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Relationship between bilateral humeral retroversion angle and starting baseball age in skeletally mature baseball players—existence of watershed age

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Background: Repetitive pitching in childhood was thought to restrict the physiological derotation process of the humeral head. Some studies reported that the side-to-side differences of humeral retroversion in baseball players occurred between the age of 9 and 11 years. The present study investigated the relationship between bilateral humeral retroversion angle and starting baseball age in skeletally mature baseball players.

Methods: One hundred and seventeen male baseball players, who belonged to a college or amateur team, were investigated. Bilateral humeral retroversion was assessed using an ultrasound-assisted technique as described by previous studies. All players were divided into four groups: players who had started playing baseball before the age of 6 years, between 7 and 8 years, between 9 and 10 years and after 11 years. Bilateral humeral retroversion angle was compared among the four starting age groups.

Results: All players started playing baseball between 5 and 12 years. Comparing the throwing arm, humeral retroversion in starting age group 11-12 (72°) was significantly smaller than the other 3 groups (81°, 82°, and 80° for groups 5-6, 7-8, and 9-10, respectively). Comparing the non-throwing arm revealed no significant differences among the 4 starting age groups (71°, 72°, 70°, and 66° for groups 5-6, 7-8, 9-10, and 11-12, respectively).

Conclusions: Skeletally mature baseball players who started playing baseball after 11 years had significantly smaller humeral retroversion in the throwing arm than those who started baseball before 11 years.

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

The Nagoya City University Graduate School of Medical Sciences Ethics Committee approved the protocol of this study (764).

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Humeral retroversion of baseball players is known to be greater in the throwing arm than in the non-throwing arm. This has been reported in junior high school,[18] high school,[9] college,[11,13,15] and professional[2,17] baseball players. A cross-sectional study of elementary school baseball players demonstrated how this side-to-side difference occurred: repetitive pitching restricted the physiological humeral derotation process in the throwing arm while humeral retroversion decreased with age in the non-throwing arm.[7] This theory is supported by biomechanical analyses of the baseball pitching motion, which showed that numerous rotational torques were generated in the throwing shoulder near the time of maximum external rotation in the cocking phase.[5,14]

Increased humeral retroversion is considered as an adaptive change in baseball players.[17] Greater humeral retroversion helps pitchers obtain greater maximum external rotation in the late cocking phase, which leads to a greater ball velocity.[1] In addition, greater humeral retroversion in the throwing arm allows pitchers to achieve maximum external rotation with less twisting and traction on the anterior capsules, long head of biceps, and rotator cuff tendons.[12] Recent clinical studies showed that increased humeral retroversion in the throwing arm was protective against throwing-related shoulder injuries.[10,12] Considering these facts, having a greater humeral retroversion in the throwing arm seems advantageous for both performance and prevention of shoulder injuries.

The mean humeral retroversion was reported to be 78° in fetuses,[4] 65° in children aged 4 months to 4 years, 38° in those aged 10 to 12 years,[3] and 30° in adults.[6] These data show that 56% of the physiological derotation process of the humerus occurs between the age of 4 and 12 years. Some studies reported side-to-side differences of humeral retroversion in baseball players occurred at fourth and fifth grades,[7,18] that is, between the age of 9 and 11 years. We therefore assumed that the age when people started playing baseball (starting baseball age) could affect the humeral retroversion after becoming skeletally mature. Moreover, the age of 11 years might be a watershed starting baseball age.

The present study investigated the relationship between the bilateral humeral retroversion angle and starting baseball age in skeletally mature baseball players. We hypothesized that skeletally mature baseball players who started playing baseball after 11 years would have significantly smaller humeral retroversion in the throwing arm than those who started playing baseball before 11 years.

Materials and methods

The study enrolled 144 male college or amateur baseball players who participated in medical checkups. Informed consent was obtained from all individuals.

Bilateral humeral retroversion was assessed by the humeral torsion angle (HTA) as described and validated by Myers et al.[8] This ultrasound-assisted technique has been used in many baseball research studies.[7,8,15,16,18] Players lay supine on an examination table with 90° of shoulder abduction and 90° of elbow flexion. An 18-MHz linear array ultrasound transducer (MyLab25; Esaote, Genoa, Italy) was placed on the anterior aspect of the shoulder with the ultrasound transducer level with the plane of the examination table (verified with a bubble level; Fig. 1, *A*). The HTA was measured at the proximal end of the bicipital groove. The humerus was passively rotated so that the line passing the apexes of the greater and lesser tuberosities would be horizontal in the screen (Fig. 1, *B*). A digital inclinometer was placed on the ulna and recorded the forearm inclination angle with respect to the horizontal line (Fig. 1, *A*). This forearm inclination angle with respect to the horizontal line represented the HTA.[8] Although this ultrasound technique was an indirect measurement of humeral retroversion, a strong correlation was demonstrated between the HTA and humeral retroversion obtained by computed tomography (CT).[8] The relationship between the HTA and CT-obtained humeral retroversion was based on a simple linear regression:

$$\text{HTA} = 32.71 + 1.2153 \times [\text{CT-obtained humeral retroversion}],$$ (coefficient of determination: 0.6349).[8]

Based on this formula, the mean value of the HTA for adults is 69° given the mean value of CT-obtained humeral retroversion for adults is 30°.

Measurements were done by 2 primary examiners (M.F. and H.N.). One performed the ultrasound scan and the other adjusted the rotation of the humerus and measured the HTA using a digital inclinometer. We previously assessed and reported intrarater and interrater reliabilities for the HTA measurement in 30 healthy shoulders.[15] The intraclass correlation coefficient and minimum detectable change (MDC) for intrarater reliability were 0.996 (95% confidence interval, 0.966-0.999) and 2.50°. The intraclass correlation coefficient and MDC values for interrater reliability were 0.974 (95% confidence interval, 0.894-0.990) and 3.40°.[15] Neither of the 2 primary examiners switched their role and knew the player's throwing arm dominance. Measurements were performed twice, and the mean value was used for data analysis.

A detailed questionnaire with 3 categories was administered. The first category was current status: age, throwing arm dominance, and current position. The second part was past baseball history: the age when the participant started playing baseball (starting baseball age), position played in the past (in elementary school, junior high school, high school, and college, if applicable), and experience of changing throwing arm. Specifically, "starting baseball age" in this study was defined as the age when players 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 the humeral retroversion.

Exclusion criteria were experience of changing throwing arm, history of Little League shoulder, current or past humeral fracture, scapular fracture, and obvious upper arm or forearm deformity. Scapular fracture was also excluded because bony adaptation of the

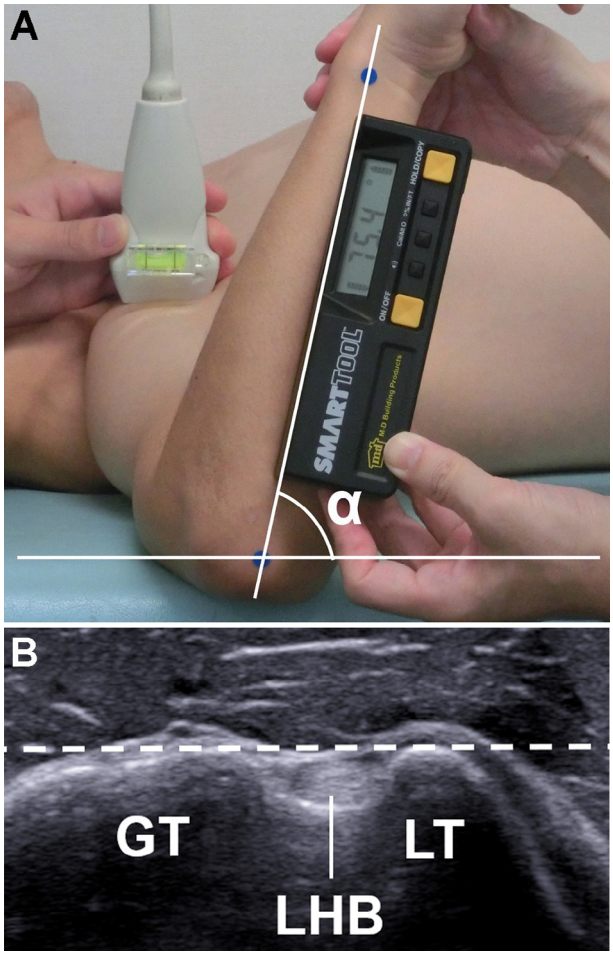

Figure 1 Assessment of humeral torsion angle (HTA). (**A**) Players lay supine with 90° of shoulder abduction and 90° of elbow flexion. A linear array ultrasound transducer was placed on the anterior aspect of the shoulder. A digital inclinometer was placed on the ulna and recorded the forearm inclination angle with respect to the horizontal line (this angle α represented HTA). (**B**) Echogram used for HTA measurement. The humerus was passively rotated so that the line passing the apexes of the greater and lesser tuberosities was horizontal in the screen. *GT*, greater tuberosity; *LHB*, long head of biceps; *LT*, lesser tuberosity.

proximal humerus and glenoid have been reported to be coupled during skeletal development in the throwing shoulder.[17] Height and weight were measured.

Statistical analysis

To investigate the relationship between the HTA and starting baseball age, players were divided into 4 groups: players who started playing baseball between age 5 and 6 years (group 5-6), between of 7 and 8 years (group 7-8), between 9 and 10 years (group 9-10), and between 11 and 12 years (group 11-12).

Next, to investigate the influence of position in the childhood, 2 groups were created according to the position played in elementary school and junior high school. The pitcher group was defined as players who played as a pitcher entirely (never played as a field player) or partially (also played as a field player). Field player group was defined as players who never played as a pitcher in elementary and junior high school. Players in both groups were divided into 4 starting age groups in the same manner as previously described.

Before we compared each parameter among the 4 starting age groups, normality of samples was judged by Kolmogorov-Smirnov test. One-way repeated-measures analysis of variance with Tukey-Kramer correction or Kruskal-Wallis test with Steel-Dwass correction were chosen to compare age, height, weight, and the bilateral HTAs among the 4 groups. The Fisher exact test was used to compare the proportion of players among the 4 groups who had played as a pitcher both totally and partially in elementary school and junior high school.

Paired *t* tests or Wilcoxon signed rank tests were used to compare the HTA between the throwing and non-throwing arm. Nonpaired *t* tests or Wilcoxon rank sum tests were used to compare mean age, starting baseball age, height, and weight between the pitcher group and field player group.

A P value of <.05 was considered to be statistically significant. The data are shown as mean ± standard deviation.

Results

We excluded 27 players because 1 player changed his throwing arm in past due to elbow pain, another had a history of Little League shoulder, and the remaining players provided no information about the baseball position they played in the past. The study thus analyzed 117 of the 144 male players. They had not played any other overhead sports habitually before they started playing baseball.

The mean age of 117 players was 21.8 ± 3.4 years old, mean height was 175.9 ± 5.8 cm, and mean weight was 76.5 ± 8.6 kg. Position at investigation was 67 pitchers, 7 catchers, 23 infielders, and 20 outfielders (to avoid overlap, a player who played multiple positions was grouped according to his main position). Regarding throwing arm dominance, there were 80 right-handed players and 37 left-handed players. The mean age when they started playing baseball (starting baseball age) was 8.0 ± 1.7 years old. All players had started playing baseball between the age of 5 and 12 years. The distribution of starting baseball age in all players and demographic data of 4 starting age groups are reported in Table I. No significant differences were found in the proportion of pitchers in childhood, mean age, height, and weight among the 4 groups.

The mean HTA of 117 players was 80° ± 7° in the throwing arm and 71° ± 8° in the non-throwing arm. The HTA in the throwing arm was significantly greater than the non-throwing arm ($P < .001$). The bilateral HTAs in all starting age groups are shown in Fig. 2. The HTA in the throwing arm was significantly greater than in the non-throwing arm in all starting age groups ($P < .001$ in all groups). Comparing the throwing arm, the HTA in starting age group 11-12 was significantly smaller than the other 3 groups. However, comparing the non-throwing arm, there were no significant differences among the 4 starting age groups.

Table I Demographic data of each starting age group (n = 117)

Variable	Starting baseball age, yr				*P* value	Test
	5-6	7-8	9-10	11-12		
	(n = 21)	(n = 60)	(n = 25)	(n = 11)		
Pitchers in childhood	13 (61.9)	44 (73.3)	16 (64.0)	7 (63.6)	.67	FET
Age, yr	22.8 ± 4.1	22.1 ± 3.6	20.7 ± 2.1	21.2 ± 2.3	.52	K-W test
Height, cm	175.4 ± 5.1	176.0 ± 6.2	174.8 ± 5.4	179.3 ± 5.0	.16	ANOVA
Weight, kg	75.6 ± 7.4	76.9 ± 9.1	75.1 ± 8.8	79.9 ± 6.5	.32	ANOVA

FET, Fisher exact test; *K-W*, Kruskal-Wallis; *ANOVA*, 1-way analysis of variance.
Categorical data are shown as number (%) and continuous data as mean ± standard deviation.

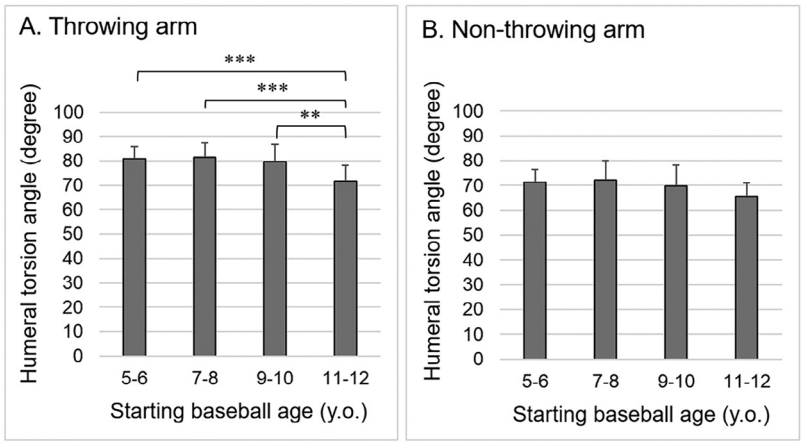

Figure 2 Humeral torsion angle and starting baseball age in all players (n = 117) in (**A**) the throwing arm and (**B**) non-throwing arm. Mean data are presented with the standard deviation (*error bars*). *y.o.*, years old. $^{**}P < .01$, $^{***}P < .001$.

Table II Demographic data of the 2 player groups

Variable	Pitcher group (n = 80)	Field player group (n = 37)	*P* value	Test
Age, yr	21.9 ± 3.3	21.7 ± 3.6	.76	WRST
Starting baseball age, yr	8.0 ± 1.6	8.0 ± 1.8	.92	WRST
Height, cm	175.8 ± 5.7	176.2 ± 6.1	.68	*t* test
Weight, kg	77.0 ± 7.8	75.5 ± 10.1	.39	*t* test

WRST, Wilcoxon rank sum test.
Data are presented as the mean ± standard deviation.

Relationship between HTA and childhood pitchers' starting age

There were 80 players (68.4%) who played as a pitcher totally or partially in elementary school and junior high school, and 48 were right-handed players and 32 were left-handed players. The mean age, height, and weight are reported in Table II. The mean starting baseball age was 8.0 ± 1.6 years old. The distribution of starting baseball age is reported in Table III. There were no significant differences in mean age, height, and weight among the 4 starting age groups.

The mean HTA of pitcher group (n = 80) was 80° ± 6° in the throwing arm and 70° ± 7° in the non-throwing arm. The HTA in the throwing arm was significantly greater than in the non-throwing arm ($P < .001$). The bilateral HTAs in all starting age groups are shown in Fig. 3. The HTA in the throwing arm was significantly greater than in the non-throwing

Table III Distribution of starting baseball age in the 2 player groups

Group	No.	Starting baseball age, yr			
		5-6	7-8	9-10	11-12
Pitcher	80	13	44	16	7
Field player	37	8	16	9	4

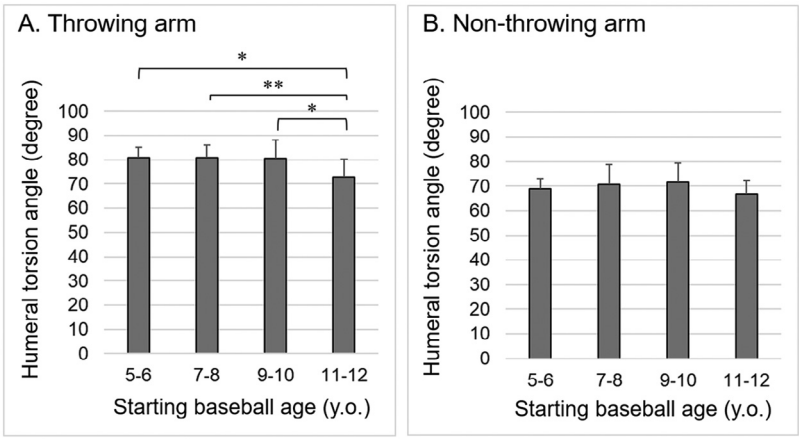

Figure 3 Humeral torsion angle and starting baseball age in childhood pitchers (n = 80) in (**A**) the throwing arm and (**B**) non-throwing arm. Mean data are presented with the standard deviation (*error bars*). *y.o.*, years old. *$P < .05$, **$P < .01$.

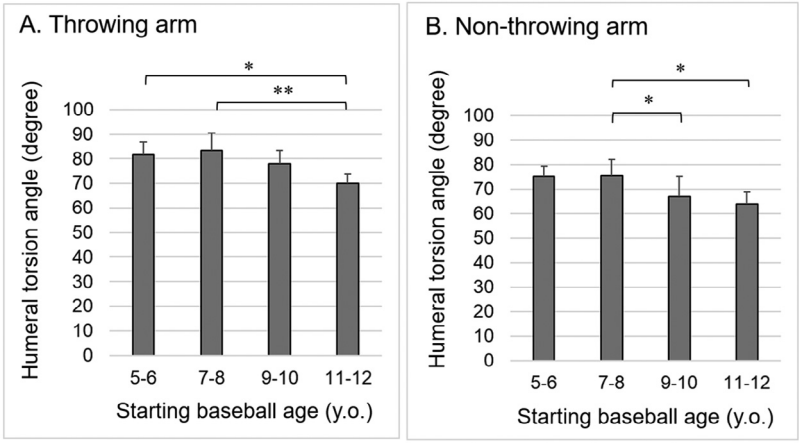

Figure 4 Humeral torsion angle and starting baseball age in childhood field players (n = 37) in (**A**) the throwing arm and (**B**) non-throwing arm. Mean data are presented with the standard deviation (*error bars*). *y.o.*, years old. *$P < .05$, **$P < .01$.

arm for all starting age groups ($P < .001$ for group 5-6, 7-8, and 9-10, and $P = .043$ for group 11-12). Comparing the throwing arm, the HTA in starting age group 11-12 was significantly smaller than in the other 3 groups. However, comparing the non-throwing arm found no significant differences among the 4 starting age groups.

Relationship between HTA and childhood field players' starting age

There were 37 players who never played as a pitcher in elementary school and junior high school, and 32 were right-handed players and 5 were left-handed players. The mean age, height, and weight were not significantly different from the pitcher group (Table II). The mean starting baseball age was 8.0 ± 1.8 years old. The distribution of starting baseball age is reported in Table III. There were no significant differences in mean age, height, and weight among the 4 starting age groups.

The mean HTA of the field player group (n = 37) was 80° ± 7° in the throwing arm and 72° ± 8° in the non-throwing arm. The HTA in the throwing arm was significantly greater than in the non-throwing arm ($P < .001$). The bilateral HTAs in all starting age groups are in Fig. 4. The HTA in the throwing arm was significantly greater than in the non-throwing arm in all starting age groups ($P < .001$ for groups 5-6 and 7-8, $P = .0013$ for group 9-10, and $P = .019$ for group 11-12). Through comparison of the throwing arm, the HTA in starting age group 11-12 was significantly smaller than in groups 5-6 and 7-8. Comparison of the non-throwing arm showed that the HTA in starting age group 7-8 was significantly greater than groups 9-10 and 11-12.

Discussion

The notable findings in this study were that skeletally mature baseball players who had started playing baseball after 11 years had significantly smaller humeral retroversion in the

throwing arm than those who had started playing baseball before 11 years. This is the first study to demonstrate the existence of a watershed age to obtain the greater humeral retroversion in the throwing arm after becoming skeletally mature.

Previous studies have clarified that repetitive pitching restricts the physiological derotation process of the humeral head and that side-to-side differences of humeral retroversion occur between the age of 9 and 11 years in baseball players.[7,18] However, little is known about the influence of starting baseball age on the humeral retroversion after becoming skeletally mature. To the best of our knowledge, only 2 studies have investigated the correlation between humeral retroversion and the number of years players played baseball before turning 16.[9,11]

These 2 studies had conflicting results. Osbahr et al[11] investigated humeral retroversion of 19 college baseball players using radiographs and reported no correlation between humeral retroversion and the number of years pitched by players between the ages of 8 and 16. Their results might have been different had they investigated more players and asked players how many years they pitched before turning 16 years. Nakase et al[9] used ultrasound to investigate humeral retroversion of 112 high school baseball players and showed a negative correlation between starting baseball age and humeral retroversion in the throwing arm of pitchers at investigation. The present study demonstrated an age that demarcates when this correlation reaches a threshold. Moreover, this watershed age is the same age as when side-to-side differences of humeral retroversion in baseball players occur.[7,18]

Another notable finding in this study was the influence of position played in childhood on the relationship between the humeral retroversion and starting baseball age. On one hand, humeral retroversion of the throwing arm of pitcher group was significantly greater in those who had started playing baseball before 11 years than those who started after 11 years (Fig. 3). On the other hand, comparison of the throwing arm of field player group showed that the HTAs of starting age groups 5-6 and 7-8 were significantly greater than in the starting age group 11-12 (Fig. 4).

We conducted this subgroup analysis to determine whether different total amount of pitches in childhood would affect the watershed age. For a more accurate and strict study, the total amount of pitches in childhood is desired; however, we failed to do so. We therefore divided players by the experience of having played as a pitcher in childhood because having played as a pitcher meant that the throwing humerus of the player was exposed to more repetitive rotational torque than a player who never played as a pitcher. The results from this subgroup analysis indicate that the watershed age might be lower than 11 years if people never played as a pitcher in childhood. In other words, if a player pitched a large amount, the throwing humerus of the player could be greater even though his starting baseball age is 9 or 10. However, a player might need to start baseball earlier for greater retroversion in the throwing arm if he does not pitch a lot.

In the non-throwing humerus, a significant difference was found in the field player group, but no significant difference was observed in the non-throwing arm of the pitcher group. There were no significant differences in demographic data, such as age, starting baseball age, height, and weight, between the pitcher group and the field player group. The effects of other baseball motions, such as batting, may need to be investigated. However, previous studies indicated no effect of playing baseball on the non-throwing arm. Kurokawa et al[7] demonstrated the physiological humeral derotation process was restricted only in the throwing arm, whereas humeral retroversion of the non-throwing arm decreased with age. Nakase et al[9] reported no correlation between humeral retroversion of the non-throwing arm and starting baseball age. Comparison of the non-throwing arm in the 117 players also showed no significant difference among 4 starting age groups in this study. Humeral retroversion was reported to widely vary among individuals.[4,12,13] The result of the non-throwing arm in the field player group might be due to a small sample size. For our future study, we will increase the number of players in the field player group.

All players were divided into a 2-year range starting age group in this study. Dividing players into a 1-year range starting age group seemed less meaningful because skeletal age varies among individuals. Our motivation was to clarify the existence of a watershed age and when the approximate watershed age is (lower grade, middle grade, or upper grade). From this study, we concluded that the watershed age was 11 years, which was consistent with the age when side-to-side differences of humeral retroversion were reported to occur. Actually, the mean HTA of the throwing arm was 80° in players who had started baseball at 9 years, 81° at 10 years, 72° at 11 years, and 72° at 12 years, although the sample size was not large enough to be statistically significant.

One of the strengths of this study was that all players were skeletally mature. Although physeal closure was not confirmed by radiographs, all players reported their height had not changed for at least 1 year. Another strength of this study was that all players were divided according to their baseball position in elementary and junior high school to investigate positional differences. As described in the former part of the Discussion, positional difference reflects the different total amount of pitches. This study investigated the effect of repetitive pitching in childhood on the humeral retroversion after skeletal maturity. Therefore, subgroup analysis by baseball position seems reasonable using the players' baseball position during their childhood. Nakase et al[9] also described assessing the effect of position during elementary and junior high school on humeral retroversion as their future study.

This study has a few limitations that should be acknowledged. First, the sample size of the field player group was rather small. There were 50 field players (42.7%) in a current position; however, the field player group consisted of 37 players (31.6%). This is because the 53 players who had played as both a pitcher and field player were put into the pitcher group. People commonly play multiple positions in childhood

baseball. Actually, 58 players (49.6%) played multiple positions in childhood, whereas only 7 players (6.0%) played multiple positions for their current team. In addition, because the players enrolled in this study were highly competitive college or amateur baseball players, it was natural that they would have been good enough players to play as a pitcher during their childhood. Increasing the number of players and confirming the positional difference of the watershed age is our future study.

Secondly, the number of players who had started playing baseball after 11 years was small, which could not be controlled. Because the players enrolled in this study were elite baseball players, most of the players started playing baseball in the lower grades of elementary school. In addition, recruiting players who started playing baseball after 11 years, with no previous experience of engaging in other sports, seems to be difficult.

A third limitation is recall bias. Some players could not remember exactly what positions they had played during their childhood, which resulted in the loss of 25 players for analysis.

Conclusion

Skeletally mature baseball players who started playing baseball after 11 years of age had significantly smaller humeral retroversion in the throwing arm than those who started playing baseball before 11 years. There may be a watershed age to obtain greater humeral retroversion in the throwing arm that is the same age when side-to-side differences of humeral retroversion in baseball players occur.

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