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**Original Article**

# Analysis of Range of Motion and Isokinetic Strength of Internal and External Rotation According to Humeral Retroversion of the Dominant Shoulder in Youth Baseball Players: A Pilot Study

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**Abstract**

**Background:** We aimed to analyze the range of motion (ROM) and internal rotation (IR) and external rotation (ER) isokinetic strength according to humeral retroversion of the dominant shoulder.

**Methods:** We included 40 elite baseball players in Korea (OBP group: n=20 players with careers spanning >10 years, age: 19.37±2.21 years, height: 181.00±5.41 cm, weight: 84.58±7.85 kg; BBP group: n=20 players with careers spanning <10 years, age: 16.55±1.36 years, height: 177.27±7.57 cm, weight: 77.27±8.14 kg). Radiography was performed to examine humeral retroversion, a goniometer was used to measure IROM and EROM, and a dynamometer was used to measure IR and ER isokinetic strength (speed set at 180°/s or 300°/s).

**Results:** The BBP and OBP groups had significantly different IR and ER isokinetic strength (180°/s and 300°/s) ($P$<0.001) and dominant shoulder retroversion ($P$=0.009). In the BBP group, retroversion had no correlation with ROM and with IR or ER isokinetic strength (180°/s and 300°/s). In the OBP group, retroversion had no correlation with ROM and with ER isokinetic strength at 180°/s, but had significant correlation with IR isokinetic strength at both 180°/s (r=0.483, $P$=0.007) and 300°/s (r=0.373, $P$=0.043) and ER isokinetic strength at 300°/s (r=0.366, $P$=0.046).

**Conclusion:** Thus, youth players with careers spanning >10 years had significantly higher humeral retroversion, IROM, EROM, and IR and ER isokinetic strength of the dominant shoulder than youth players with careers spanning <10 years. Furthermore, humeral retroversion and ROM were not significantly related, but IR and ER isokinetic strength were significantly positively related with retroversion in both groups.

**Keywords:** Baseball, Humeral retroversion, Isokinetic strength, Range of motion

## Introduction

During throwing motion in baseball, the tractive force at the shoulder is generally 1.5–2 times the humeral angular speed at >7,000°/s, and the rotary force at the shoulder is 1,400 inch-pounds (1-2). These forces cause functional and structural changes in the shoulder joint as well as restriction of range of motion (ROM) of bone and soft tissue (3). In addition, frequent overhead motion while playing baseball results in abnormal symptoms, instability of the shoulder joint, and change in ROM due to tightness and/or a loosened articular capsule. Therefore, many authors have studied differences in ROM between dominant and non-dominant shoulders (4). Brown et al. (5) and Bigliani et al. (1) reported that the dominant shoulder has a greater external rotation range of motion (EROM)—by 9–14°—as compared to the nondominant shoulder, whereas other researchers have shown that it has a smaller internal rotation range of motion (IROM) (6-8). These authors explained that changes in the soft tissue that occur over time consequently change the retroversion angle of the shoulder joint, resulting in the restriction of ROM.

Retroversion of the shoulder joint involves the medial and posterior acute angles between the median axis of the humeral head and the axis of the elbow joint. Generally, the retroversion angle of the humeral head is 26–30°; however, radiography has shown that changes in shoulder joint ROM by twisting of the humeral head growth plate increases the humeral retroversion angle. Moreover, Reagan et al. (4) reported that repeated twisting results in a decrease in muscle strength.

In baseball, absolute flexibility of the shoulder joint is needed, because external rotation (ER) provides stability during throwing motion; however, excessive flexibility can result in injury owing to instability of the humeral head. Thus, to prevent injury, structural and functional stability of the shoulder joint are needed; therefore, baseball players should stabilize their shoulder joints during throwing motion. The shoulder joint is stabilized by primary structures, including the articular capsule, glenohumeral ligament, and labrum. Secondary structures, including the rotator cuff, deltoid, and biceps, also provide dynamic stabilization to the fixed nerve root during throwing motion (9). The shoulder muscle is not well developed during childhood compared with that during adulthood; therefore, youth players experience frequent injuries of the shoulder joint owing to weak and unstable primary and secondary structures. In particular, epiphysitis, or "little league shoulder," occurs frequently in youth baseball players.

Kibler et al. (10) found that significant increases in ER and significant decreases in internal rotation (IR) of the dominant shoulder shorten an athlete's career and prevent their progress to higher levels in terms of skill and professional achievements. Many studies have documented consistent changes in musculature, bone, and ROM of the dominant shoulder of overhand-throwing athletes (3). These authors have attributed the difference in ROM to changes in the soft tissue enveloping the shoulder (4).

Shoulder joint ROM and strength of the internal and external rotator muscles are important factors for preventing repetitive overuse syndrome and for rehabilitating athletes who experience this condition (11). Moreover, it is necessary to determine whether changes in the shoulder joint of youth players are caused by the soft tissue or humeral retroversion by using radiography, in order to evaluate IROM and EROM (8). However, few authors have studied structural changes in the dominant shoulder and strength of the internal and external rotator muscles according to the duration of the baseball career.

Thus, we investigated the differences in humeral retroversion, ROM, and isokinetic strength of the dominant shoulder in youth baseball players to provide basic data for a shoulder strengthening program in youth baseball training and analyzed the correlations between humeral retroversion and ROM and isokinetic strength.

## Methods

### *Subjects*

This study analyzed 40 elite youth baseball players who had visited SM Sports Rehabilitation Clinic in B City, Korea. They were classified into 2 groups: players with a baseball career spanning >10 years (OBP group, n = 20) and players with a baseball career spanning <10 years (BBP group, n = 20). The subjects had no medical problems, received an explanation of the study, and signed an informed consent form. All study procedures were approved by SM Sports Rehabilitation Clinic.

The average ages of participants in the OBP and BBP groups were 19.37 ± 2.21 and 16.55 ± 1.36 years, average heights were 181.00 ± 5.41 and 177.27 ± 7.57 cm, average weights were 84.58 ± 7.85 and 77.27 ± 8.14 kg, and average career durations were 12.04 ± 0.54 and 5.12 ± 1.90 years, respectively. The characteristics of the subjects are shown Table 1.

**Table 1:** Subject characteristics

| Male (N = 40) | Age, years | Weight, kg | Height, cm | Career, years |
|---|---|---|---|---|
| OBP (n = 20) | 19.37 ± 2.21 | 84.58 ± 7.85 | 181.00 ± 5.41 | 12.04 ± 0.54 |
| BBP (n = 20) | 16.55 ± 1.36 | 77.27 ± 8.14 | 177.27 ± 7.57 | 5.12 ± 1.90 |

Values are expressed as mean ± standard deviation. / Abbreviations: OBP, career spanning >10 years as an elite youth baseball player; BBP, career spanning <10 years as an elite youth baseball player

### *Radiography of the shoulder joint*

Radiography of the humerus in the semi-axial view was conducted by an expert for evaluating shoulder retroversion, as described by Osbahr et al. (12) who had modified the method by Söderlund et al. (13). In the supine position, the subject grabbed the fixture at 90° flexion and 10° abduction of the shoulder joint and 90° flexion of the elbow joint (Fig. 1). Simultaneously, the subject maintained his forearm at 0° to avoid pronation or supination. The radiograph cassette was placed behind the shoulder and elbow, and a vertical shot was taken. Retroversion was defined as the angle between the vertical line to the humeral head and the epicondylar axes (in degrees).

**Fig. 1:** The subject is placed in the supine position, and grabs the fixture with 90° flexion and 10° abduction of the shoulder joint and 90° flexion of the elbow joint

### *Measurement of IROM and EROM of the shoulder joint*

First, the subject was asked to maintain a supine position with 90° flexion of the shoulder joint, 90° flexion of the elbow joint, and 0° of the forearm and to avoid pronation or supination. Thereafter, the subject was asked to relax the forearm on the table but not the elbow joint. The humerus was placed horizontal to the acromion process by placing a pad under the humerus. The pin hole of the protractor was placed on the olecranon process with the anchor arm perpendicular to the ground and the adjustable arm fixed to the ulna based on the olecranon process and the ulnar styloid. The largest extent of IROM of the shoulder was measured by moving the forearm toward the front with the palm facing the ground, whereas the largest extent of EROM of the shoulder was measured by moving the forearm backward.

### *Evaluation of IR and ER isokinetic strength of the shoulder joint*

The Cybex 770 Model (Division of Lumex, Inc., NY, USA) was used to evaluate IR and ER isokinetic strength of the shoulder. The subjects performed tests at 180°/s and 300°/s, 4 times in the supine position, with 90° flexion of the shoulder joint and 90° flexion of the elbow joint. During the test, the subject's trunk was anchored by a belt, and a dynamometer was attached to the exercising arm. There were 3 practice tests, and sufficient resting time was provided before the test. The tests for the nondominant shoulder were performed before those for the dominant shoulder, and auditory feedback using a voice was provided to encourage maximal strength.

### *Statistical analysis*

Statistical analysis was conducted using SPSS Ver. 18.0 for Windows (Chicago, IL, USA). The characteristics of the subjects were analyzed by descriptive statistics, the normality of all measured values was tested using the one-sample Kolmogorov-Smirnov test, and homoscedasticity was evaluated using Levene's variance F test. In addition, an independent *t* test was conducted for the variables in each group, whereas the relationships between retroversion and ROM and isokinetic strength were analyzed using Pearson's correlation analysis. Statistical significance was set at $\alpha < 0.05$.

## Results

### *Analysis of retroversion and ROM*

The results of shoulder retroversion, IROM, and EROM in the 2 groups are shown in Table 2. There was a significant difference in retroversion (*P* = 0.009) between the OBP and BBP groups (37.82 ± 5.15 Nm vs. 31.50 ± 1.23 Nm). IROM was 54.55 ± 10.56 Nm in the OBP group and 56.63 ± 7.86 Nm in the BBP group, whereas EROM was 144.79 ± 3.90 Nm in the OBP group and 140.55 ± 1.54 Nm in the BBP group. The differences in ROM were not significant between the 2 groups.

### *Analysis of isokinetic strength*

The results of IR and ER isokinetic strength are shown in Table 3. The OBP and BBP groups showed significant differences in IR at 180°/s (28.00 ± 4.98 Nm vs. 19.29 ± 4.73 Nm, *P* < 0.001), IR at 300°/s (24.42 ± 5.56 Nm vs. 17.00 ± 4.12 Nm, *P* = 0.001), ER at 180°/s (19.53 ± 3.13 Nm vs. 13.73 ± 2.28 Nm, *P* < 0.001), and ER at 300°/s (16.21 ± 3.19 Nm vs. 10.82 ± 2.56 Nm, *P* < 0.001).

**Table 2:** Analysis of retroversion and ROM in the OBP and BBP groups

| Trial | OBP (n = 20) | BBP (n = 20) | *t* | *P*-value |
|---|---|---|---|---|
| Retroversion, Nm | 37.82 ± 5.15 | 31.50 ± 1.23 | -2.790 | 0.009** |
| IROM, Nm | 54.55 ± 10.56 | 56.63 ± 7.86 | -0.617 | 0.542 |
| EROM, Nm | 144.79 ± 3.90 | 140.55 ± 1.54 | -0.301 | 0.766 |

Values are expressed as mean ± standard deviation. ** *P* < 0.01

Abbreviations: ROM, range of motion; OBP, career spanning >10 years as an elite youth baseball player; BBP, career spanning <10 years as an elite youth baseball player; IROM, internal rotation range of motion; EROM, external rotation range of motion

**Table 3:** Analysis of isokinetic strength in the OBP and BBP groups

| Trial | OBP (n=20) | BBP (n=20) | *t* | *P* |
|---|---|---|---|---|
| IR 180°/s, Nm | 28.00 ± 4.98 | 19.29 ± 4.73 | -4.700 | <0.001*** |
| IR 300°/s, Nm | 24.42 ± 5.56 | 17.00 ± 4.12 | -3.840 | 0.001** |
| ER 180°/s, Nm | 19.53 ± 3.13 | 13.73 ± 2.28 | -5.350 | <0.001*** |
| ER 300°/s, Nm | 16.21 ± 3.19 | 10.82 ± 2.56 | -4.770 | <0.001*** |

Values are expressed as mean ± SD. ** *P* < 0.01. *** *P* < 0.001

Abbreviations: OBP, career spanning >10 years as an elite youth baseball player; BBP, career spanning <10 years as an elite youth baseball player; IR, internal rotation; ER, external rotation

### *Correlations of retroversion and ROM and isokinetic strength*

The correlations of retroversion and ROM and isokinetic strength are shown in Table 4. In the OBP group, no correlation was noted between retroversion and ROM (IROM: r = 0.104, *P* = 0.584; EROM: r = -0.044, *P* = 0.816) and ER isokinetic strength at 180°/s (r = 0.360, *P* = 0.050), but significant correlations were noted between retroversion and IR isokinetic strength at 180°/s (r = 0.483, *P* = 0.007), IR isokinetic strength at 300°/s (r = 0.373, *P* = 0.043), and ER isokinetic strength at 300°/s (r = 0.366, *P* = 0.046). In the BBP group, there was no correlation between retroversion and ROM (IROM: r = -0.172, *P* = 0.364; EROM: r = 0.334, *P* = 0.072), IR isokinetic strength at 180°/s (r = -0.044, *P* = 0.818), IR isokinetic strength at 300°/s (r = -0.016, *P* = 0.935), ER isokinetic strength at 180°/s (r = -0.123, *P* = 0.516), and ER isokinetic strength at 300°/s (r = -0.263, *P* = 0.160).

**Table 4:** Correlations among retroversion, range of motion, and isokinetic strength in the OBP and BBP groups

| Retroversion Trial | IROM | EROM | IR 180°/s | IR 300°/s | ER 180°/s | ER 300°/s |
|---|---|---|---|---|---|---|
| OBP (n = 20) | 0.104 | -0.044 | 0.483** | 0.373* | 0.360 | 0.366* |
| BBP (n = 20) | -0.172 | 0.334 | -0.044 | -0.016 | -0.123 | -0.263 |

* $P < 0.05$. ** $P < 0.01$/Abbreviations: OBP, career spanning >10 years as an elite youth baseball player; BBP, career spanning <10 years as an elite youth baseball player; IROM, internal rotation range of motion; EROM, external rotation range of motion; IR, internal rotation; ER, external rotation

## Discussion

Tullos & King (14) reported that a larger EROM results in a faster throwing speed in overhead-throwing baseball players. However, players who pitch frequently can develop instability and pain due to lack of shoulder ROM, a loosened articular capsule, and lower flexibility (15). Increased ER of the dominant shoulder joint is the result of physiologic change in soft tissue; in particular, a stretched coracohumeral ligament increases ER and loosens the capsule. IR of the dominant shoulder decreases owing to extension of the anterior articular capsule and tightness of the posterior articular capsule as well as microdamage caused by repetitive throwing motion (1).

However, it is not certain whether these results are due to changes in the soft tissue or retroversion through bone adaptation to throwing motion. Moreover, retroversion of the humerus may decrease IR and may increase ER of the shoulder joint. Osbahr et al. (12) reported that in a university baseball player, increased ER in retroversion, as observed on radiography, was caused by twisting of the humerus growth plate. Reagan et al. (4) reported a similar condition in a university baseball player.

Yamamoto et al. (16) studied 66 elementary school baseball players and reported that they had a smaller bicipital-forearm angle in the dominant arm, which increased ER and retroversion. This result indicates that the dominant shoulder tends to have a larger retroversion compared with the nondominant shoulder. Retroversion that occurs during the elementary, middle, and high school years is assumed to be caused by changes in the growth plate and soft tissue of the shoulder joint during the growth period. Previous studies on shoulder joint ROM in baseball players have reported that the IROM decreased and EROM increased in the dominant shoulder, which causes asymmetrical ROM of the rotator cuff (1, 5, 17-18). Crockett et al. (7) measured the scapular plane in 90° abduction in baseball players and reported that IROM had decreased and EROM had increased in the dominant shoulder of baseball players, but these changes were not different when compared with IROM and EROM as well as overall ROM in nonplayers. William et al. (19) divided baseball players into groups according to age (8–12 years, 13–14 years, and 15–28 years) and found that ER was larger in the dominant shoulder and IR was larger in the nondominant shoulder as age increased.

Crockett et al. (7) reported increased ER and decreased IR after 12 years of age, and stated that this change results from retroversion of the humeral head. Furthermore, the period of 13–16 years of age, during which the growth plate of the humeral head opens, is a window of opportunity for baseball players because the increase in ER has a positive effect on pitching. Lyman et al. (20) reported that "little league shoulder" is caused by overuse, and is considered a kind of stress fracture of the growth plate. In addition, they reported that at approximately 14 years of age, there is a stronger relationship between the frequency of pitching and strength, and better players have a larger retroversion. In the present study, there was a significant difference in retroversion between the group with a career spanning >10 years and the group with a shorter career, with a larger retroversion observed in players with longer careers.

Our results showed a larger retroversion in players with longer careers but no significant difference in IROM or EROM; these results are contradictory of those of previous studies. It is believed that there is some extent of tightness as young individuals age, and that retroversion—affected by the flexibility of the shoulder joint—does not restrict ROM.

The rotator cuff's function is to move the shoulder joint, fix the humeral head, and stabilize the joint. It also controls against the changes in the joint and protects the glenoid labrum and articular capsule (21). The strength of the rotator cuff is important for the prevention of injury as well as for performance in baseball players. Ellenbecker et al. (11), who studied isokinetic rotation strength in pitchers, and Cook et al. (22) reported that the ratio between IR and ER strength was smaller in the dominant shoulder of university baseball players. In addition, Hinton (23) reported that IR power was greater than ER power in the dominant shoulder of high school baseball players, whereas Brown et al. (5) reported that major league players had significantly higher IR than ER of the dominant shoulder at 180, 240, and 300°/s. Ivey et al. (24) reported no significant difference in rotation strength of the dominant shoulder of nonplayer university students compared with players, but that the rotation strength of nonplayers increased in the dominant shoulder.

Starkey & Ryan (21) reported that the ratio between IR and ER strength at 60°/s was 76.7% in the dominant shoulder and 88% in the nondominant shoulder, whereas Ellenbecker et al. (11) reported that the ideal ratio is 66%, and that the ratio changes when the shoulder joint is unstable. Ellenbecker et al. (11) also recommended that the ratio increases by 10% when the anterior-inferior glenohumeral joint is unstable. In the present study, there was a significant difference between the OBP and BBP groups with regard to IR at 180°/s, IR at 300°/s, ER at 180°/s, and ER at 300°/s. These results correspond to those of a previous study that reported that the dominant shoulder has higher strength and larger retroversion as age increases, which improves isokinetic rotation strength. We also determined a significant correlation between retroversion and isokinetic rotation strength, which seems to indicate that increased retroversion increases isokinetic rotation strength. This study is limited in that there is a time gap of 7–11 years in the initial age when performing sports activity between the OBP and BBP groups. Therefore, a better designed study is needed.

## Conclusion

The present study is a pilot approach to elucidate initial evidence that would help research groups to appropriately establish an original investigation. According to our results, the BBP group had a smaller retroversion compared with the OBP group, and there was a significant difference between the groups in isokinetic strength at each angular speed. We also determined a significant correlation between retroversion and isokinetic strength. Because retroversion was found to increase with increase in the length of career, early strength training is needed to minimize this retroversion difference.

## Ethical considerations

Ethical issues (Including plagiarism, Informed Consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc) have been completely observed by the authors.

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