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The differences of humeral torsion angle and the glenohumeral rotation angles between young right-handed and left-handed pitchers

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Background: The differences between young right-handed and left-handed baseball players are not well known. This study compared the range of the shoulder motion and humeral torsion angle (HTA) between right-handed and left-handed young baseball pitchers.
Methods: A total of 65 young baseball pitchers (age, 9-12 years; 46 right-handed throwers, R group; and 19 left-handed throwers, L group) were analyzed. The glenohumeral internal rotation (IR) angle and external rotation (ER) angle were measured at 90° shoulder abduction, and HTA was assessed using indirect ultrasonographic techniques. The side-to-side difference in HTA (d-HTA), glenohumeral ER difference (GERD), and glenohumeral IR deficit (GIRD) were calculated. The adjusted GIRD and adjusted GERD were defined as the angles obtained by subtracting d-HTA from GIRD and GERD, respectively, to exclude the influence of humeral retrotorsion difference.
Results: HTA and ER of the throwing limb were significantly greater than those of the nonthrowing limb in the R group (HTA: 84° vs. 77°; $P < .001$, ER: 116° vs. 111°; $P < .001$), but no significant differences were observed in the L group (HTA: 79° vs. 77°, $P = .103$; ER: 113° vs. 114°, $P = .380$). Compared with the R group, the L group showed a significantly smaller d-HTA (2° vs. 8°, $P < .001$) and GERD (5° vs. –2°, $P = .004$), but no significant difference was observed in adjusted GERD between the groups (–3° vs. –4°, $P = .690$).
Conclusion: Compared with the right-handed pitchers, the side-to-side differences of glenohumeral external rotation angle and humeral torsion angle were significantly smaller in the left-handed pitchers at a young age.
Level of evidence: Anatomy Study; Imaging

Keywords: Humeral retroversion; humeral torsion angle; baseball; young baseball player; young baseball pitcher; throwing arm dominance; left-handed thrower; ultrasound

The Nagoya City University Graduate School of Medical Sciences Ethics Committee approved the protocol of this study (No.764).

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Approximately 20% to 70% of baseball players are reported to experience shoulder and elbow pain, with many of these injuries occurring at a young age.[17,29] Joint laxity, lack of maturity of the muscles, and open epiphyseal plates are the unique aspects of young players and also can be risk factors for shoulder and elbow injuries.[14]

During a throwing motion, the humerus undergoes great rotational force. The torque values of the shoulder at maximum external rotation (ER) reach 92 ± 16 N · m in professional pitchers and 32 ± 7 N · m in young pitchers.[9,26] In response to such tremendous stress during the throwing motion, various changes take place in the shoulder. Previous studies have documented that repetitive throwing motion caused increased ER and decreased internal rotation (IR) in the throwing limb of baseball players. The reasons for these changes include increased humeral retrotorsion and posterior capsular or muscular tightness.[2,13,33,35] Myers et al[20] reported that the throwing limb of the baseball players demonstrated greater humeral retrotorsion than the nonthrowing limb, which was considered to be an adaptive change due to the rotational force. Previous findings indicate that the greatest retrotorsion adaptation occurs between the ages of 11 and 12 years, which corresponds to high growth plate activity at the humerus.[5,37]

Glenohumeral IR deficit (GIRD), which indicates a loss of IR of the throwing limb compared with the nonthrowing limb,[2] along with decreased glenohumeral ER and decreased side-to-side difference of humeral retrotorsion were previously reported as risk factors of throwing-related injuries.[3,4,10,12,18,28,29] Meanwhile, some recent studies reported that these factors were not related to throwing injury risk.[12,23,27] Therefore, the relationships between these factors and throwing injuries are still controversial.[22]

Prior studies have reported the differences between right-handed and left-handed throwers in adult age. In a biomechanical study, Werner et al[34] reported that significant greater peak shoulder horizontal adduction angular velocity and passive ER of the nonthrowing limb were found in left-handed collegiate pitchers compared with right-handed pitchers. In addition, although the right-handed pitchers had significantly greater ER ranges of motion in their throwing limb compared with the nonthrowing limb, left-handed pitchers exhibited similar ranges of passive ER in both limbs.

Takenaga et al[30] reported that the side-to-side difference in the humeral torsion angle (HTA) in left-handed skeletally matured baseball players was smaller than that in right-handed players. In previous biomechanical studies, increased peak shoulder horizontal adduction angular velocity was shown to be related to increased shoulder distraction stress,[33,35] which might be caused by excessive stress to the posterior muscle and capsule. Decreased side-to-side differences in the humeral retrotorsion and the range of the shoulder ER led to twisting and shear forces on the long head of the biceps, superior glenoid labrum, and rotator cuff tendons.[24] Therefore, the risks of throwing-related injuries might be different between right-handed and left-handed adult baseball players.

A significant number of throwing injuries occur in pitchers aged 9 to 12 years, and future disabilities in throwing caused by pain or limited motion occur as a result of pitching at these ages.[1] Therefore, investigation of the characteristics of physical findings is needed to prevent throwing injuries at a young age. However, no study investigating the differences of physical findings between young right-handed and left-handed baseball players has been conducted. Thus, this study aimed to compare the range of the shoulder motion and HTA between young right-handed and left-handed baseball pitchers. We hypothesized that there would be differences in the range of the shoulder motion and HTA between right-handed and left-handed young baseball pitchers.

Materials and methods

This was a retrospective cross-sectional study of young baseball players in an attempt to reveal the differences between right-handed and left-handed pitchers.

Participants

The study participants included 67 pitchers from 325 young baseball players who underwent medical checkups between 2015 and 2017. These medical checkups were performed during the off season in January for elementary school students aged 9 to 12 years. Questionnaires about age, handedness in daily life, throwing arm dominance, hitting side, baseball playing experience, throwing experience as a pitcher, and current and past upper extremity injuries, including fractures and Little League shoulder (proximal humeral epiphysiolysis), were conducted. The participants were excluded if they had current and past upper extremity injuries, pain, and obvious tenderness. Written informed consent was obtained from all participants.

Examination procedure

The participants were placed supine on a portable treatment table with 90° of shoulder abduction and 90° of elbow flexion. The examiner stabilized the scapula and passively rotated the limb until maximal IRs and ERs were achieved. The glenohumeral IR angle and ER angle were measured using a digital inclinometer (DigiLevel Compact; DGL-C, Myzox Co., Ltd., Nagakute, Aichi, Japan), as described in previous studies.[13,18] GIRD was calculated by subtracting IR of the throwing limb from that of the nonthrowing limb. The side-to-side difference in ER between throwing and nonthrowing limbs was defined as the glenohumeral ER difference (GERD), which was calculated by subtracting ER of the nonthrowing limb from that of the throwing limb.

HTA was assessed using an indirect ultrasonographic technique, as described by Myers et al[19] and Whiteley et al.[36] The examiner positioned an ultrasound 11-MHz linear array transducer (LOGIQe expert; GE Healthcare, Chicago, IL, USA) with a standard coupling gel on the participant's anterior shoulder. The transducer was placed perpendicular to the horizontal plane, which was verified with a bubble level. The participant's humerus was passively rotated so that the bicipital groove appeared in the center of the ultrasound image with the line connecting the apices of the greater and lesser

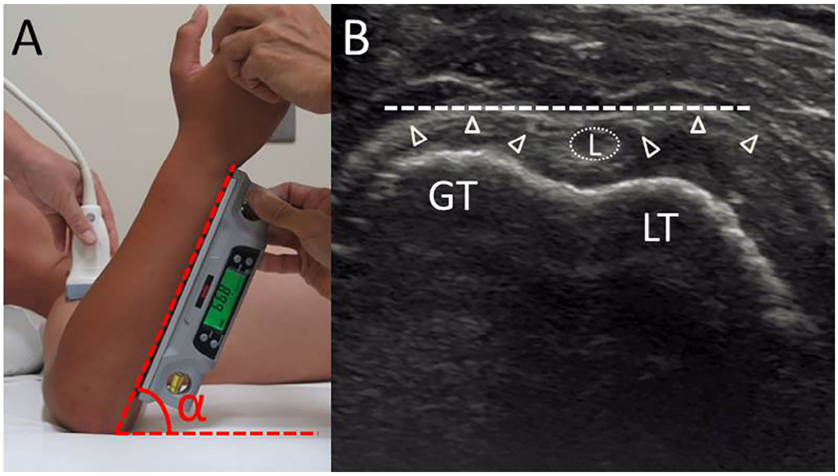

Figure 1 Humeral torsion angle (HTA) assessment. (**A**) Participants were positioned supine with 90° of shoulder abduction and 90° of elbow flexion. An ultrasound 11-MHz linear array transducer was placed on the participant's anterior shoulder perpendicular to the horizontal plane. A digital inclinometer was placed on the ulnar side of the forearm, and the angle between the participant's forearm and horizontal plane was measured (this angle α represents HTA). **(B)** Ultrasound image used for HTA measurement. The participant's humerus was passively rotated so that the bicipital groove appeared in the center of the ultrasound image with the line connecting the apices of the greater and lesser tubercles parallel to the horizontal plane. *GT*, greater tuberosity; *LT*, lesser tuberosity; *L*, long head of the biceps tendon. The *white triangles* (△) indicate the cartilage surface of the greater and lesser tubercles.

tubercles parallel to the horizontal plane. After that, the angle between the participant's forearm and the horizontal plane was measured using a digital inclinometer (Fig. 1).

Intrarater and inter-rater reliabilities for HTA measurement were assessed by 2 examiners in 22 shoulders with SPSS Statistics 23.0 software (IBM, Armonk, NY, USA). Each examiner was blinded to the results obtained by the other examiner. The intraclass correlation coefficient (ICC) with a 95% confidence interval (CI) was 0.995 (0.988-0.998), and standard error of measurement (SEM) was 0.58°. The ICC (95% CI) and SEM for inter-rater reliability were 0.960 (0.839-0.986) and 1.55°, respectively.

The side-to-side difference in HTA between the throwing and nonthrowing limbs was defined as d-HTA, which was calculated by subtracting HTA of the nonthrowing limb from that of the throwing limb. The adjusted GIRD and adjusted GERD were defined as the angles obtained by subtracting d-HTA from GIRD and GERD, respectively, to exclude the influence of humeral retrotorsion.[13]

Classification

The participants were classified into 2 groups by the laterality of their throwing limb: the right-handed throwers (R group) and left-handed throwers (L group).

Statistical analysis

At the beginning of the present study, a priori power analysis was performed to determine the appropriate sample size by using G*Power3 3.1.9.2 statistical analysis software (Heinrich Heine University Duesseldorf, Duesseldorf, Germany).[7,8] The value for d-HTA was chosen as the primary outcome for comparisons between the R and L groups. A minimum sample size of 52 pitchers (37 right-handed throwers and 15 left-handed throwers) was required to achieve statistical significance of 0.05 with 80% power ($1-\beta = 0.8$, $\alpha = 0.05$). Therefore, all of the 65 pitchers (46 right-handed throwers and 19 left-handed throwers) who volunteered were included and underwent medical checkups.

The Kolmogorov-Smirnov test was used to confirm a normal distribution for all data. Data related to range of motion and HTA were compared between throwing and nonthrowing limbs for R and L groups using 1-way analysis of variance (ANOVA) not to affect the chance of committing a type 1 error. When significance was observed in 1-way ANOVA, post hoc Tukey tests were performed to reveal significance between them. For statistical comparison of demographics and d-HTA between the R and L groups, data were analyzed using Mann-Whitney *U* tests, Fisher exact tests, or independent *t* tests to compare independent groups. These statistical analyses were performed using R 1.33 software (Saitama Medical Center, Jichi Medical University, Saitama, Japan)[15] with significance set at $P < .05$.

Results

The analysis included 65 of the 67 pitchers because 2 were excluded due to current shoulder pain. Table I summarizes the players' characteristics. No significant statistical differences were observed between the 2 groups in age, height, weight, body mass index, playing experience, throwing experience as a pitcher, and the rate of handedness opposite to the throwing limb (Table II).

One-way ANOVA revealed significant differences in IR, ER, and HTA ($P < .001$); therefore, post hoc pairwise comparisons were performed between throwing and nonthrowing limbs or R and L groups using Tukey tests. Significant differences were seen in IR between throwing and nonthrowing limbs in the R ($P < .001$) and L ($P = .023$) groups, but no significant differences were observed between the groups in both limbs (Table III). A significant difference was observed in ER

Table I Demographics of study participants

Variable	All players (n = 65)
Age, yr	10.9 ± 0.9
Height, cm	147.0 ± 7.7
Weight, kg	40.3 ± 7.2
Body mass index, kg/m^2	18.6 ± 2.4
Playing experience, yr	3.2 ± 1.5
Throwing experience, yr	2.4 ± 1.3
Throwing side	
Right	46
Left	9
Hitting side	
Right	39
Left	25
Switch	1

Continuous data are shown as the mean ± standard deviation and categorical data as the number of players.

between throwing and nonthrowing limbs in the R group ($P < .001$), but no significant differences were observed in the other pairs (Table IV). HTA was significantly greater in the throwing limb than in the nonthrowing limb in the R group ($P < .001$), but no significant difference was observed between both limbs in the L group ($P = .103$). HTA of the throwing limb was significantly smaller in the L group than in the R group ($P = .033$); however, no significant differences were observed in HTA of the nonthrowing limb ($P = .991$; Table V).

Compared with the R group, the L group showed significantly smaller GERD ($P = .004$) and d-HTA ($P < .001$), but no significant difference was observed in GIRD (Table VI). After adjusting GIRD and GERD with d-HTA, no significant differences were identified in adjusted GIRD and adjusted GERD.

Discussion

To the best of our knowledge, this is the first study to investigate the differences of the range of the shoulder motion and HTA between right-handed and left-handed baseball pitchers focusing on young age. The most important findings in this study were no significant difference was identified between both limbs in the L group in HTA, whereas it was significantly greater in the throwing limb than in the nonthrowing limb in the R group. Moreover, the L group showed significantly smaller GERD and d-HTA compared with the R group. After adjusting with d-HTA, the significance of GERD between both groups was no longer observed. Therefore, the difference of GERD might be accounted from d-HTA.

Humeral head retrotorsion gradually decreases from age 4 months to 4 years, and most of the derotation to adult values occurs by 8 years.[25] The great rotational force during a throwing motion has been reported to suppress the derotation process of humeral retrotorsion, leading to a larger degree of humeral retrotorsion in the throwing limb than that in the nonthrowing limb.[5,25] A previous study showed that young baseball players demonstrated significant side-to-side difference in humeral retrotorsion between the throwing and nonthrowing limbs at an early age (8-10.5 years) compared with young athletes who did not participate in baseball.[11] Kurokawa et al[16] reported that the side-to-side difference in humeral retrotorsion became obvious between ages 9 and 10 years. However, baseball positions and throwing dominances were not distinguished in these studies.

In the present study, d-HTA and HTA of the throwing limb in the L group were smaller than those in the R group. As a result, the difference of d-HTA between right-handed and left-handed throwers already existed in young baseball players aged 9 to 12 years, which is the same as left-handed skeletally mature baseball players reported in a previous study.[30] However, no significant difference was identified between throwing and nonthrowing limbs in left-handed throwers in young players, but the difference was observed in collegiate players.[30] The results indicate that the side-to-side difference of HTA has not yet occurred in young age and that it may progress by age. The discrepancy between young and adult players may occur because HTA suppression of the derotation process of humeral retrotorsion is gradually progressing by age and hard to occur in the throwing limb in left-handed throwers.

Several studies have related ER and HTA throwing injuries.[3,10,12,21] Decreased ER of the throwing limb was associated with shoulder and elbow injuries.[3,10,12] Greater humeral retrotorsion of the throwing limb has been linked to a lower risk of shoulder injuries.[21] In the present study, the L group showed significantly smaller HTA in the throwing limb, d-HTA, and GERD than the R group. Therefore, left-handed young baseball pitchers who have smaller d-HTA and GERD may be at a higher risk for throwing injuries compared with right-handed pitchers. However, other studies have not revealed a significant relationship between ER or humeral retrotorsion and throwing-related injuries.[31,32] Thus, the relationship between throwing injuries and decreased ER or HTA of the throwing limb is controversial. Further prospective studies with long-term follow-up are necessary to investigate the differences in risk of injuries between right-handed and left-handed young baseball pitchers.

The reasons for differences in the HTA between right-handed and left-handed throwers remain unclear. Edelson[6] revealed that humeral retroversion was greater in the right limb than in the left limb, regardless of sex and race, by measuring humeral retroversion of dry bone specimens. The reasons for the difference were not reported in the study; however, the fact may be related to the results of the present study. As the derotation processes of humeral retrotorsion are naturally different between the right and left limbs, right-handed throwers obtain greater humeral retrotorsion in the throwing limb than left-handed throwers. Even if the suppression of the derotation process occurred in the throwing limb of left-handed throwers, the side-to-side difference in left-handed

Table II Demographics of right-handed and left-handed throwers

Variable	Right-handed throwers (R group, n = 46)	Left-handed throwers (L group, n = 19)	*P* value*
Age, yr	10.9 ± 0.9	11.1 ± 0.8	.331
Height, cm	146.0 ± 8.0	149.5 ± 6.2	.104
Weight, kg	39.6 ± 7.5	42.0 ± 6.4	.234
Body mass index, kg/m^2	18.5 ± 2.3	18.8 ± 2.5	.612
Playing experience, yr	3.0 ± 1.4	3.6 ± 1.6	.140
Throwing experience, yr	2.2 ± 1.2	3.0 ± 1.4	.091
Handedness in daily life, No.			
Right	45	2	
Left	1	17	
Handedness opposite to throwing limb, %	2.2	10.5	.202
Hitting side, No.			
Right	39		
Left	6	19	
Switch	1		

Continuous data are shown as mean ± standard deviation and categorical data as indicated.
* Significant difference ($P < .05$).

Table III Comparisons of IR between throwing and nonthrowing limbs of R and L groups

Variable	Group	Throwing limb	Nonthrowing limb	*P* value
IR, mean ± SD, °	R	41 ± 15	49 ± 16	<.001*
	L	41 ± 17	48 ± 16	.023*
P value		.956	.888	

IR, internal rotation; *SD*, standard deviation, *R*, right-handed throwers; *L*, left-handed throwers.
* Significant difference ($P < .05$).

Table IV Comparisons of ER between throwing and nonthrowing limbs of R and L groups

Variable	Group	Throwing limb	Nonthrowing limb	*P* value
ER, mean ± SD, °	R	116 ± 14	111 ± 13	< .001*
	L	113 ± 11	114 ± 12	.380
P value		.394	.312	

ER, external rotation; *R*, right-handed throwers; *L*, left-handed throwers.
* Significant difference ($P < .05$).

Table V Comparison of HTA between throwing and nonthrowing limbs of R and L groups

Variable	Group	Throwing limb	Nonthrowing limb	*P* value
HTA, mean ± SD, °	R	84 ± 9	77 ± 9	<.001*
	L	79 ± 10	77 ± 9	.103
P value		.033*	.991	

HTA, humeral torsion angle; *SD*, standard deviation; *R*, right-handed throwers; *L*, left-handed throwers.
* Significant difference ($P < .05$).

Table VI Comparison of GIRD, GERD, d-HTA, adjusted GIRD, and adjusted GERD between R and L groups

Variable	R group (mean ± SD)	L group (mean ± SD)	*P* value
GIRD,°	8 ± 12	7 ± 13	.805
GERD, °	5 ± 8	−2 ± 8	.004*
d-HTA, °	8 ± 7	2 ± 5	<.001*
Adjusted GIRD, °	0 ± 14	5 ± 12	.574
Adjusted GERD, °	−3 ± 11	−4 ± 9	.690

SD, standard deviation; *GIRD*, glenohumeral internal rotation deficit; *GERD*, glenohumeral external rotation difference; *d-HTA*, difference in the humeral torsion angle between the throwing and nonthrowing limbs; *R group*, right-handed throwers; *L group*, left-handed throwers.
* Significant difference ($P < .05$).

throwers might be less than in right-handed throwers. It must be one of the reasons; however, the differences of the HTA are not concise. They may also be caused by the differences in the throwing mechanism between right-handed and left-handed throwers as well as in other movements in baseball unrelated to throwing such as hitting, catching, running, and sliding. Further studies are necessary to reveal the relationships between HTA and these factors.

In contrast, the reason for differences in the GERD between right-handed and left-handed throwers may be comprehensible. The L group showed significantly smaller GERD than the R group; however, the difference became nonsignificant after adjusting GERD with d-HTA. The results mean that the difference of the GERD may be caused by the difference of humeral retroversion, not soft tissue factors.

The present study has several limitations. First, the number of left-handed throwers was smaller than that of right-handed throwers. However, the percentage of left-handed throwers was 29.2%, which was almost the same as observed in previous studies.[34] Moreover, an a priori power analysis was performed to determine the appropriate sample size with sufficient power.

Second, the present study was a cross-sectional study. Therefore, we could not investigate the incidence rates of shoulder and elbow injuries. Further studies with long-term follow-up will be necessary to investigate the differences in risk of injuries between right-handed and left-handed baseball pitchers.

Third, the skeletal maturities was not evaluated among the individuals. At a young age, skeletal maturity vary from one individual to another. The difference in HTA may be related to the differences in skeletal maturity. However, this is the first study to demonstrate the differences in HTA between young right-handed and left-handed baseball pitchers.

Conclusion

In young pitchers, left-handers showed significantly smaller GERD and d-HTA than right-handers. Moreover, after adjusting GERD with d-HTA, the significance of GERD between both groups was no longer observed. These results indicate that the difference in d-HTA between right-handed and left-handed throwers was already present at a young age same as skeletally matured players, and the difference of GERD was almost accounted from d-HTA.

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Disclaimer

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