Bilateral Humeral Retrotorsion Angle Measured Using an Ultrasound-Assisted Technique in Asian Baseball Players

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Background: Repetitive pitching is thought to restrict the physiological derotation process of the humeral head. Some studies have reported that side-to-side differences in the humeral retrotorsion angle (ΔHRA) occur between the ages of 9 and 11 years in baseball players. However, it remains unclear whether the ΔHRA in Asian baseball players depends on pitching skill or competitive level.

Purpose: To evaluate the ΔHRA in Asian collegiate and professional baseball players and to determine the effects of pitching activity on the physiological derotation process of the humeral head.

Study Design: Cross-sectional study; Level of evidence, 3.

Methods: We evaluated 128 shoulders in 64 Asian baseball players who were stratified into 4 groups as follows: 13 professional pitchers; 9 professional fielders; 8 collegiate pitchers; and 34 collegiate fielders. The throwing and nonthrowing side HRA was assessed using an ultrasound-assisted technique, and the ΔHRA was compared among the 4 groups. In addition, Pearson correlation analysis was used to assess the relationship between ΔHRA and glenohumeral range of motion, baseball starting age, and fastball velocity in pitchers.

Results: The HRA was significantly greater in the throwing arm than in the nonthrowing arm in each group, with no significant differences among the groups. There was no correlation between ΔHRA and range of motion or fastball velocity. There was a significant negative correlation between baseball starting age and ΔHRA in professional fielders ($r = –0.633$; $P = .036$).

Conclusion: The findings of the present study provide evidence that in Asian baseball players, the HRA was significantly greater in the throwing arm than in the nonthrowing arm. There were no clear associations between HRA and pitching ability or competitive level.

Keywords: baseball; competitive level; humeral retrotorsion; ultrasound

Baseball pitchers exhibit increased proximal humeral retrotorsion in the throwing shoulder compared with the nonthrowing shoulder.[2,8,11] Side-to-side differences in humeral retrotorsion are considered to be morphologic adaptations that result from throwing during skeletal development and have been shown to influence shoulder range of motion (ROM).[1,4,14] Greater humeral retrotorsion helps pitchers obtain greater maximum external rotation (ER) in the late cocking phase, which leads to a higher ball velocity.[1] In addition, greater humeral retrotorsion in the throwing arm enables pitchers to achieve maximum ER with lower twisting and shear forces on the long head of the biceps tendon and rotator cuff tendons.[9]

During the baseball pitch, large forces from the lower and upper extremities are generated to produce extreme linear and angular velocities at ball release.[3] Performing this throwing motion repetitively over time creates torque and distraction forces at the shoulder, which may alter the ultimate bone and soft tissue structure over time.[15,16] A previous study on Asian baseball players reported that pitching ability and competitive level affect the distribution pattern of mechanical stress through the glenohumeral joint in pitchers.[7] In addition, the magnitude of long-term stress on the glenohumeral joint appears to be low in asymptomatic professional pitchers. However, the effect of pitching ability and competitive level on the humeral retrotorsion angle (HRA) in Asian baseball players is unknown.

We hypothesized that the HRA of the throwing side in an Asian population would affect affects pitching ability and competitive level. To test this hypothesis, we analyzed the

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bilateral HRA in baseball players of different competitive levels using an established ultrasound method.[4,14] This study aimed to assess the difference in HRA (ΔHRA) between the throwing and nonthrowing shoulders and to compare these values in collegiate pitchers (CP) and collegiate fielders (CF) with those in professional pitchers (PP) and professional fielders (PF) groups.

METHODS

Study Participants

Institutional review board approval was obtained before the initiation of the study, and informed consent was obtained from all participants. Included were 64 Asian male baseball players (N = 128 shoulders)—34 CF players, with a mean age of 20.4 years (range, 19-24 years); 8 CP players, with a mean age of 21.4 years (range, 20-23 years); 9 PF players, with a mean age of 22.9 years (range, 19-27 years); and 13 PP group players, with a mean age of 23.1 years (range, 19-28 years). All participants in the collegiate groups were volunteers, and those in the professional groups participated in the study as part of an annual medical check of the throwing shoulder and had no symptoms or history of shoulder disorder or trauma. Physeal closure was confirmed by radiographs. Those in both fielder groups and pitcher groups had been on a baseball team as a fielder since junior high school

The participants completed a detailed questionnaire with 3 categories. The first category was current status, including age, throwing arm dominance, and current position. The second category was past baseball history, including starting age, position played in the past (elementary school, junior high school, high school, and college, if applicable), and any history of changes to the throwing arm. We defined starting age as the age at which a player joined a baseball club or started playing baseball at least once a week throughout the year. The third category was current and past upper extremity injuries, including fractures and Little League shoulder (proximal humeral epiphysiolysis) that could affect humeral retrotorsion.

Participants were excluded if they reported changing their throwing arm, having a history of Little League shoulder, or having a current or past humeral fracture, a scapular fracture, or an obvious upper arm or forearm deformity. Scapular fracture was excluded because the bony adaptation of the proximal humerus and glenoid has been reported to be coupled during skeletal development in the throwing shoulder. All included participants underwent physical examination of both the throwing and the nonthrowing shoulders. In addition to the HRA, we measured passive glenohumeral ROM in ER and internal rotation (IR) at 90° of shoulder abduction in the supine position with restriction of the scapulothoracic movement. Finally, we measured the fastball velocity for participants in the CP and PP groups.

HRA on Ultrasound

The HRA was measured bilaterally with an ultrasound-assisted technique widely used in research related to the shoulder, using an Aplio 500 US unit (Toshiba Medical Systems Corp) and an 8.0-MHz center frequency (bandwidth, 5-12 MHz) linear transducer (PLT-805AT; Toshiba Medical Systems). The participants were placed in the supine position with the shoulder at 90° of abduction, the elbow at 90° of flexion, and the forearm in the neutral position. The HRA was defined as the angle between the long axis of the forearm and a line parallel to the trunk when the line tangential to the greater tuberosity and lesser tuberosity was parallel to the horizontal baseline on the ultrasound monitor when the ultrasound probe was held parallel to the floor. A greater numerical value implied greater humeral torsion at a posterior angle (retrotorsion). The primary examiner (S.I.) performed the ultrasound scans and adjusted the rotation of the humerus, and another examiner (D.M.) measured the HRA using a goniometer. Measurements were performed by 2 primary examiners (S.I. and D.M.).

Pitching Velocity Protocol

The 8 CP and 13 PP participants were given an unlimited time to perform their individual prethrowing warm-up (mean warm-up time, 10 minutes) and become familiar with the testing procedures. We chose not to standardize the warm-up in an attempt to better simulate each participant's prethrowing game preparation. Participants threw 3 fastballs to a catcher at the regulation distance (60 feet 6 inches [18.44 m]) on a mound and were instructed to throw as they typically would in a game setting. A radar gun (Stalker Pro II; Stalker Radar) was used to measure pitch velocity.[13] The fastest velocity trial was used for analysis based on previous research and because only the maximal stress values were of interest for the present study.

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Ethical approval for this study was obtained from Hokkaido University Hospital (ref No. 020-0114).

TABLE 1
Participant Characteristics[a]

	CF (n = 34)	CP (n = 8)	PF (n = 9)	PP (n = 13)
Throwing side, n				
Right	33	8	9	10
Left	1	0	0	3
Age, y	20.4 ± 1.2	21.4 ± 1.4	22.9 ± 2.7[b]	23.1 ± 2.9[c]
Height, cm	175.1 ± 5.6	178.0 ± 8.8	178.1 ± 6.3	178.6 ± 4.4
Weight, kg	78.5 ± 9.2	79.9 ± 9.5	85.2 ± 11.6	83.5 ± 5.8
Baseball starting age, y	8.1 ± 1.2	8.3 ± 1.6	8.5 ± 1.9	8.5 ± 1.3
Glenohumeral ER ROM, deg				
Throwing side	102.2 ± 6.3	104.4 ± 9.8	103.9 ± 12.7	104.6 ± 12.7
Nonthrowing side	94 ± 6.6	96.9 ± 7	95 ± 5	96.5 ± 4.3
P	**<.001**	.105	.068	.039
Glenohumeral IR ROM, deg				
Throwing side	41.2 ± 13.4	39.4 ± 16.6	40 ± 17.1	36.9 ± 8
Nonthrowing side	49.3 ± 10.3	48.8 ± 12.2	55 ± 13	55.8 ± 12.6
P	**.007**	.218	.053	<.001
HRA, deg				
Throwing side	77.7 ± 8.4	83.3 ± 7	81.6 ± 9.4	81.2 ± 7.4
Nonthrowing side	71.6 ± 7	71.6 ± 6.8	72.7 ± 4.6	74.4 ± 5.6
P	**.002**	**.005**	**.022**	.015

[a]Data are expressed as mean ± SD unless otherwise indicated. CF, collegiate fielder; CP, collegiate pitcher; ER, external rotation; HRA, humeral retrotorsion angle; IR, internal rotation; PF, professional fielder; PP, professional pitcher; ROM, range of motion.
[b]$P < .001$ versus the CF group.
[c]$P = .006$ versus the CF group.

Statistical Analysis

Outcomes were compared among the CF, CP, PF, and PP groups. The normality of samples was judged by the Kolmogorov-Smirnov test. One-way repeated-measures analysis of variance with Tukey-Kramer correction or the Kruskal-Wallis test with Steel-Dwass correction was chosen to compare age, height, weight, and bilateral HRA among the 4 groups. Paired *t* tests or Wilcoxon signed-rank tests were used to compare the ΔHRA. In addition, Pearson correlation analysis was used to assess the relationship between ΔHRA and glenohumeral ROM, baseball starting age, and fastball velocity. Statistical analyses were performed with JMP 14.0.0. software (SAS Institute Inc). $P < .05$ was considered to be statistically significant.

RESULTS

Participant Characteristics

Table 1 lists the characteristics of the participants. There was right-handed throwing in 33 of 34 (97.1%), 8 of 8 (100%), 9 of 9 (100%), and 10 of 13 (76.9%) players in the CF, CP, PF, and PP groups, respectively. The mean age was significantly higher in the PF and PP groups than in the CF group ($P < .001$ and $P = .006$, respectively). In the CF and PP groups, the mean ER was significantly greater in the throwing arm than in the nonthrowing arm ($P < .001$ and $P = .039$, respectively), and the mean IR was significantly less in the throwing arm than in the nonthrowing arm ($P = .007$ and $P < .001$, respectively). In all groups, the HRA was significantly greater in the throwing arm than in the nonthrowing arm ($P = .002$ in the CF group; $P = .005$ in the CP group; $P = .022$ in the PF group; and $P = .015$ in the PP group), with no significant difference among the groups. 4 players had started playing baseball after 11 years of age, and 39 players (60.9%) had played multiple positions in childhood.

Relationship Between ΔHRA and Glenohumeral ROM

There were no significant correlations between ΔHRA and glenohumeral ROM. In the throwing arm, the correlation coefficient between the ΔHRA and the ER was –0.2326 and the IR was –0.3248. In the nonthrowing arm, the correlation coefficient between the ΔHRA and the ER was 0.1217 and the IR was 0.0018.

Relationship Between ΔHRA and Baseball Starting Age

All players had started playing baseball before the age of 11 years. Figure 1 shows the linear relationship between ΔHRA and baseball starting age for all participants. There was a negative but nonsignificant correlation between ΔHRA and starting age ($r = –0.227$; $P = .464$). When stratified according to the study group, there was also a negative correlation between ΔHRA and starting age; however, the correlation was only significant for the PF group ($r = –0.0961$, $P = .762$ in the CF group; $r = –0.248$, $P = .448$ in

the CP group; $r = –0.633$, $P = .036$ in the PF group; and $r = –0.330$, $P = .297$ in the PP group) (Figure 2, A-D).

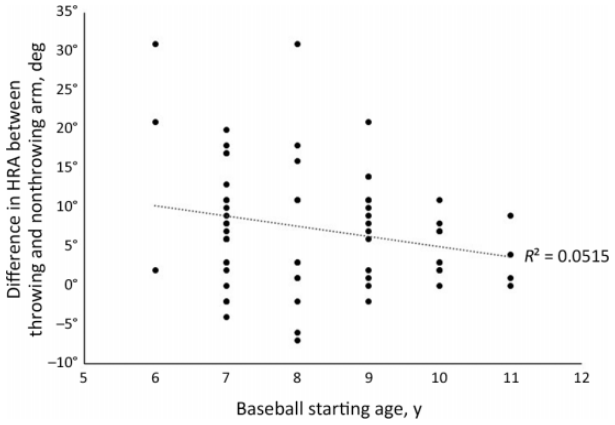

Figure 1. A linear model of difference in HRA between throwing and nonthrowing arms according to baseball starting age in all participants. HRA, humeral retrotorsion angle.

Relationship Between ΔHRA and Fastball Velocity

The mean fastball velocity of the CP and PP groups was 40.4 ± 1.3 and 41.6 ± 0.8 m/s respectively. Figure 3 shows the linear relationship between ΔHRA and fastball velocity. There was a nonsignificant negative correlation between ΔHRA and fastball velocity for all pitchers ($r = –0.135$; $P = .670$) (Figure 3A), a nonsignificant positive correlation between ΔHRA and fastball velocity in the CP group ($r = 0.153$; $P = .627$) (Figure 3B), and a nonsignificant negative correlation between ΔHRA and fastball velocity in the PP group ($r = –0.030$; $P = .925$) (Figure 3C).

DISCUSSION

The present results demonstrated that for all 4 of the study groups, the HRA was significantly greater in the throwing arm than in the nonthrowing arm ($P = .002$ in the CF group; $P = .005$ in the CP group; $P = .022$ in the PF group; and $P = .015$ in the PP group), with no significant difference among the groups. In addition, we found a significant negative correlation between baseball starting age and ΔHRA

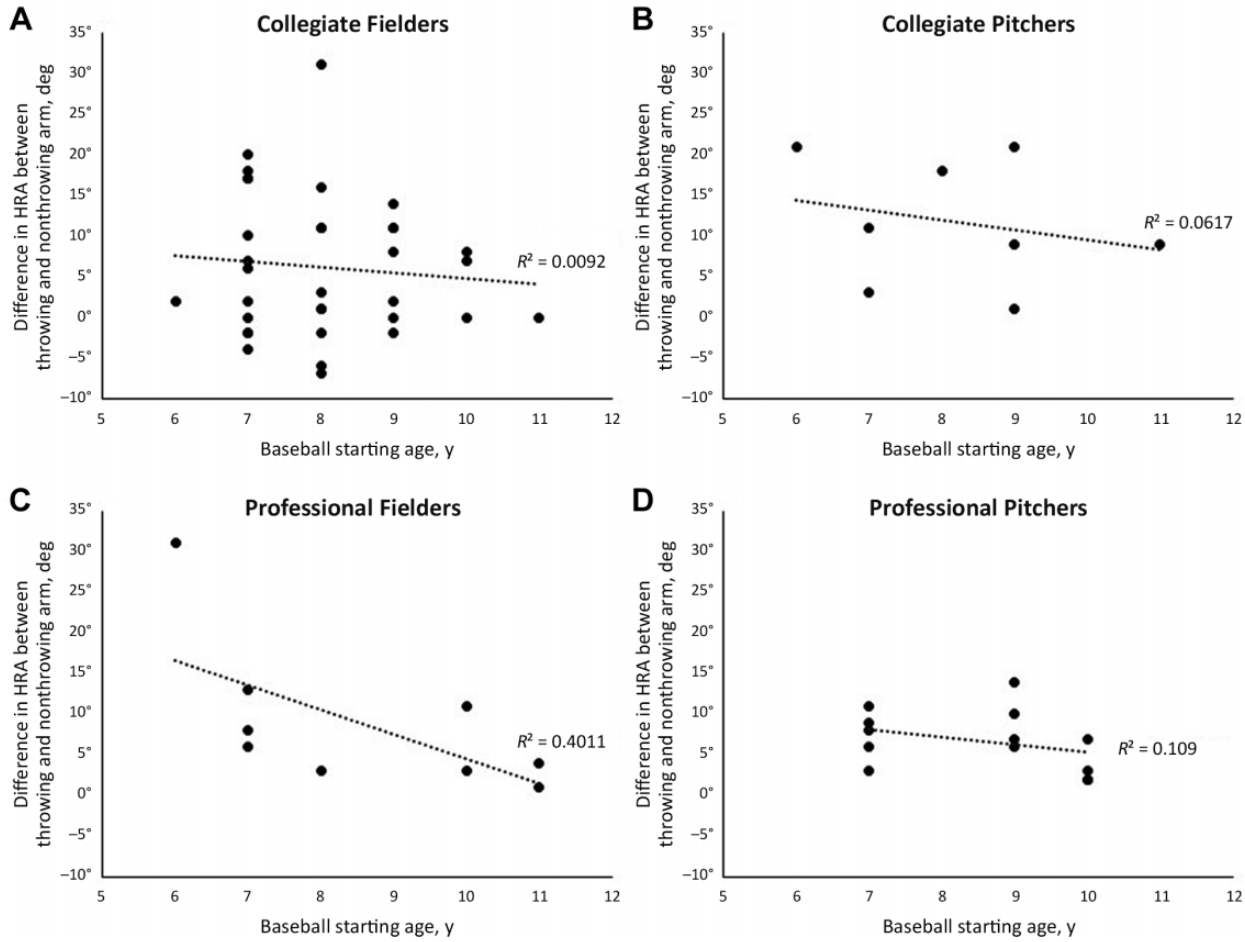

Figure 2. A linear model of difference in HRA between throwing and nonthrowing arms according to baseball starting age for (A) collegiate fielders (B) collegiate pitchers, (C) professional fielders, and (D) professional pitchers. HRA, humeral retrotorsion angle.

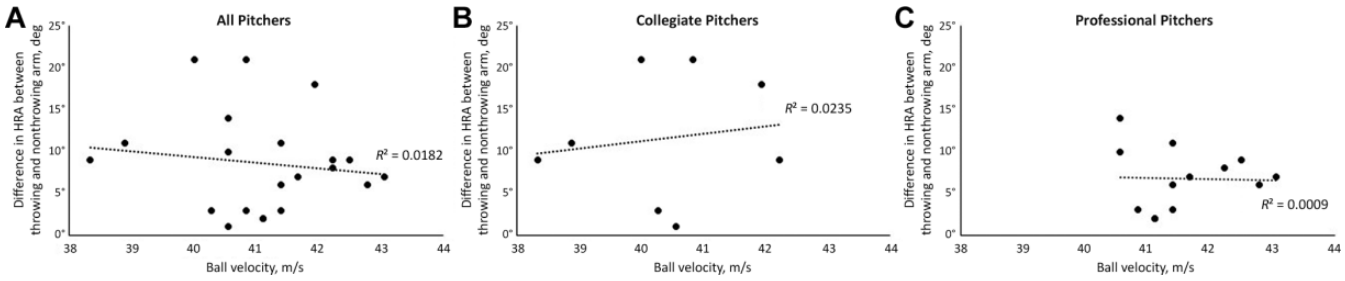

Figure 3. The difference in HRA between throwing and nonthrowing arms according to fast ball velocity for (A) all pitchers, (B) collegiate pitchers, and (C) professional pitchers. HRA, humeral retrotorsion angle.

in the PF group ($r = –0.633$; $P = .036$). To the best of our knowledge, this is the first evaluation of the bilateral HRA in Asian collegiate and professional baseball players.

Previous studies have clarified that repetitive pitching restricts the physiological derotation process of the humeral head and that side-to-side differences in humeral retrotorsion occur between the ages of 9 and 11 years in baseball players.[6,17] The present finding of a negative correlation between baseball starting age and humeral retrotorsion is comparable with those of previous reports. The effects of other baseball motions, such as batting, may need to be investigated. However, according to previous studies, playing baseball has no effect on the nonthrowing arm. Kurokawa et al[4] demonstrated that the physiological humeral derotation process was restricted only in the throwing arm, whereas humeral retrotorsion of the nonthrowing arm decreased with age. Nakase et al[6] reported no correlation between humeral retrotorsion of the nonthrowing arm and starting age. One of the strengths of the present study was that all players were skeletally mature.

The maximum IR velocity of an elite pitcher is approximately 7000 deg/s, making it perhaps the fastest human motion in all of sport.[1] The most effective way to maximize IR velocity is to maximize the arc of rotation using hyperexternal rotation in late cocking. The longer the arc of rotation through which angular acceleration is achieved, the greater the velocity of the hand and therefore the greater the velocity of the baseball at ball release. The study of Roach and Richmond[12] found a significant positive correlation ($r = 0.44$; $P = .03$) between HRA and pitching velocity within collegiate baseball; however, this result was not replicated within the present sample. Contributions from other forces and interactive moments at various points within the kinetic chain are of high importance.[10] The differences in findings between the previous study and ours may stem from various issues. First, there may be several factors involved in high pitching velocity that are unrelated to achieving a high degree of ER and humeral torsion, including player weight, degree of horizontal abduction during the throwing motion, and the player's muscular power of IR. Other anatomical considerations may account for a long arc of motion even in the absence of humeral hyperexternal rotation, including arm length, elbow carrying angle, and hand position.[5] Since the HRA varies greatly between individuals, we compared the difference in the HRA to eliminate individual influence. There were differences between the present study population and that in the previous study. Our study included a group of Asian professional baseball pitchers with a mean age of 23.1 years. As the proposed influence of HRA on pitching velocity relies upon a series of events in which increased HRA creates a shift in glenohumeral motion favoring ER, analyzing all aspects of the contributing factors is of significant importance.

Limitations

This study has some limitations that should be acknowledged. First, the sample size of the CF group was large (n = 34) compared with the other groups. However, people commonly play multiple positions in childhood baseball, and 39 players (60.9%) played multiple positions in childhood. Second, the number of players who had started playing baseball after the age of 11 years and who had played a single position in childhood was small, which could not be controlled. Because the players enrolled in this study were elite baseball players, most of the players had started playing baseball in the lower grades of elementary school. Third, the sample size was small for the CP and PF groups, and we assessed only male baseball players. In addition, we only evaluated HRA, ROM, and pitch velocity; hence, further studies are needed to assess other factors that contribute to pitching velocity, such as trunk rotation strength and hip abduction strength. Finally, there was variation in the competition histories and playing periods of the participants. Further studies are needed to reveal the relationship between HRA and shoulder injuries.

CONCLUSION

The findings of the present study provide evidence that the HRA was significantly greater in the throwing arm than in the nonthrowing arm in Asian baseball players. There were no clear associations between HRA and pitching ability or competitive level.

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