrasonographic image was adjusted to ensure that the tangent line connecting the greater and lesser tuberosity was horizontal. *BG*, bicipital groove; *GT*, greater tuberosity; *LT*, lesser tuberosity.

Table II
Results of the comparison between the R and L groups.

Shoulder angles	R group			L group		
	Throwing side	Non-throwing side	*P* value	Throwing side	Non-throwing side	*P* value
ABER	103.3 ± 8.1°	98.0 ± 7.9°	.004*	102.5 ± 11.8°	99.4 ± 7.6°	.13
ABIR	45.2 ± 10.6°	56.0 ± 10.0°	<.001*	49.0 ± 9.6°	55.5 ± 10.4°	.01*
TA	148.5 ± 12.2°	153.9 ± 13.0°	.01*	151.5 ± 13.8°	154.9 ± 11.8°	.31
FIR	21.1 ± 9.5°	35.0 ± 8.3°	<.001*	32.4 ± 8.5°	33.0 ± 7.3°	.75
AA	140.0 ± 9.0°	157.2 ± 7.3°	<.001*	151.2 ± 10.5°	149.6 ± 10.4°	.72
HFA	97.4 ± 11.4°	127.5 ± 8.5°	<.001*	125.0 ± 10.5°	113.9 ± 9.3°	.002*
HTA	86.4 ± 18.9°	72.7 ± 14.4°	.003*	79.0 ± 25.0°	73.6 ± 20.7°	.40

R group, right-side throwers; *L group*, left-side throwers; *ABER*, external rotation angle in abduction position; *ABIR*, internal rotation angle in abduction position; *TA*, total arc; *FIR*, internal rotation angle in forward flexion; *AA*, abduction angle; *HFA*, horizontal flexion angle; *HTA*, humeral torsion angle.
* Statistically significant ($P < .05$).

ABIR: 45.5 ± 10.0° vs. 51.4 ± 8.0°, $P = .11$, TA: 148.5 ± 12.2° vs. 151.5 ± 13.8°, $P = .42$, respectively). With regard to the posterior tightness parameters, the FIR, AA, and HFA in the R group had significantly lower angles than those in the L group (R group vs. L group; FIR: 21.1 ± 9.5° vs. 32.4 ± 8.5°, $P < .001$, AA: 140.0 ± 9.0° vs. 151.2 ± 10.5°, $P < .001$, HFA: 97.4 ± 11.4° vs. 125.0 ± 10.5°, $P < .001$, respectively). There was no significant difference in the HTA between the R and L groups according to the throwing side (R group vs. L group; 86.4 ± 18.9° vs. 78.5 ± 25.4°, $P = .19$). These results are summarized in Table III.

Comparison of the same sides between the R and L groups

For the comparison between each right side, although the R group had a significantly larger ABER and lower ABIR than the L group, the TA showed no significant difference between the 2 groups (R group vs. L group; ABER: 103.3 ± 8.1° vs. 99.4 ± 7.6°, $P = .03$, ABIR: 45.2 ± 10.6° vs. 55.5 ± 10.4°, $P = .002$, TA: 148.5 ± 12.2° vs. 154.9 ± 11.8°, $P = .07$, respectively). With regard to the posterior tightness parameters, the FIR, AA, and HFA in the R group had significantly lower angles than those in the L group

Table III
Results of the comparison of the throwing sides between the 2 groups.

Shoulder angles	R group	L group	P value
ABER	103.3 ± 8.1°	102.5 ± 11.8°	.99
ABIR	45.2 ± 10.6°	49.0 ± 9.6°	.11
TA	148.5 ± 12.2°	151.5 ± 13.8°	.42
FIR	21.1 ± 9.5°	32.4 ± 8.5°	<.001*
AA	140.0 ± 9.0°	151.2 ± 10.5°	<.001*
HFA	97.4 ± 11.4°	125.0 ± 10.5°	<.001*
HTA	86.4 ± 18.9°	78.5 ± 25.4°	.19

R group, right-side throwers; *L group*, left-side throwers; *ABER*, external rotation angle in abduction position; *ABIR*, internal rotation angle in abduction position; *TA*, total arc; *FIR*, internal rotation angle in forward flexion; *AA*, abduction angle; *HFA*, horizontal flexion angle; *HTA*, humeral torsion angle.
* Statistically significant ($P < .05$).

(R group vs. L group; FIR: 21.1 ± 9.5° vs. 33.0 ± 7.3°, $P < .001$, AA: 140.0 ± 9.0° vs. 149.6 ± 10.4°, $P < .001$, HFA: 97.4 ± 11.4° vs. 113.9 ± 9.3°, $P < .001$, respectively). The HTA in the R group had significantly lower angles than those in the L group (R group vs. L group; 86.4 ± 18.9° vs. 73.6 ± 20.7°, $P = .03$).

For the comparison between each left side, although the ABIR of the L group had significantly lower angles than those of the R group, the ABER and TA were not significantly different between the 2 groups (R group vs. L group; ABER: 98.0 ± 7.9° vs. 102.5 ± 11.8°, $P = .06$, ABIR: 56.0 ± 10.0° vs. 49.0 ± 9.6°, $P = .02$, TA: 153.9 ± 13.0° vs. 151.5 ± 13.8°, $P = .50$, respectively). For the posterior tightness parameters, although the AA in the L group had significantly lower angles than that in the R group, the FIR and HFA were not significantly different between the 2 groups (R group vs. L group; FIR: 35.0 ± 8.3° vs. 32.4 ± 8.5°, $P = .29$, AA: 157.2 ± 7.3° vs. 151.2 ± 10.5°, $P = .02$, HFA: 127.5 ± 9.3° vs. 125.0 ± 10.5°, $P = .47$, respectively). The HTA was not significantly different between the 2 groups (R group vs. L group; 72.7 ± 14.4° vs. 79.0 ± 25.0°, $P = .09$). These results are summarized in Table IV.

Physical findings

There were no significant differences in the crank test, Neer test, Hawkins test, and Ellman test between the R and L groups. However, the positive ratio of the posterior jerk test, Kim test, anterior drawer sign and PDS, sulcus sign, and scapular winging in the L group were significantly higher than those in the R group. These results are summarized in Table V.

Discussions

The current study was the first to investigate whether the characteristics of patients with a throwing shoulder injury depended on the throwing side with respect to the ROM, humeral torsion, and physical findings regarding the shoulder. According to our results, the R group on the throwing side showed a typical ROM shift, consisting of an ER increase and IR decrease,[1,3,5,10,21] and the same posterior shoulder tightness[3,15,20] as found in previous studies. On comparing throwing sides, ABER, ABIR, and TA did not show any significant change, while the posterior tightness parameters in the R group were significantly smaller than those in the L group. The HTA on the throwing side in the R group was larger than that on the non-throwing side, as previously described.[21,24,25,28] The reason for which the ROM shift occurred in the R group may be explained by the increase in the HTA, as reported by some authors,[5,19,21] and in GIRD, as reported by Burkhart et al.[3] By increasing the HTA, a ROM shift occurred, consisting of an ABER increase and ABIR decrease. However, if the increase in the HTA was the only reason, the TA would not be expected to change. The fact that the TA of the throwing side in the R group decreased compared with the non-throwing side is considered to be related not only to the osseous condition of the increased humeral torsion[5,19,21] but also to the soft tissue condition and posterior shoulder tightness,[3,15,20] as explained by Wilk et al[27] and Ruotolo et al.[22] As a result, humeral head postero-superior translation may occur during the throwing motion, following by internal impingement.[3,10,11,16,20] This was reflected in the physical findings of the R group.

In contrast, the HTA in the L group showed no significant differences between the throwing and non-throwing sides. Furthermore, in the comparison between the right sides, the HTA of the R group was significantly larger than that of the L group, while in the comparison between the left sides, there was no significant difference with respect to the humeral torsion. The purpose of the comparisons was to confirm whether the right humerus would always have high retroversion regardless of the pitching side as described by Edelson,[6] thereby having a different ROM compared to the left-handed players. To date, few papers have compared the HTA between right- and left-side throwers. Takenaga et al reported that the HTA of the left-handed players was smaller in the dominant hand and larger in the nondominant hand and that there was no side-to-side difference other than that of right-handed players among adult baseball players.[24] Takeuchi et al reported that side-to-side differences in the HTA between dominant hands usually arise in childhood.[25] This is because the HTA of the right side is significantly larger than that of the left, as described by Edelson.[6] He and Yamamoto et al also reported that the HTA subsequently changed depending on the osseous maturity.[6,28] In addition, Yamamoto indicated that the physiologic changes related to humeral anteversion were suppressed by repetitive throwing motion, as retroversion remained.[28] This is why this current study excluded little league shoulders, which often develop in early childhood when bones are still immature. However, why does suppressing such an effect not work for the left-side throwers?

Table IV
Results of the comparison of the same sides between the 2 groups.

Shoulder angles	Right side			Left side		
	R group	L group	P value	R group	L group	P value
ABER	103.3 ± 8.1°	99.4 ± 7.6°	.03*	98.0 ± 7.9°	102.5 ± 11.8°	.06
ABIR	45.2 ± 10.6°	55.5 ± 10.4°	.002*	56.0 ± 10.0°	49.0 ± 9.6°	.02*
TA	148.5 ± 12.2°	154.9 ± 11.8°	.07	153.9 ± 13.0°	151.5 ± 13.8°	.50
FIR	21.1 ± 9.5°	33.0 ± 7.3°	<.001*	35.0 ± 8.3°	32.4 ± 8.5°	.29
AA	140.0 ± 9.0°	149.6 ± 10.4°	<.001*	157.2 ± 7.3°	151.2 ± 10.5°	.02*
HFA	97.4 ± 11.4°	113.9 ± 9.3°	<.001*	127.5 ± 8.5°	125.0 ± 10.5°	.47
HTA	86.4 ± 18.9°	73.6 ± 20.7°	.03*	72.7 ± 14.4°	79.0 ± 25.0°	.09

R group, right-side throwers; *L group*, left-side throwers; *ABER*, external rotation angle in abduction position; *ABIR*, internal rotation angle in abduction position; *TA*, total arc; *FIR*, internal rotation angle in forward flexion; *AA*, abduction angle; *HFA*, horizontal flexion angle; *HTA*, humeral torsion angle.
* Statistically significant ($P < .05$).

Table V
Results of the physical findings between the 2 groups.

Physical findings	R group	L group	*P* value
Crank test			
Positive	25	23	.94
Negative	2	2	
Posterior jerk test			
Positive	5	16	<.001*
Negative	22	9	
Kim test			
Positive	7	14	.03*
Negative	20	11	
Neer test			
Positive	5	10	.09
Negative	22	15	
Hawkins test			
Positive	12	13	.59
Negative	15	12	
Ellman test			
Positive	11	14	.27
Negative	16	11	
ADS			
Positive	20	25	.01*
Negative	7	0	
PDS			
Positive	14	25	<.001*
Negative	13	0	
Sulcus			
Positive	15	24	<.001*
Negative	12	1	
Scapular winging			
Positive	7	18	<.001*
Negative	20	7	

R group, right-side throwers; *L group*, left-side throwers; *ADS*, anterior drawer sign; *PDS*, posterior drawer sign.
* Statistically significant ($P < .05$).

Furthermore, on the throwing side of the L group, although ABIR decreased significantly compared to the non-throwing side, there were no significant differences in the ABER and TA nor the posterior tightness parameters. Instead, the HFA in the throwing side was significantly larger than in the non-throwing side, in contrast to the R group. In the comparison between the right sides, all posterior tightness parameters in the R group were significantly smaller than those in the L group. However, on comparing the left sides, only AA in the L group was significantly smaller than that in the R group. In addition, the left side of the L group experienced an ABIR decrease compared with the same side in the R group, despite the lack of any significant differences with regard to ABER and TA, signifying that left-handed players are less likely to experience posterior shoulder tightness. This is the first time that such an aspect has ever been reported.

This was also shown by the differences between the R and L groups in the positive ratio of the posterior instability physical findings, including the posterior jerk test, Kim test, and PDS. Therefore, as expected, it was found that there may be differences in the pathogenesis of throwing shoulder injuries between the right- and left-side throwers. With regard to conditions associated with throwing shoulder injuries, posterior tightness with minor anterior instability, followed by internal impingement, posteroinferior instability,[12,13] multidirectional instability,[8,12] and scapular dysfunction, including a winging scapula[4] are suggested. Generally, left-handed individuals account for only a small fraction, 10%, of the population. However, among baseball players, the percentage of left-handed players increases to approximately 30%.[26] This is probably because left-handed pitchers experience technical and mechanical advantages, such as the difference in the ball release point or how to throw the balls to the first base after catching, compared to right-handed pitchers. Werner et al reported that left-handed players had a specific ROM spectrum and specific throwing-associated biomechanics.[26] Solomito et al also noted that there was no GIRD in the throwing side and that there were differences in the motions of the shoulder, elbow, and wrist in left-handed baseball pitchers.[23] The reason remains unclear but may be associated with the baseball-specific rule of anticlockwise rotation. In other words, the way left-hand pitchers make a pickoff throw is different from that of right-handed players, and left-handed players have a limited number of positions (only pitchers, first base men, or outfielders) they can conveniently serve. The other reason may be the underlying anatomical difference between right and left, such as with regard to circulation or brain activity.[29] For example, it is well known that the right and left sides of the body have different hemodynamics, such as the aorta or azygos venous system. In addition, it is widely accepted that the left and right hemispheres of the human brain show both structural and functional asymmetries at different periods of life and in different ways, and such lateralization was implicated in handedness.[30] Since human's left and right brain functions are consistent, it is no wonder that there is a difference in musculoskeletal growth between right- and left-handed.

Although our current study uncovered new knowledge that has never been reported, there remain some limitations. First, it presents occult problems due to the retrospective, non-randomized nature of the study. Since the number of left-dominant people was less, the number of subjects would inevitably also be less. With regard to the hitting side, there were some left-side hitters in the R group, which may have affected the results. Second, there were many speculative and few literature-based considerations in our study, since no previous report has documented a difference in the degree of posterior shoulder tightness between left- and right-side players, which may have related to the difference in the pathogenesis of the throwing shoulder injuries. Third, as is especially true for professional baseball players, it may be possible that the condition may not be constant since the timing of each patient's visit to our hospital was quite inconsistent. Fourth, since no surgical treatment was undergone by all these patients, exact structural diagnoses were not demonstrated. Therefore, each pathological condition could be different. Finally, since the physical findings were qualitative, the results may differ if another examiner performed the assessments.

Conclusion

We compared shoulder ROMs, humeral torsion measured by ultrasonography, and physical findings between right-side and left-side throwers having sustained throwing shoulder injuries. In comparing the throwing and non-throwing sides, the R group showed a ROM shift to the ER and posterior shoulder tightness in the throwing side, while the L group showed no ROM shift or posterior shoulder tightness, except for a smaller ABIR and larger HFA in the throwing side. On comparing the throwing side between the R and L groups, the R group showed more posterior tightness than the L group. Regarding the physical findings, the R group in the throwing side showed posterior shoulder tightness followed by internal impingement, while the L group experienced internal impingement and posterior instability.

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