Baseball Players With an Ulnar Collateral Ligament Tear Display Increased Nondominant Arm Humeral Torsion Compared With Healthy Baseball Players

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Am J Sports Med published online September 2, 2016
DOI: 10.1177/0363546516664718

AJSM PreView, published on September 2, 2016 as doi:10.1177/0363546516664718

Baseball Players With an Ulnar Collateral Ligament Tear Display Increased Nondominant Arm Humeral Torsion Compared With Healthy Baseball Players

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Background: Previous work has suggested that an increase in the amount of developmentally acquired, dominant arm humeral retrotorsion (D HRT) in the thrower's shoulder may be a potentially protective mechanism. Although the relationship between HRT and shoulder injuries has been reported, the relationship between HRT and ulnar collateral ligament (UCL) tears in baseball players is not known.

Purpose: To determine whether D HRT and nondominant arm HRT (ND HRT) measurements in baseball players with a UCL tear differ statistically from a matched healthy cohort.

Study Design: Case-control study; Level of evidence, 3.

Methods: D HRT and ND HRT were measured in 112 male competitive high school and collegiate baseball players seen over an 18-month period from 2013 to 2015. A total of 56 participants with a clinical and magnetic resonance imaging–confirmed diagnosis of a throwing-arm UCL tear (UCLInj group) were compared with 56 healthy baseball players with no history of an elbow injury who were matched for age, experience, and position (NUCLInj group). The mean ages in the UCLInj and NUCLInj groups were 17.9 $\pm$ 2.2 and 17.6 $\pm$ 2.8 years, respectively. Using a previously validated ultrasound method, D HRT and ND HRT were measured in the supine position, and the HRT side-to-side difference (D HRT – ND HRT) was calculated. A 1-way multivariate analysis of variance was used to determine the mean statistical differences between groups ($P < .05$).

Results: Baseball players with a UCL tear displayed significantly more humeral torsion (ie, less retrotorsion) in their nondominant arm compared with healthy baseball players (UCLInj = 33.27° $\pm$ 10.27°, NUCLInj = 27.82° $\pm$ 10.88°; $P = .007$). Baseball players with a UCL tear did not display any differences in D HRT compared with healthy baseball players (UCLInj = 18.67° $\pm$ 9.41°, NUCLInj = 17.09° $\pm$ 9.92°; $P = .391$). Significant side-to-side differences in HRT existed between groups (UCLInj = −14.60° $\pm$ 6.72°, NUCLInj = −10.72° $\pm$ 6.88°; $P = .003$).

Conclusion: There was a significant increase in mean nondominant arm humeral torsion (ie, less retrotorsion) in the UCL tear group, but there was no significant difference in the mean D HRT between the injured and uninjured groups. A greater HRT side-to-side difference was displayed in the UCL tear group. The extent to which a thrower has developmentally acquired both D HRT and ND HRT may affect elbow UCL tear risk. Furthermore, it is possible that the extent of genetically predisposed ND HRT may influence the throwing-related increase in D HRT.

Keywords: ulnar collateral ligament; humeral retrotorsion; baseball

Baseball players have been shown to have differences in shoulder passive range of motion (ROM), which is a predictor for injury.[19,24] Achieving maximal external rotation required for throwing can be attained by both soft tissue and osseous adaptations.[23,26] Humeral retrotorsion (HRT) is the relative relationship in the axial rotation of the long axis of the humerus between the proximal and distal articular surfaces.[16,20,22] The development of HRT can be attributed to a combination of genetic makeup and relative upper limb activity, especially in the throwing arm.[8,23] HRT is defined when the humeral head is directed in a posterior medial direction with the humerus rotated in the transverse plane.[6] An increase in HRT results in a posterior humeral rotational displacement, shifting the rotational ROM toward external rotation and thus increasing the available external rotation ROM at the shoulder.[2,16,20,22,23]

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One or more of the authors has declared the following potential conflict of interest or source of funding: J.E.C. receives royalties from Arthrex Inc.

The American Journal of Sports Medicine, Vol. XX, No. X
DOI: 10.1177/0363546516664718

TABLE 1
Participant Demographics[a]

Variable	Healthy Baseball Players (n = 56)	Baseball Players With a UCL Injury (n = 56)	*P* Value
Age, y	17.57 ± 2.78	17.96 ± 2.17	.41
Height, cm	186.5 ± 5.39	184.38 ± 5.57	.09
Weight, kg	85.09 ± 6.43	86.95 ± 9.7	.34
Experience, y	12.49 ± 2.93	13.25 ± 2.4	.15
Arm dominance (right/left), n	47/9	44/12	.49
Position (pitcher/catcher/infield/outfield), n	31/5/10/10	41/2/7/6	.28

[a]Values are reported as means ± SD unless otherwise indicated. UCL, ulnar collateral ligament.

Previous studies suggest an increase in HRT to be a healthy adaptation in overhead athletes that is caused primarily from a retrotorsion moment placed on the shoulder during the late-cocking phase of throwing.[11,27] Dominant arm HRT (D HRT) values are shown to be increased compared with nondominant arm HRT (ND HRT) values.[13] Previous research has shown contradictory results on the correlation between injury risk and overall HRT or side-to-side limb differences.[12,15,16,23] The majority of the literature suggests that increased HRT in the dominant upper extremity may decrease the risk of shoulder injuries because of the decreased stress placed on soft tissue to achieve maximal external rotation ROM while throwing.[3,12,14] Similar studies propose that larger overall values of D HRT may suggest an amplified risk of developing a severe shoulder injury.[15] ND HRT values are believed to represent the amount of congenital retrotorsion.[23] The amount of D HRT in a throwing athlete represents both congenital torsion as well as the amount gained from throwing.[23] As a result, side-to-side differences between D HRT and ND HRT offer insight on the amount of humeral torsion caused by an osseous adaptation from throwing.[12] With this in mind, larger side-to-side differences in HRT suggest a greater retrotorsion adaptation of the dominant arm caused by overhead throwing, as a result of the greater torsion value (ie, less retrotorsion) on the nonthrowing limb.[23]

Previous research demonstrates a correlation between greater side-to-side differences and increased shoulder injury risk, as the more retrotorsion that occurs from bony adaptation is associated with increasing levels of stress placed on the shoulder from overhead throwing.[23] Unfortunately, there is a lack of understanding of why certain athletes are predisposed to these injuries. In contrast with the idea of increased HRT measures as a protective mechanism for shoulder injuries, a different hypothesis has been presented for the risk of developing elbow injuries. However, limited research is available on the effect of HRT on elbow injuries in baseball players. An earlier study suggests that HRT has a different relationship in the prevalence of injuries at the elbow and shoulder. Myers et al[12] found that increased side-to-side differences in HRT were correlated with an increased risk of elbow injuries compared with healthy participants without an upper extremity injury. These differences represent the amount of retrotorsion gained from throwing over time and appear to be associated with nonspecific elbow conditions that occurred with throwing. Although this information is helpful and points to a possible association between HRT and elbow injury in the throwing athlete, there is a void in the literature regarding the relationship between HRT and elbow UCL tears in baseball players. With recent increases of UCL reconstructions in professional baseball players,[7] there is a need for better understanding of the role of HRT and elbow UCL tears in the baseball community. Therefore, this study aimed to determine whether a difference in D HRT and ND HRT measurements in baseball players exists and whether this difference might be a factor that contributes to UCL tears in elite baseball athletes. We hypothesized that in a group of asymptomatic elite-level baseball athletes, HRT in the nondominant shoulder would be significantly less than in baseball players who were diagnosed with a UCL tear. We also hypothesized that a smaller side-to-side HRT difference would exist in the healthy cohort of elite baseball athletes compared with baseball athletes with a UCL injury.

METHODS

Participants

This was a prospective case-control study; the Institutional Review Board of Texas Health Resources approved the research procedures. A total of 112 male competitive high school and collegiate baseball players (mean age, 17.7 ± 2.5 years) volunteered to participate in this study. Participants reported playing baseball for a mean of 12.8 years (range, 6-17 years). Descriptive demographic characteristics of the participants are presented in Table 1.

Fifty-six participants with a diagnosis of an elbow UCL tear of their throwing (dominant) arm (UCLInj group; mean age, 17.9 ± 2.2 years) were compared with 56 players without an elbow UCL tear who were matched for age, experience, and position (NUCLInj group; mean age, 17.6 ± 2.8 years). Control participants were recruited from local high schools and colleges. The diagnosis of an elbow UCL tear was made based on a clinical examination by a fellowship-trained, board-certified orthopaedic surgeon (J.E.C.) and was confirmed via magnetic resonance imaging (MRI) results. Of the 112 participants, 72 were pitchers, 7 were catchers, 17 were infielders, and 16 were outfielders.

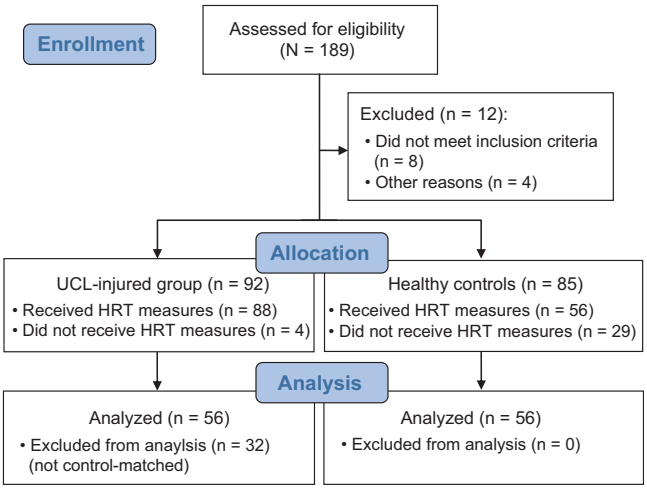

Figure 1. Consolidated Standards of Reporting Trials flow diagram. HRT, humeral retrotorsion; UCL, ulnar collateral ligament.

Subjects were identified and collective measurements were taken during regularly scheduled visits to the participating physician (J.E.C) and/or physical therapist (J.C.G.) over an 18-month period from 2013 to 2015. For both groups, participants were considered for the study if they were a baseball player between the ages of 13 and 25 years. Inclusion criteria for the UCL tear group included the following: (1) the athlete was a baseball player between the ages of 13 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 his previous level before the UCL tear, (4) clinical examination results were positive for a UCL tear, (5) there was confirmation of a UCL tear diagnosis via MRI, and (6) the athlete was attempting to return to his sport at a competitive level. Exclusion criteria were (1) a previous UCL reconstruction that failed, (2) a previous shoulder surgery for labral or rotator cuff involvement, and (3) no plan for the athlete to return to baseball after treatment. Patients who experienced one of the previously listed conditions after enrollment were removed from data collection. The same exclusion criteria were applied to the control participants. Patients were enrolled in the study by an investigator at the outpatient sports medicine facility once they were confirmed to meet the inclusion and exclusion criteria (Figure 1).

Testing

For participants with a UCL injury, testing was performed at the initial visit to the outpatient sports medicine facility. All control participants were measured before the fall baseball season using the same methods as the group with a UCL injury. Measurement of HRT can be accomplished through the use of a diagnostic ultrasound examination. The diagnostic ultrasound technique indirectly measures HRT by calculating internal rotation angles while the apexes of the humeral tubercles are aligned horizontally.[10,22] Both the

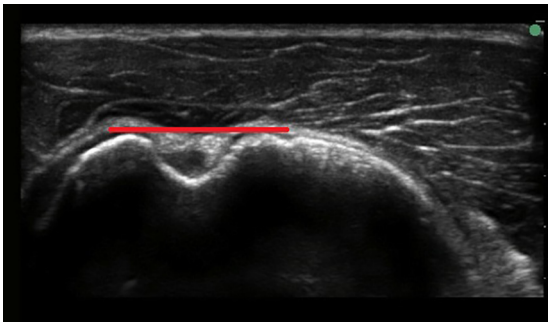

Figure 2. Ultrasound image of humeral retrotorsion measurement. The tuberosities were aligned while taking the measurement for humeral retrotorsion (line).

D HRT and ND HRT measurements were assessed using this ultrasound technique for both the UCLInj and NUCLInj groups.[10,12] The diagnostic ultrasound technique was used in place of computed tomography examinations because the ultrasound technique was readily available, included no additional costs, and required no unnecessary ionizing radiation to our participants. To minimize variability with HRT measurements, the primary investigator (J.C.G.) performed all of the measurements, and intrarater reliability standards were established in pilot testing for HRT (intraclass correlation coefficient: $ICC_{3,1}$ = 0.993; standard error of measurement = 2.77°). During setup for HRT 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 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 primary examiner's other hand 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 2).

A transparent grid, with horizontal lines, was used to aid in determining the parallel positioning of the tubercles.[12] When the greater and lesser tubercles were determined to be parallel, the second examiner used a bubble goniometer to measure the amount of humeral torsion. Two trials were completed for each arm (dominant and nondominant) while the primary examiner was blinded from the measured torsion value. The measures were averaged to obtain D HRT, ND HRT, and HRT limb differences (D HRT – ND HRT).

Statistical Analyses

All statistical analyses were conducted with SPSS Statistics software (version 23.0; IBM Corp). A priori statistical power analysis was performed using humeral torsion differences as the primary outcome, and we determined that a total of 40 participants (20 in the control group and 20 in the UCL tear group) would be needed to detect statistical significance based on an 80% power calculation. One-way multivariate analysis of variance (MANOVA) was used to

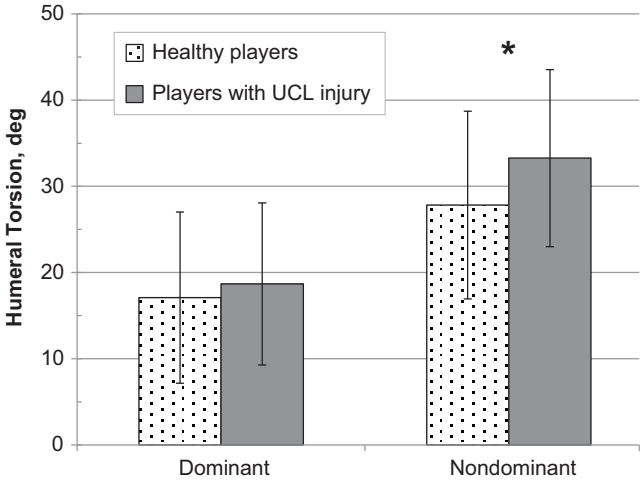

Figure 3. Baseball players with a diagnosed ulnar collateral ligament (UCL) tear displayed more nondominant humeral torsion (less retrotorsion) compared with healthy baseball players. *Statistically significant between-group difference ($P < .05$).

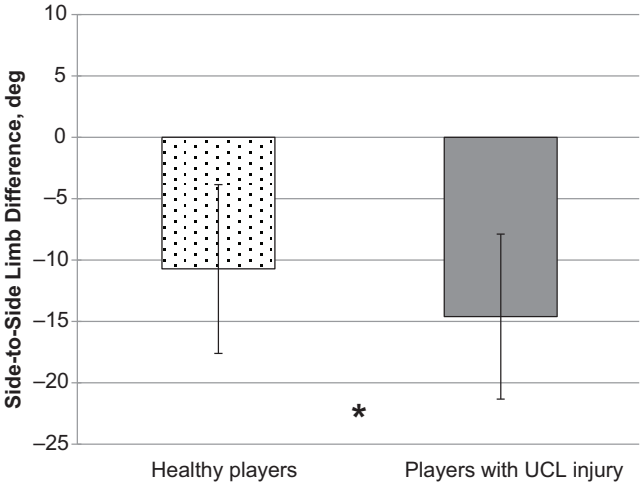

Figure 4. Baseball players with an ulnar collateral ligament (UCL) tear displayed greater side-to-side differences in humeral retrotorsion (dominant limb – nondominant limb) compared with healthy baseball players. *Statistically significant between-group difference ($P < .05$).

compare ND HRT, D HRT, and side-to-side differences between the UCLInj and NUCLInj groups. A separate 2-way MANOVA was used to assess for differences between group and position. Statistical significance was set at $P < .05$.

RESULTS

There were no significant differences in age ($P = .41$), years of experience ($P = .15$), or position ($P = .28$) between the UCLInj and NUCLInj groups (Table 1). Baseball players with a UCL tear displayed significantly more humeral torsion (ie, less retrotorsion) in their nondominant arm compared with healthy baseball players (UCLInj = 33.27° ± 10.27°, NUCLInj = 27.82° ± 10.88°; $P = .007$) (Figure 3).

No differences were seen for D HRT between groups (UCLInj = 18.67° ± 9.41°, NUCLInj = 17.09° ± 9.92°; $P = .391$). However, significant side-to-side HRT differences were seen between groups (UCLInj = −14.60° ± 6.72°, NUCLInj = −10.72° ± 6.88°; $P = .003$) (Figure 4).

The mean values for ND HRT, D HRT, and HRT side-to-side limb differences are presented in Table 2. When HRT differences were considered for position (pitchers vs position players) across both groups, there was no significant group × position interaction ($P = .296$).

DISCUSSION

Our results demonstrate that baseball players who have UCL tears display greater nondominant arm humeral torsion (lower retrotorsion) measures and greater HRT side-to-side limb differences than healthy controls. To our knowledge, this is the first study to examine and show the influence of ND HRT and side-to-side limb differences in a large cohort of baseball players with UCL tears. The results of the current study are similar to previous findings of less ND HRT in adolescent baseball players with injuries to their throwing arm.[23] In that prospective study of 35 baseball players (aged 16.6 ± 0.6 years), 19 athletes went on to experience an injury to the throwing arm over the 30-month investigation and had significantly less ND HRT compared with those who did not experience an injury. Although Whitely et al[23] did not define injury to the throwing arm in this particular study, their results are in line with our study, which revealed less ND HRT in baseball players with UCL tears. These findings suggest that the genetic makeup of ND HRT may play a role in the development of injury in the dominant arm of baseball players as they attempt to achieve optimal external rotation during throwing.

Greater side-to-side HRT limb differences were also seen in the UCL group compared with healthy controls during the current study, and these results are similar to previous findings reported in the literature. Myers et al[12] used ultrasonography to measure HRT in 40 collegiate baseball pitchers and stratified the participants based on injury history (elbow, shoulder, and no injury). Individuals with a past elbow injury demonstrated greater HRT side-to-side differences than those who had no history of elbow injury. The history of previous elbow injury was best classified by the variable of HRT limb differences (area under the curve = 0.74).[12] Although the average HRT side-to-side limb difference in the study by Myers et al[12] was slightly higher (21.7° ± 7.7°) than in our study (14.6° ± 6.7°), the disagreement may be accounted for through the type of diagnoses involved. The current study examined HRT in a group of baseball players with a diagnosed UCL tear, whereas individuals in the study by Myers et al[12] had a history of nonspecific elbow injury. Although the groups were similar in terms of age (17.9 ± 2.2 years [UCL tear] vs 19.3 ± 1.2 years [elbow injury]) and years of playing experience

TABLE 2
Humeral Torsion Values in Healthy Baseball Players and Baseball Players With a UCL Injury[a]

Variable	Healthy Baseball Players (n = 56)	Baseball Players With a UCL Injury (n = 56)	*P* Value
Humeral torsion, deg			
Dominant shoulder	17.09 ± 9.92	18.67 ± 9.41	.391
Nondominant shoulder	27.82 ± 10.88	33.27 ± 10.27	.007[b]
Absolute side-to-side difference	−10.72 ± 6.88	−14.60 ± 6.88	.003[b]

[a]Values are reported as means ± SD. Healthy baseball players displayed greater humeral retrotorsion (smaller torsion value) for both dominant and nondominant limbs. UCL, ulnar collateral ligament.
[b]Statistically significant between-group difference ($P < .05$, 1-way multivariate analysis of variance).

(UCL tear = 13.2 ± 2.4 years [UCL tear] vs 14.0 ± 1.9 [elbow injury]), the diagnoses were distinctly different, which may help to explain some of the variances in study results.

Although the current understanding is that HRT is a healthy adaptation to gain external rotation at the shoulder complex, the increase in external rotation may lead to an increased risk for injury at the elbow. Increased values of dominant arm external rotation coupled with a high total arc of motion at the shoulder allow an athlete to develop more rotational shoulder torque resulting in a greater potential for increased throwing velocity.[21,25] However, increases in dominant arm external rotation also result in increased valgus stress at the medial elbow during overhead throwing.[1,5,18] Biomechanical analyses demonstrate a maximum internal varus torque value of 64 ± 12 N·m at the elbow during the late-cocking phase.[5] According to previous research, the UCL provides approximately 54% of the varus torque needed to resist the valgus motion during throwing.[9] On the basis of this literature, Fleisig et al[5] determined that the UCL is able to provide approximately 34.6 N·m of varus torque. Cadaveric testing indicates that the isolated UCL (minus muscle and soft tissue forces) can produce a maximum varus torque of 32.1 ± 9.6 N·m before failing. With this in mind, the ability to reach maximal external rotation during throwing appears to place the UCL near its maximum torque capacity. As such, individuals who have lower ND HRT values may require greater adaptations in the dominant (throwing) arm over time to achieve the shoulder external rotation needed for maximal throwing performance. That said, the cohort with a UCL injury may have required increased side-to-side differences to achieve the necessary HRT to reach a favorable cocked position to achieve overhead throwing. These data suggest that individuals in the UCL cohort may have experienced an increased volume of throwing at an adolescent age to achieve similar values of HRT in their dominant throwing arm.

Passive shoulder ROM is commonly used as an assessment tool for preseason screenings to identify increased risks associated with throwing. Although passive shoulder ROM is important in the throwing athlete, measuring within the context of HRT may allow a more accurate assessment of the osseous adaptations that may be contributing to changes in shoulder ROM. Previous literature is inconclusive in determining the amount of variance in which HRT influences shoulder ROM measurements. Although it appears that HRT is related to both glenohumeral internal ($r = -0.42$ to 0.48) and external ($r = -0.17$ to 0.86) rotation in healthy college and professional baseball players to some degree, the overall extent of the effect is variable.[2,13,14,17] In addition, HRT explains approximately 16% of the variance in glenohumeral internal rotation difference and 24% of the variance in external rotation difference in baseball players with a diagnosed UCL tear of the throwing arm (B.J. Lee, J.C. Garrison, S. Aryal, J.E. Conway, unpublished data, 2015). Although these data are somewhat inconsistent and limited, the ability to recognize the effect of HRT on shoulder ROM may help clinicians in determining how to direct treatment.[6] On the basis of our results, knowledge of the amount of physiologic ND HRT may influence our ability to assess the amount of HRT change that is developed in the dominant arm via throwing. The extent to which a thrower has developmentally acquired HRT may affect UCL injury risk.

Limitations existed within the current study and warrant acknowledgment. This was a case-control study; as such, the results cannot be directly interpreted as a contributing factor for a UCL tear. Although individuals who displayed less ND HRT had experienced a UCL tear of the dominant arm, the measurements were taken after the injury had occurred. Because of the clinical nature of this study, the average time from injury until the date of humeral torsion measurement was 4.5 months in the UCL group. Because of this delay in measurement, it is possible that the amount of HRT might have changed since the time of the injury. It has been suggested that the natural derotation process of the humerus is substantially complete by age 16 years.[4] Therefore, given the ages of those in the UCL group (17.7 ± 2.5 years), the participants would have reached a level of skeletal maturity to suggest minimal, if any, additional HRT adaptation since the onset of injury. In addition, background information on throwing and playing history was self-reported and thus limits the ability to control for the total throwing volume of each participant. To strengthen the power of our study, several individuals had to be removed from the analysis to properly match specific variables between groups secondary to the limited number of healthy matched controls available for comparison. Although certain individuals from

the UCL group were not analyzed for this study, the HRT data (ie, numbers) for this group were not significantly different from participants (with a UCL injury) who were included in the analysis.

CONCLUSION

High school and collegiate baseball players with a UCL tear of their dominant arm exhibited greater nondominant limb humeral torsion (ie, less retrotorsion) values compared with a healthy cohort. Those same baseball players with a UCL tear also showed greater HRT side-to-side limb differences compared with those who did not sustain a UCL tear; however, there were no differences in D HRT between groups. These findings suggest that the amount of developmentally genetic HRT in the nondominant arm of a thrower may potentially affect the risk of injury to the UCL in the dominant arm.

ACKNOWLEDGMENT

The authors acknowledge Kalyssa Pollard, Renee Pegram, and Heather Powell for assistance in data collection during this study.

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