Showa Univ J Med Sci 27(2), 63～69, June 2015

Original

Assessment of Humeral Retroversion Angle in Baseball Players: A Chronological Study

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Abstract: The objective of this study was to compare the humeral retroversion angles (HRA) between baseball players, including children, and those without a history of playing baseball, clarify the characteristics of the HRA in baseball players, and to determine whether or not chronological changes of the HRA are affected by a throwing motion. We studied 32 young baseball players (Group A), 10 elementary and junior high school students who had never played competitive overhead throwing sports (Group B), 65 adult baseball players who had been playing baseball since childhood in a little league or boy's baseball team (Group C), and 11 adults who had never played competitive overhead throwing sports such as baseball or handball (Group D). Computed tomography of both humeri in these subjects was taken with a 5 mm slice thickness. For the measurement of HRA, slices from the center of the humeral head and slices from the humeral epicondyle were examined. In baseball players, the mean HRA on the throwing side was larger than that on the non-throwing side, regardless of age and carrier. The HRAs of the elementary and junior high school baseball players as well as those of adult baseball players were larger on the throwing side. The HRA of the throwing side was significantly greater than that of the non-throwing side in both groups of baseball players. Furthermore, the mean HRA on the throwing side of young baseball players was significantly larger than that of adult baseball players, suggesting that the adaptive bony change of the humerus was caused by throwing stress and might occur in the early formative years of a player's career.

Key words: humeral retroversion angle, computed tomography, baseball players, chronological study

Introduction

Various osseous changes are observed in athletes because of the repetitive stress to their bodies during sporting activities. Accordingly, it is anticipated that baseball players also undergo bony changes due to their repetitive throwing motion. In particular, external rotation is

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Table 1. Subjects and their demographic data

Group A	Elementary and junior high school baseball players without a symptom in the shoulder joint	32 subjects (18 elementary and 14 junior high school baseball players) Age：10～15 years old (average：12.1 years old) Years of play：2～9 years (average：5.4 years)
Group B	Elementary and junior high school students who have never played a sport involving a throwing motion	10 subjects (7 elementary and 3 junior high school students) Age：8～14 years old (average：10.7 years old)
Group C	Adult baseball players who started to play baseball in childhood by belonging to a little league or boys' baseball team and are still playing baseball	65 subjects (37 professional baseball players, 27 corporate team players, and 1 student) Age：20～36 years old (average：26.0 years old) Years of play：10～28 years (average：19.8 years)
Group D	Adults who have never played a sport involving a throwing movement such as baseball or handball since childhood	11 subjects Age：23～32 years old (average：28.0 years old)

increased and internal rotation is decreased in their throwing shoulder when measured at 90° of abduction[1]. Thus we hypothesized that particular attention should be paid to the humeral retroversion angle (HRA) in baseball players. The objective of this study was to compare the HRA between baseball players, including children, and control subjects without a history of playing baseball, to clarify the characteristics of HRA in baseball players, and to determine whether chronological changes to the HRA are affected by the throwing action.

Materials and methods

This study included 32 elementary and junior high school baseball players without any shoulder joint symptoms (Group A), 10 elementary and junior high school students who have never played competitive sports involving overhead throwing such as baseball or handball (Group B), 65 adults who have been playing baseball since childhood in a little league or boy's baseball team (Group C), and 11 adults who have never played competitive sports involving overhead throwing (Group D). Group A consisted of 18 elementary school students and 14 junior high school students, ranging in age from 10 to 15 years (average: 12.1) and with a history of baseball playing of 2 to 9 years (average: 5.4). Group B comprised 7 elementary school students and 3 junior high school students, ranging in age from 8 to 14 years (average: 10.7). Group C consisted of 37 professional baseball players, 27 corporate team players, and 1 college student, ranging in age from 20 to 36 years (average: 26.0) and with a history of baseball playing for 10 to 28 years (average: 19.8). The age range of group D was 23 to 32 years (average: 28.0) (Table 1). Computed tomography (CT) of both humeri was performed for all subjects while in the supine position with their forearms naturally hanging down. An Image Max Ⅱ (GE Health-

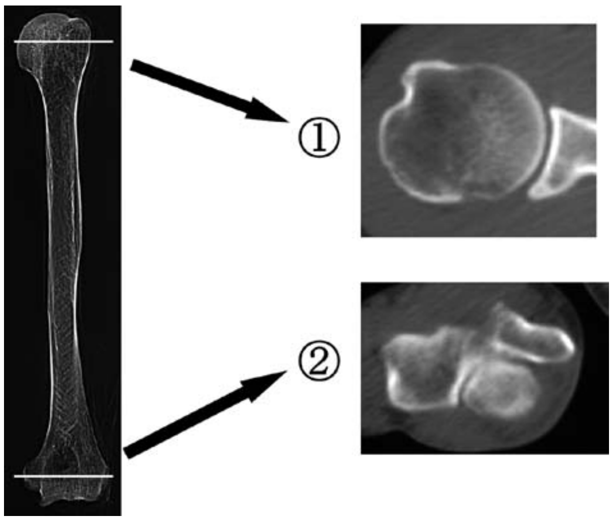

Fig. 1. Humerus with corresponding CT slices
① Center of the humeral head
② Humeral epicondyle

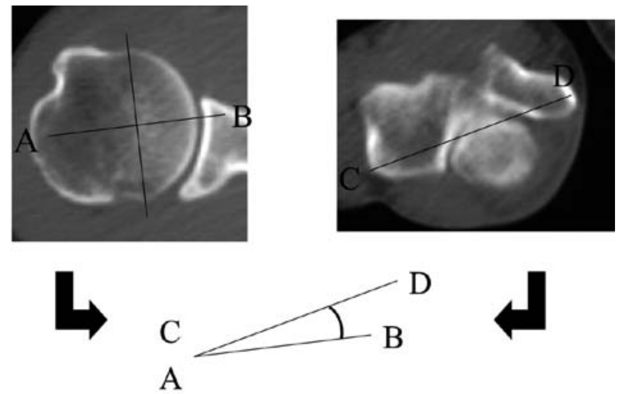

Fig. 2. Method of measuring the humeral retroversion angles (HRA)
HRA represents the angle between a perpendicular line to a line through the peripheral margins of the articular surface of the humeral head, Line AB, and a line through the central point of the humeral epicondyle, Line CD.

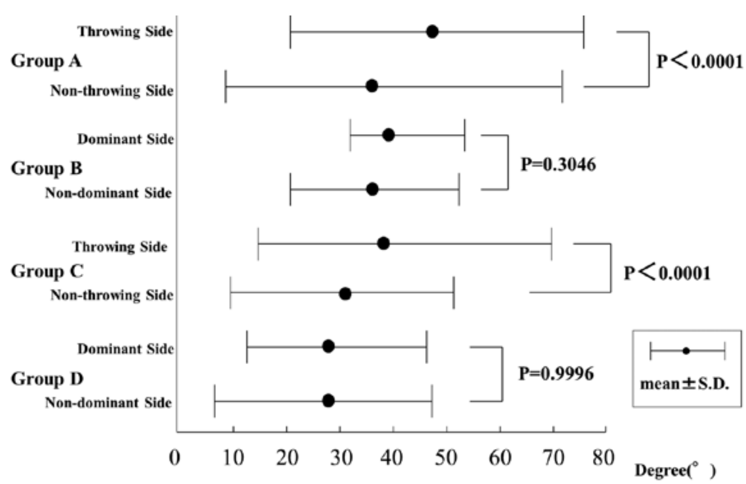

Fig. 3. HRA measurements

care Japan: former Yokogawa Medical System, Tokyo, Japan) was used for CT with the bone images processed at 5-mm scan slice thickness. For the measurement of HRA, slices from the center of the humeral head and from the humeral epicondyle were examined (Fig. 1). HRA represents the angle between a perpendicular line to a line through the peripheral margin of the articular surface of the humeral head, designated as Line AB, and to a line through the central point of the humeral epicondyle, Line CD. Line AB was derived based on the method of Simeonides *et al*[2] while line CD was measured by following the method of Randelli and Gambrioli[3] (Fig. 2). A t-test was used for the statistical analyses with a significance level set at less than 5 %. All patients and their families provided informed consent that the case data from this study could be submitted for publication. This report was approved by our institutional review board.

Results

HRA within each group (Fig. 3)

The mean HRA of Group A was 47.8° ± 12.5° (20.2° ～ 76.0°) on the throwing side and 35.6° ± 12.8° (8.6° ～ 71.6°) on the non-throwing side, and this difference between sides was significant ($P < 0.0001$).

In Group B, the mean HRA was 39.6° ± 6.2° (31.4° ～ 52.1°) on the dominant side and 35.8° ± 9.1° (20.3° ～ 51.3°) on the non-dominant side, with no statistical difference observed ($P = 0.3046$).

The mean HRA in Group C was 38.6° ± 11.7° (14.4° ～ 69.8°) on the throwing side and 30.7° ± 9.7° (9.5° ～ 50.8°) on the non-throwing side, with the difference being significant ($P < 0.0001$).

In Group D, the mean HRA was 27.6° ± 12.6° (12.6° ～ 45.9°) on the dominant side and 27.6° ± 13.1° (7.0° ～ 46.8°) on the non-dominant side, with no statistically significant difference observed ($P = 0.9996$).

Comparison among groups

For inter-group comparisons, the HRA on both the throwing and non-throwing sides were significantly larger in Group A than in Group C ($P < 0.05$). In contrast, the HRA on the throwing side in Group A tended to be larger than those on the dominant side in Group B, but this difference was not significant ($P = 0.0542$), and no statistical significance was noted when comparing HRA between the non-throwing side in Group A and the non-dominant side in Group B ($P = 0.9611$).

Finally, the HRA was significantly larger on the throwing side in Group C than on the dominant side in Group D ($P = 0.0053$), and no statistically significant difference was observed between the HRA on the non-throwing side in Group C and on the non-dominant side in Group D ($P = 0.3596$).

Discussion

The literature to date indicates that athletes undergo various bony changes due to stress applied to their body. In one study, Jones *et al*[4] found that the thickness of the humeral cortex among professional tennis players was increased on the dominant side by 34.9% in men and 28.4% in women. Furthermore, Krahl *et al*[5] reported that the length of the upper extremity on the dominant side was increased among professional tennis players. We thus proposed that similar asymmetric bony changes takes place among baseball players, and accordingly, investigated the increased external rotation and decreased internal rotation at 90° of abduction seen in the shoulders of baseball players, using changes in humeral retroversion as a readout based on their reported association to a bony factor. In 1999 we reported mean HRA on the throwing and non-throwing sides of 32 adult baseball players as 36.0° and 29.6°, respectively[6], while in 2003 in 9 elementary and junior high baseball players, we reported a mean HRA of 40.9° and 27.9° on the

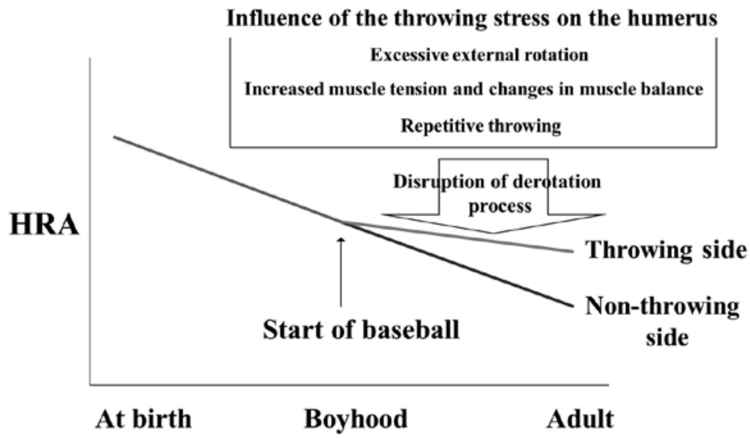

Fig. 4. Changes in HRA in baseball players (hypothesis)
HRAs start to show a difference from birth between right and left, which indicates that since the humerus on the pitching side undergoes repetitive stress due to a throwing motion, osseous changes begin to take place during childhood.

throwing and non-throwing sides, respectively[7]. As a result of these investigations, we concluded that mean HRA in baseball players was larger on the throwing side than on the non-throwing side, regardless of age and career.

Pieper[8] also measured HRA in 51 handball players using an X-ray image intensifier, and reported a 9.4° increase on average for the dominant side compared to the non-dominant side. In addition, Crockett *et al*[9] reported a mean HRA in 25 professional baseball players of 40° in their pitching shoulder and 23° in their non-pitching shoulder. Similarly, Osbahr *et al*[10] reported mean HRA of 33.2° on the throwing side and 23.1° on the non-throwing side, while Reagan *et al*[11] reported a mean HRA of 36.6° on the throwing side and 26.0° on the non-throwing side. The present study now provides more detail on this issue, by revealing that HRA on the throwing side in the elementary and junior high school baseball players (Group A) and in the adult baseball players (Group C) was larger than the equivalent measurement on the non-throwing side, whereas the HRA on the dominant and non-dominant sides were not significantly different in both elementary and junior high students (Group B) and adults (Group D) who have never played sports involving a throwing motion.

In a study of HRA in 336 cadavers, Edelson[12] reported a mean of 78° in fetuses, 65° in infants aged 4 months to 4 years, and 38° in children aged 10 to 12 years. Since the average HRA in adults is approximately 30°[13, 14], we can conclude that HRA are markedly larger at birth in humans, but then become smaller in the course of their development. According to our study, elementary and junior high school students recorded larger HRA in general than adults, and mean HRA was also larger on the throwing side of elementary and junior high school baseball players compared with adult baseball players.

Based on these results of changes in the retroversion angles in baseball players, we postulated that a markedly large HRA at birth would start to show a difference between the right and left sides during the regular de-rotation process as a result of playing baseball during childhood, and as a result, the HRA on the throwing side remains large. This suggests that since the humerus on the pitching side undergoes repetitive stress due to the throwing motion, osseous changes begin to take place in childhood (Fig. 4). It is well known that the pitching motion produces an excessive force and torque on both the shoulder and elbow joints[15], with Sabick[16] reporting a peak in mean humeral axial torque of 92 ± 16 Nm near the point of maximum shoulder external rotation at the end of the cocking phase. Wermel *et al*[17] also reported a significant effect on humeral torsion when the muscles attached to the humerus were cut during the growth period in rabbits. In studying such a relationship between the humeral torsion and muscle tension of the rotator cuff, Evans and Krahl[18] concluded that the humeral torsion is affected by the interaction of two factors: primary torsion, which is an innate retroversion, and secondary torsion, which is caused by muscle strength. They concluded that an elevation in muscle tension of the rotator cuff contributes to an increase in humeral retroversion. On the other hand, Pieper[8] postulated that this increased retroversion could be attributed to adaptive changes in athletes' bodies resulting from excessive external rotation during pitching in the players' early formative years. However, despite these various reports, to date the mechanism affecting the torsion of the humerus remains to be elucidated. Furthermore, it is not known at which developmental phase athletes become vulnerable to these changes. The present study has clarified that the markedly large HRA at birth could be unilaterally disrupted during the de-rotation process as a result of children starting to play baseball at a young age, and that HRA becomes larger on the throwing side in these children.

Conflict of interest disclosure

The authors have declared no conflict of interest.

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[Received January 6, 2015 : Accepted January 26, 2015]