Original Research

The Relationship Between Humeral Retrotorsion and Shoulder Range of Motion in Baseball Players With an Ulnar Collateral Ligament Tear

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Background: Humeral retrotorsion has been investigated in relation to shoulder range of motion (ROM) in healthy baseball players. Currently, there is limited information on the osseous anatomy and development of ulnar collateral ligament (UCL) tears.

Purpose: To determine the relationship between humeral retrotorsion and shoulder ROM in baseball players with a UCL tear.

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

Methods: Fifty-four baseball players (mean age, 18.5 ± 2.0 years) with a UCL tear volunteered for this study. Participants were measured bilaterally for shoulder internal (IR) and external rotation (ER) ROM and humeral retrotorsion. Differences between sides (involved to uninvolved) were used to calculate the glenohumeral internal rotation deficit (GIRD), external rotation ROM difference (ERDiff), total rotational motion difference (TRM), and humeral retrotorsion difference (HTDiff). A multivariate regression analysis was performed with GIRD, ERDiff, and TRM regressing on HTDiff. Univariate analysis was performed to further evaluate the effect of the predictors on each outcome separately. To control for the effect of age, weight, duration of symptoms, and years of experience, the variables were included as covariates. An a priori level was set at $P < .05$.

Results: There was a statistically significant relationship between the GIRD, ERDiff, and TRM results compared with HTDiff ($P = .003$). Independent analysis revealed a statistically significant relationship between GIRD and HTDiff ($P = .004$) and between ERDiff and HTDiff ($P = .003$) but no significant relationship between TRM and HTDiff ($P = .999$). After adjusting for age, weight, duration of symptoms, years of experience, dominant arm, and position, a significant relationship was found between GIRD and HTDiff ($P = .05$) and between ERDiff and HTDiff ($P = .01$). No significant relationship was found between TRM and HTDiff ($P = .54$). Adjusted univariate regression analysis determined that HTDiff explains approximately 16% of the variance in GIRD ($r^2 = 0.158$) and approximately 24% of the variance in ERDiff ($r^2 = 0.237$).

Conclusion: In baseball players with a UCL tear, approximately 16% of the variance in GIRD and 24% of the variance in ERDiff can be attributed to differences found in humeral retrotorsion between sides. This indicates that humeral retroversion contributes significantly to GIRD and increased ER ROM in baseball players. Recognition of differences in humeral retrotorsion between the dominant and nondominant upper extremities may help explain some but not all of the changes in shoulder ROM commonly seen in baseball players.

Keywords: UCL; humeral retrotorsion; shoulder ROM; overhead athlete

Repetitive overhead throwing leads to physiologic adaptations in shoulder and elbow anatomy and mechanics. It has been found that healthy overhead-throwing athletes present with adaptive changes in external rotation (ER) range of motion (ROM) in their dominant shoulder compared with the nondominant shoulder (range, 8.3°-15.6°).[1,2,4,13,17,21] In healthy baseball players, a loss of glenohumeral internal rotation (IR) ROM, a gain in glenohumeral ER ROM, and a preservation or slight decrease of the total arc of motion between sides is commonly reported.[1,2,4,17,21] Previous studies have reported a mean range of external rotation

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gain (ERG) between 9.0° and 9.7° and glenohumeral internal rotation deficit (GIRD) between 8.2° and 9.7° in college and professional baseball pitchers.[2,21] It has been postulated that these adaptations in ROM in baseball players may be due to capsular, osseous, and soft tissue changes. However, previous studies have shown that laxity between the dominant and nondominant shoulders of elite-level pitchers does not differ between sides, indicating that changes seen in rotational ROM cannot exclusively be attributed to differences in capsular restraints between sides.[2,4]

One of the primary osseous adaptations investigated in overhead-throwing athletes is humeral retrotorsion (HT). In the dominant shoulder of these athletes, the natural derotation process is impeded due to repetitive throwing,[3,33] resulting in decreased humeral antetorsion or increased humeral retrotorsion compared with the nondominant shoulder.[3,18,21] Increased HT in the dominant shoulder is purported to account for the observed shift in rotational ROM (ERG and GIRD) in overhead-throwing athletes.[1,4] Studies have shown that as HT increases, there is a shift toward increased ER ROM[3,10,21,22,24] with a concurrent decrease in IR ROM.[3,21,22,24] It has been hypothesized that this osseous adaptation may enhance performance by increasing ER ROM and protect the shoulder from excess stress on the anterior capsuloligamentous structures.[4,17,19]

In healthy baseball players, studies have found that the mean difference in HT between the dominant and nondominant shoulder ranges from 8.3° to 15.6°.[3,13,15,21,24] These values are similar to the values previously reported for the adaptive changes in ER ROM (range, 8.3°-15.6°).[1,2,4,13,17,21] For pitchers, the mean difference in HT increases slightly to 10.1° to 17°.[4,15,17,25,32] In healthy college baseball players, it has been found that when ER and IR ROM is adjusted for humeral torsion difference between shoulders, the baseball players demonstrated more ERG but no difference in GIRD compared with controls. These findings suggest that differences in IR found between limbs may be solely due to osseous restrictions rather than posterior soft tissue restrictions in healthy baseball players.[15]

Research has begun to investigate HT and its relationship to pain in the dominant upper extremity of overhead-throwing athletes. In a group of adolescent baseball players, it was found that reduced HT in the nondominant limb, which is representative of congenital/genetic retrotorsion, was predictive of upper extremity injury.[28] Similarly, a lower degree of dominant shoulder HT has been shown to have a strong relationship with severe upper extremity injuries in professional baseball pitchers.[20] When specifically looking at shoulder injuries, Olympic handball athletes with chronic shoulder pain have a mean 5.2° less HT in their dominant shoulder when compared with handball athletes without any shoulder pain.[19] However, only 1 known study to date has investigated HT and elbow injuries. Myers et al[16] found that collegiate baseball pitchers with a history of elbow injury had a significantly greater mean side-to-side difference in HT of 7.2° than athletes without any upper extremity injuries.

Research has shown that baseball players with an ulnar collateral ligament (UCL) tear demonstrate decreased dominant shoulder total range of motion,[8] ER ROM,[7] and increased GIRD[5] compared with healthy baseball players. Previous findings indicate that HT may help to explain side-to-side differences in IR ROM in healthy baseball players.[15] Currently, there is debate about the contribution of shoulder soft tissue and osseous anatomy to the development of UCL tears, and to date, no known studies have investigated the relationship between HT, shoulder ROM, and UCL tears in baseball players. Therefore, the purpose of this study was to determine the relationship between HT and shoulder ROM in baseball players with a UCL tear. The authors hypothesized that the difference in HT between shoulders would account for a portion of the differences in IR ROM in baseball players diagnosed with a UCL tear.

METHODS

Participants

Fifty-four male competitive high school and collegiate baseball players who sustained a UCL tear (mean age, 18.5 ± 2.0 years) volunteered to participate in the study. Participants reported playing baseball for a mean 13.6 years (range, 5-20 years). The diagnosis of a complete UCL tear was made based on clinical examination by a fellowship-trained and board-certified orthopaedic surgeon (J.E.C.) and confirmed via magnetic resonance imaging (MRI). Of the 54 participants, 40 were pitchers, 8 were outfielders, 5 were infielders, and 1 was a catcher. Patients were identified during regularly scheduled visits to the participating physician (J.E.C.) and/or physical therapists (J.C.G., B.J.S.L.). Inclusion criteria for study participation included the following: (1) the athlete was a baseball player between the ages of 16 and 25 years; (2) the athlete's ability to throw was affected by the injury; (3) the athlete was unable to continue participating in baseball at the level before the UCL tear, making surgery a necessary next step; (4) clinical examination results were positive for a UCL tear; (5) there was confirmation of a UCL diagnosis via MRI; and (6) the athlete was attempting to return to his sport at a competitive level to ensure successful rehabilitation. Exclusion criteria were (1) a previous UCL tear, (2) a previous shoulder surgery for labral or rotator cuff involvement, and (3) if the patient did not plan to return to baseball after treatment. If, after a patient was enrolled, it was discovered that he was experiencing one of the previously listed conditions, then he was removed from data collection. Patients were enrolled in the study by an investigator in the outpatient sports medicine facility once they were confirmed to meet the inclusion and exclusion criteria. Once a patient consented to participate in the study, objective measurements were taken on the patient's shoulder during the initial evaluation. The institutional review board of Texas Health Resources approved the research procedures.

Testing

For all study participants, shoulder ROM testing was performed at the initial visit to the outpatient sports medicine

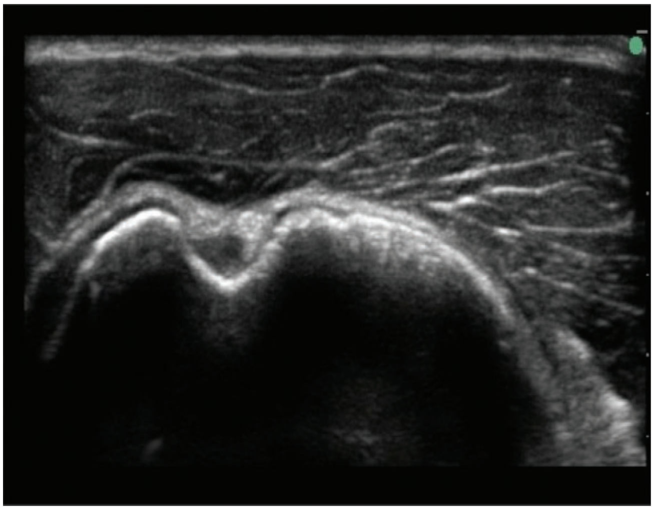

Figure 1. Humeral retrotorsion as shown on ultrasound imaging.

facility by physical therapists. Before testing shoulder ROM, reliability standards were established in pilot testing among those participating in measurements for shoulder IR ROM (intraclass correlation coefficient $[ICC]_{2,k} = 0.97$; SEM, 1.6°) and ER ROM ($ICC_{2,k} = 0.97$; SEM, 1.51°) and were found to be good. Bilateral IR and ER ROM were measured in each participant. The shoulder ROM measurement methods utilized have been previously described in the literature.[8,31] For glenohumeral joint ER, the participant was positioned supine with the arm elevated to 90° of abduction and in the scapular plane. The scapula was stabilized by the therapist, and the arm was taken to the end of the available ROM of the glenohumeral joint. This was defined as the point before the participant's scapula moved under the stabilizing hand. Any pain found was noted in the data but did not limit the ROM measurement. Measurements were taken using a bubble goniometer with the stationary arm at 0°, the axis at the elbow, and the moving arm along the ulna to the ulnar styloid process. For IR, the positioning of the participant was the same as for ER, but while the scapula was stabilized, the arm was moved into IR until end range was reached or scapular motion was felt beneath the therapist's hand. For this study, GIRD was defined as a deficit of IR of the throwing arm in relation to the nonthrowing arm.[8] Likewise, the difference in total arc of motion was determined based on the combination of shoulder ER and IR ROM of the participant's throwing arm in comparison with the nonthrowing arm. This method has been described in earlier studies.[30,31] Side-to-side differences in IR (GIRD), ER (ERDiff), and total rotational motion (TRM) were then calculated and used for analysis.

Humeral retrotorsion for both shoulders was assessed using the indirect ultrasound technique previously described in the literature[13-15,27] and was measured for the dominant and nondominant shoulders in both groups. A previous study compared the indirect ultrasound technique to the "gold standard" computed tomography scan and found a strong relationship between the 2 measurements, with greater reliability and lower amounts of error with the indirect ultrasound technique.[14] During setup for HT measurements, the participant was positioned supine with 90° of shoulder abduction and elbow flexion. The primary examiner used 1 hand to apply the diagnostic ultrasound (SonoSite FujiFilm Edge ultrasound system) head over the anterior aspect of the shoulder at the deepest point in the bicipital groove and in the plane of the treatment table. This position was verified with a bubble level and aligned perpendicular with the long axis of the humerus in the frontal plane. The other hand of the primary examiner was used to rotate the forearm until the bicipital groove appeared in the center of the ultrasound image and the apexes of the greater and lesser tubercles were parallel to the horizontal plane (Figure 1). A transparent grid, with horizontal lines, was used to aid in determining the parallel positioning of the tubercles.[14] When the greater and lesser tubercles were determined to be parallel, the second examiner used a bubble goniometer to measure the amount of HT. Two trials were completed for each arm (dominant and nondominant), and effort was made to ensure the measurements were within 2° of one another. The measures were averaged to obtain dominant-limb humeral retrotorsion (HT_Dom), nondominant-limb humeral retrotorsion (HT_NDom), and humeral retrotorsion limb difference (HTDiff = dominant limb humeral retrotorsion – nondominant limb humeral retrotorsion). To minimize variability with HT measurements, the primary investigator (J.C.G.) performed all measurements, and intrarater reliability standards were established in pilot testing for humeral retrotorsion ($ICC_{3,1} = 0.993$; SEM, 2.77°).

Data Analysis

A multivariate regression analysis was performed between the 3 dependent variables (GIRD, ERDiff, and TRM) and the independent variable HTDiff, dominant humeral retrotorsion (HT_Dom), and nondominant humeral retrotorsion (HT_NDom). When a significant relationship was observed using multivariate analysis, univariate analysis was performed to evaluate the effect of the predictors on each outcome separately. To control for the effect of age, weight, duration of symptoms, and years of experience, the variables were included as covariates. An a priori level was set at $P < .05$. All analyses were conducted using SAS 9.3 (SAS Institute).

RESULTS

Descriptive statistics of the participants are shown in Table 1. The mean age of study participants was 18.5 ± 2.0 years, with a mean weight of 86.5 ± 8.4 kg. The mean duration of symptoms was 4.2 ± 5.8 months, and the mean years of experience was 13.6 ± 2.7. Over 80% of subjects used the right arm for throwing, and 74.1% of participants were pitchers. Table 2 displays the means, standard deviations, and ranges of shoulder ROM and humeral retrotorsion for all of the study participants.

The results of the multivariate regression analysis revealed a significant relationship between GIRD, ERDiff,

TABLE 1
Participant Demographics[a]

Age, y	18.54 ± 1.98 (16-23)
Height, cm	184.87 ± 5.71 (170.2-198.1)
Weight, kg	86.48 ± 8.40 (63.5-104.3)
Duration of symptoms, mo	4.24 ± 5.81 (0.25-24)
Years of experience	13.58 ± 2.76 (5-20)
Arm dominance (right:left), n	44:10
Position (P:C:I:O), n	40:1:5:8

[a]Data are reported as mean ± SD (range) unless otherwise indicated. C, catcher; I, infield; O, outfield; P, pitcher.

TABLE 2
Range of Motion and Humeral Retrotorsion Measures in Baseball Players With a UCL Tear[a]

Variable	Players With UCL Injury (n = 54)
IR ROM, deg	
Dominant shoulder	29.63 ± 10.08
Nondominant shoulder	41.78 ± 10.43
GIRD	–12.15 ± 10.24
ER ROM, deg	
Dominant shoulder	101.32 ± 9.68
Nondominant shoulder	95 ± 8.83
ERDiff	6.31 ± 9.88
Total rotational motion, deg	
Dominant shoulder	130.94 ± 11.92
Nondominant shoulder	136.78 ± 10.55
TRM	–5.83 ± 10.22
Humeral retrotorsion, deg	
Dominant shoulder	17.54 ± 8.65
Nondominant shoulder	30.49 ± 11.07
HTDiff	–12.95 ± 9.73

[a]Values are reported as mean ± SD. ER, external rotation; ERDiff, side-to-side difference in ER; GIRD, glenohumeral internal rotation deficit; HTDiff, side-to-side difference in humeral retrotorsion; IR, internal rotation; ROM, range of motion; TRM, side-to-side difference in total arc of motion; UCL, ulnar collateral ligament.

and TRM (dependent variables) and the independent variable HTDiff ($F_{(2,\ 51)} = 6.45$, $P = .0032$). No significant relationship was found between GIRD, ERDiff, or TRM and HT_Dom ($F_{(2,\ 51)} = 1.99$, $P = .15$) or HT_NDom ($F_{(2,\ 51)} = 2.42$, $P = .10$). Relationships between the outcome factors indicate a moderate negative correlation between GIRD and ERDiff ($r = –0.50$, $P = .0002$), a moderate positive correlation between GIRD and TRM ($r = 0.5328$, $P < .0001$), and a moderate positive correlation between ERDiff and TRM ($r = 0.4817$, $P = .0002$).

Independent univariate regression analysis revealed a statistically significant relationship between GIRD and HTDiff ($P = .004$) and ERDiff and HTDiff ($P = .003$). There was no significant relationship between TRM and HTDiff ($P = .999$). After adjusting for age, weight, duration of symptoms, years of experience, dominant arm, and position, a significant relationship was observed between GIRD and HTDiff ($t = 2.04$, $P = .0488$). Similarly, a significant relationship was found between ERDiff and HTDiff ($t = –2.69$, $P = .0107$) for the adjusted analysis, but no significant relationship was observed between TRM and HTDiff ($P = .5413$). Adjusted univariate regression analysis r^2 values determined that HTDiff explains approximately 16% of the differences in IR ROM between sides ($r^2 = 0.158$) and approximately 24% of the differences in ER ROM between sides ($r^2 = 0.237$).

DISCUSSION

The results of this study show that in baseball players with a UCL tear, 15.8% of the variance in GIRD and 23.7% of the variance in ERDiff between shoulders can be attributed to differences in HT between sides while adjusting for age, weight, duration of symptoms, years of experience, dominant arm, and position. Only a few studies have investigated the relationship between HTDiff, ERDiff, GIRD, and TRM. Reagan et al[21] found that HTDiff was significantly correlated with ER and IR ROM at 90° of abduction in healthy college baseball players. These results are similar to a previous study that examined humeral retrotorsion variance in a group of healthy, competitive baseball players.[3] In a study of 19 competitive baseball players (mean age ± SD, 23.4 ± 1.4 years), HTDiff accounted for approximately 20.6% of the variability in the measured ERDiff and 15.0% of the variability in GIRD.[3] The findings of Chant et al[3] are similar to the 23.7% (ER Diff) and 15.8% (GIRD), respectively, found in the current study of baseball players with UCL tears. Despite similar results, significant differences in methodology can be noted between the former and current study. Chant et al[3] utilized computed tomography scans, the gold standard, to measure humeral retrotorsion while the current study used diagnostic ultrasound. In addition to measuring shoulder ROM passively, the former study[3] also used active range of motion for ERDiff and GIRD when analyzing the relationship with HTDiff. When the measurements were taken actively, HTDiff accounted for 13.6% of the variance in ERdiff and 22.0% of the variance in GIRD. While Chant et al[3] looked at a healthy population of baseball players, the current study observed HT difference in baseball players with a confirmed diagnosis of a UCL tear, indicating that the relationship between HTDiff, GIRD, and ERDiff may not be significantly different between healthy athletes and those with an injured UCL. Regardless of the differences in methodology, the results are similar and suggest that HTDiff may help explain some of the differences in shoulder ROM. To our knowledge, this is the first study that has examined the direct relationship between HT and side-to-side deficits of shoulder ROM in baseball players with a UCL tear.

Studies agree that the dominant shoulders of healthy overhead-throwing athletes present with an ERG[1,2,4,11-13,17,21,26,33] and GIRD[1,2,4,11,13,15,17,21,33] in ROM while maintaining[2,4,17,21] or showing a slight decrease in total arc of motion compared with the nondominant side.[3,12,13,15,23,25] Any ROM differences found between the current study and those frequently reported in the literature may be due to the population tested and the presence of injury (UCL tear) in the current study. A previous study has shown that GIRD is significantly higher in baseball players with a UCL tear compared with healthy controls.[5] The mean humeral retrotorsion difference between sides for healthy baseball players ranges from –8.3° to –15.6°[3,13,15-17,21,24,29] and in pitchers specifically from –11.0° to –17.0°.[4,25,32] The HT results of the current study fall within the range reported in the literature.

The relationship between humeral retrotorsion and ER ROM, IR ROM, and total arc of motion has been examined. Thomas et al[24] found a significant positive relationship (r = 0.295, P = .042) between humeral retrotorsion and ER ROM and a significant negative correlation (r = –0.472, P = .001) between humeral retrotorsion and IR ROM in healthy collegiate baseball players (mean age ± SD: pitchers, 19.4 ± 1.2 years; position players, 19.8 ± 1.5 years). Similarly, Roach et al[22] found a significant positive correlation between humeral torsion and IR ROM (r = 0.741, P < .001). Both of the previously mentioned studies, though worded differently, indicate that as the amount of humeral retrotorsion increases, IR ROM decreases. To date, no studies support a relationship between humeral retrotorsion and the total arc of motion.[3,17,21,22]

Variables that may affect ERDiff and GIRD in baseball players are capsular, soft tissue, and other bony restraints. While previous findings suggest that increased ER ROM and decreased IR ROM in the dominant shoulders of pitchers cannot be solely attributed to anterior capsular laxity and posterior capsular tightness,[4] results from Thomas et al[24] demonstrate a positive correlation between humeral retrotorsion and posterior capsule thickness. After physeal closure, no changes in HT are seen with repetitive throwing[18]; thus, any changes in ROM may be attributed to soft tissue restraints. In addition, in 32 professional baseball pitchers, Wyland et al[32] found that the retroversion of the glenoid was significantly greater on the dominant side compared with the nondominant side. Furthermore, there was a positive correlation (r = 0.43, P = .016) between humeral and glenoid retroversion, suggesting that these may be coupled during growth. Thus, baseball players demonstrate bony adaptations of the humerus and the glenoid that contribute to the adaptations seen in ROM between sides. Overall, these results suggest that osseous contributions to ROM are significant and soft tissue restrictions may be of secondary importance.[22] It has also been suggested that increased amounts of humeral retrotorsion in the dominant limb of baseball players allows for increased acceleration with throwing due to increased ER ROM.[6,9] This increased acceleration during the late cocking phase could potentially increase the stress placed across the UCL and may lead to an increased risk of injury.

Even though it appears that the results of the current study point to the importance of humeral retrotorsion in the context of the measurement of shoulder ROM in baseball players with a UCL tear, it cannot fully account for the contributions of soft tissue and other osseous structures (glenoid version) within the shoulder. Likewise, this study was limited by its relatively small sample size, lack of a control group of uninjured athletes for comparison, the cross-sectional nature of the study, and the use of diagnostic ultrasound for measurement of humeral retrotorsion. However, Myers et al[15] found an intertester reliability of 0.96 to 0.98 of humeral retrotorsion measurement with diagnostic ultrasound. Similarly, Whiteley et al[27] found the diagnostic ultrasound method to have excellent intertester reliability (ICC = 0.94). In another study by Myers et al,[14] diagnostic ultrasound was found to have a strong relationship to computed tomography scan measurements of humeral retrotorsion. The current study found significant results while controlling for age, weight, duration of symptoms, years of experience, dominant arm, and position. Furthermore, this is the first study to investigate the relationship between humeral retrotorsion side-to-side differences, ER ROM side-to-side difference, and GIRD in baseball players with a UCL tear.

CONCLUSION

The results of this study suggest that differences in humeral retrotorsion between the dominant and nondominant upper extremities may help explain some of the commonly found shoulder IR and ER ROM differences between sides in baseball players with a UCL tear. However, it does not account for all of the differences in ROM seen between sides in baseball players with a UCL tear. Future research should continue to investigate the relationship between osseous adaptations to include glenoid version of the throwing shoulder with changes in ROM found in baseball players with different types of injury. Furthermore, a comparison with healthy controls may be useful to further elucidate differences between a healthy population and those with a UCL tear.

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