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original research

Dominant-Limb Range-of-Motion and Humeral-Retrotorsion Adaptation in Collegiate Baseball and Softball Position Players

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Context: Biomechanically, the motions used by baseball and softball pitchers differ greatly; however, the throwing motions of position players in both sports are strikingly similar. Although the adaptations to the dominant limb from overhead throwing have been well documented in baseball athletes, these adaptations have not been clearly identified in softball players. This information is important in order to develop and implement injury-prevention programs specific to decreasing the risk of upper extremity injury in softball athletes.

Objective: To compare range-of-motion and humeral-retrotorsion characteristics of collegiate baseball and softball position players and of baseball and softball players to sex-matched controls.

Design: Cross-sectional study.

Setting: Research laboratories and athletic training rooms at the University of North Carolina at Chapel Hill.

Patients or Other Participants: Fifty-three collegiate baseball players, 35 collegiate softball players, 25 male controls (nonoverhead athletes), and 19 female controls (nonoverhead athletes).

Intervention(s): Range of motion and humeral retrotorsion were measured using a digital inclinometer and diagnostic ultrasound.

Main Outcome Measure(s): Glenohumeral internal-rotation deficit, external-rotation gain, total glenohumeral range of motion, and humeral retrotorsion.

Results: Baseball players had greater glenohumeral internal-rotation deficit, total–range-of-motion, and humeral-retrotorsion difference than softball players and male controls. There were no differences between glenohumeral internal-rotation deficit, total–range-of-motion, and humeral-retrotorsion difference in softball players and female controls.

Conclusions: Few differences were evident between softball players and female control participants, although range-of-motion and humeral-retrotorsion adaptations were significantly different than baseball players. The throwing motions are similar between softball and baseball, but the athletes adapt to the demands of the sport differently; thus, stretching/strengthening programs designed for baseball may not be the most effective programs for softball athletes.

Key Words: upper extremity, shoulder, injury prevention

Key Points

- Compared with softball players, baseball players had greater glenohumeral internal-rotation deficit and humeral-retrotorsion and total range-of-motion differences.
- Few differences were observed between softball players and female control participants,.

Because of the repetitive nature of overhead sport, shoulder and elbow pain is common among overhead athletes. The overhead-throwing motions performed by baseball and softball players are the primary factors placing the upper extremity, particularly the shoulder and elbow, at risk for overuse injuries.[1] In an analysis of the National Collegiate Athletic Association Injury Surveillance System data from 1988 to 2004, 45% of all time lost from baseball and 33% of all time lost from softball (for practices and games) because of injury was attributed to the upper extremity.[2,3] Overhand throwing in position players was the most common injury mechanism for the shoulder, accounting for 24.3% in high school baseball players and 50.2% in high school softball players.[4] Although the shoulder of the baseball player has received substantial attention, sports medicine research assessing the shoulder of the softball player is limited, despite the fact that the prevalence of shoulder injuries in softball players parallels that in baseball athletes.[2,5–7]

To date, research surrounding the overhead athlete's shoulder range of motion (ROM) has focused on baseball players. Substantial evidence shows alterations in ROM of the baseball player's dominant shoulder as compared with the nondominant arm and with nonoverhead athletes, which have been theorized to be shoulder and elbow injury risk factors.[8–13] The general pattern of adaptation in the baseball player's shoulder is increased external rotation and decreased internal rotation, horizontal adduction, and total ROM. In addition to ROM adaptations, baseball players show differences in humeral torsion when the throwing arm

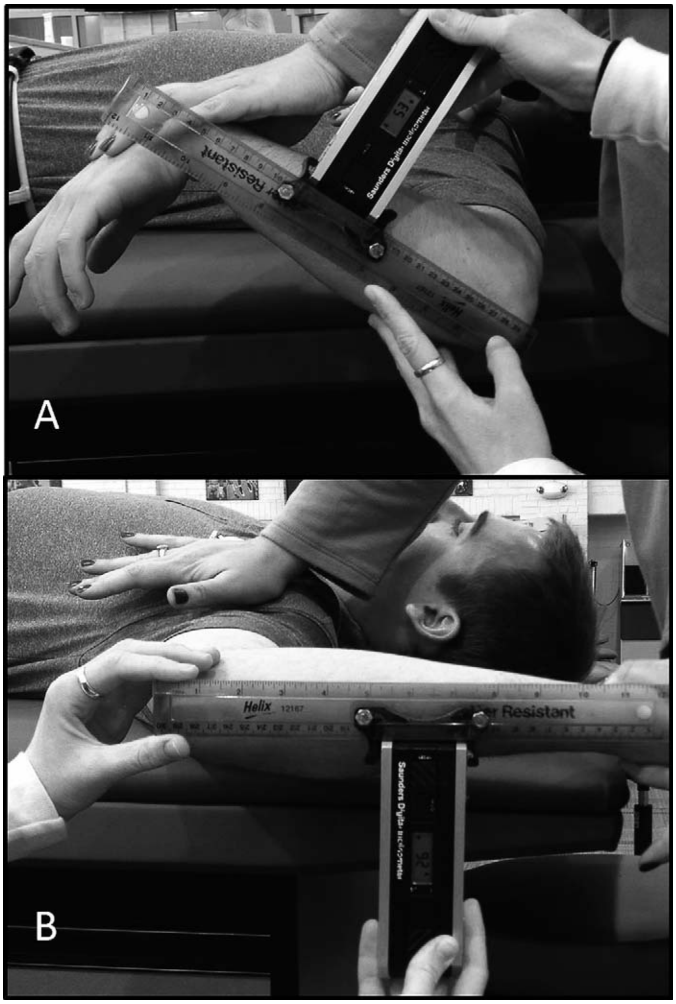

Figure 1. A, Shoulder internal rotation. B, External rotation.

is compared with the nonthrowing arm. Side-to-side differences in baseball players range from 0° to 29°, with baseball players demonstrating greater humeral torsion in the throwing arm, whereas control groups show no differences bilaterally.[9,11,14–16] Bilateral variations suggest that torsion is influenced by the degree of upper extremity activity.[14] Increased humeral retrotorsion is of interest because it has been shown to contribute to increased external-rotation and decreased internal-rotation ROM in the throwing arm and has been linked to a history of upper extremity injury in baseball players.[9,11,14,17,18]

Although these adaptations have been identified in baseball players and hypothesized to be caused by repetitive throwing, research on ROM and humeral-retrotorsion adaptations in softball players is very limited.[15,19] It is important to understand ROM alterations and potential injury risk factors in softball players, as injury rates between softball and baseball athletes are comparable. Baseball and softball athletes appear to have a similar throwing motion, but on average, the female athlete has less height, mass, overall size, muscle mass, limb length, and absolute muscle strength[20] and uses a larger, heavier ball on a smaller field in softball,[21,22] which would influence the force production and kinetics of the throwing motion and the stresses at the shoulder joint. Differing stresses at the shoulder during baseball and softball throwing could clinically present with different physical adaptations between athletes in each sport and thus differing injury mechanisms. Often, baseball and softball athletes are prescribed similar injury-prevention programs, as the assumption is that physical characteristics and injury risk factors are the same between the sports because of the similar overhead throwing motions.[23] Understanding the physical adaptations that are present in softball players will help clinicians to develop injury-prevention programs specific to softball athletes or support the use of programs that are aimed at influencing the physical adaptations seen in baseball players. Therefore, the purpose of our study was to compare ROM and humeral-retrotorsion characteristics of collegiate baseball position players, softball position players, and sex-matched controls.

Table 1. Reliability and Precision of Measurements

	Intrasession		Intertester	
Measurement	Intraclass Correlation Coefficient	Standard Error of Measurement	Intraclass Correlation Coefficient	Standard Error of Measurement
Internal rotation	0.976	1.36°	0.929	2.46°
External rotation	0.988	1.2°	0.911	2.56°
Humeral torsion	0.997	0.8°	0.991	1.5°

METHODS

Participants

Fifty-three collegiate baseball players, 35 collegiate softball players, 25 male controls (nonoverhead athletes), and 19 female controls (nonoverhead athletes) between the ages of 18 and 26 years were included in this study. Baseball and softball participants were members of a collegiate baseball or softball team and were position players (pitchers were excluded). Control participants had no history of involvement in an overhead sport team (eg, baseball, softball, tennis, volleyball). Volunteers were excluded from both groups if they had any current shoulder or elbow pain that had limited participation, a history of rotator cuff tear or neck injury within the past year, recurring subluxation or dislocation of the glenohumeral joint, upper extremity nerve condition (eg, cervical plexus and accessory nerve), cervical spine condition, or scoliosis. The participants read and signed an informed consent form approved by the University of North Carolina at Chapel Hill's Institutional Review Board. After an explanation of the procedures, each participant underwent bilateral testing for shoulder ROM and humeral retrotorsion.

Procedures

We used a digital inclinometer (The Saunders Group Inc, Chaska, MN) to collect ROM data. The digital inclinometer can measure angles to 360° and is accurate to 1.0°, as reported by the manufacturer. Bilateral internal- and external-rotation ROM were measured passively with the participant lying supine on a table in 90° of shoulder abduction and elbow flexion. Scapular stabilization was provided by the examiner through a posteriorly directed force at the acromion to isolate motion at the glenohumeral joint. The examiner passively rotated the limb to end range in internal (Figure 1A) and external rotation (Figure 1B) while aligning the digital inclinometer with the forearm to record the *humeral-rotation*

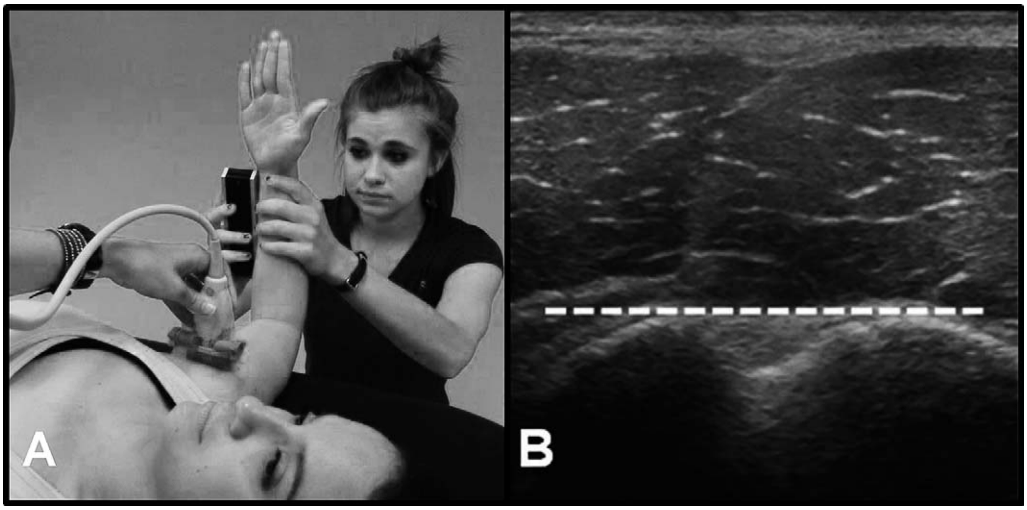

Figure 2. A, Ultrasonographic assessment of humeral retrotorsion. B, Ultrasonographic image of the upper humerus with the humeral tubercles pointing superiorly.

angle, measured as the angle between the forearm and the vertical axis and perpendicular to the treatment table. *End ROM* was defined as the point at which the examiner felt increased pressure from the acromion under the stabilizing hand. The investigators demonstrated strong intrasession and intertester reliability and precision for internal- and external-rotation measurements (Table 1).[24]

A diagnostic ultrasound (LOGIQ model; General Electric, Fairfield, CT) with a 4-cm linear transducer was paired with the digital inclinometer to measure humeral retrotorsion. Humeral retrotorsion assessed with diagnostic ultrasound has previously been shown[25] to have a strong correlation with the humeral-torsion measurements calculated using computed tomography. The ultrasound image was used to isolate the bony prominences of the greater and lesser tuberosities and place the proximal humerus in a standardized position. Humeral retrotorsion was assessed with the participant lying supine on a table; the participant's shoulder was passively abducted and the elbow was flexed to 90°. The first examiner positioned the ultrasound head on the anterior shoulder with the ultrasound head parallel with the floor and aligned 90° perpendicular to the long axis of the humerus (verified with a bubble level). The first examiner instructed the second examiner to move the humerus into internal and external rotation until the bicipital groove of the humerus appeared in the center of the ultrasound image, with the line connecting the apexes of greater and lesser tubercles parallel to the horizontal plane (Figure 2B). The second examiner then aligned the digital inclinometer firmly with the forearm to record the *humeral-rotation angle*, which was the angle from the horizontal plane in the internal-rotation direction (Figure 2A).[16,18,25] Strong intrasession and intertester reliability and precision were demonstrated for the ultrasonographic assessment by the investigators (Table 1).[25]

Table 2. Participant Demographics, Mean ± SD

Group	No.	Age, y	Height, m	Weight, kg
Baseball players	53	19.29 ± 1.2	1.81 ± .06	86.4 ±10.4
Softball players	35	18.97 ± 1.2	1.67 ± .08	70.2 ± 10.2
Male controls	25	20.04 ± 1.7	1.82 ± .08	81.7 ± 12.4
Female controls	19	19.89 ± 1.2	1.65 ± .18	59.6 ± 12.8

Data Analysis

We calculated a 3-trial mean for bilateral measurements. From these averages, we assessed humeral-retrotorsion difference, glenohumeral internal-rotation deficit (GIRD), external-rotation gain (ERG), total ROM, and total-ROM difference. Side-to-side differences were measured so that we could evaluate how the dominant limb adapted to overhead activity, using the nondominant limb as a baseline. *Humeral-retrotorsion difference* was calculated as the difference between dominant-limb retrotorsion and nondominant-limb retrotorsion. *Glenohumeral internal-rotation deficit* was defined as the difference between internal rotation measured in the dominant and nondominant shoulders. *External-rotation gain* was defined as the difference between external rotation measured in the dominant and nondominant shoulders. *Total ROM* was calculated as the sum of internal and external rotation. *Total ROM difference* was calculated as the difference between dominant- and nondominant-limb total ROM.

Statistical analyses were run using SPSS (version 20.0; IBM Corp, Armonk, NY). Univariate analyses of variance were used to assess group means of humeral-retrotorsion differences, GIRD, ERG, and total-ROM difference among baseball players, softball players, male controls, and female controls. An α level of .05 was set for all comparisons for statistical significance. Bonferroni post hoc testing compared baseball with softball players, baseball players with male controls, and softball players with female controls, so we used a corrected α level of 0.017 (0.05/3) for post hoc testing of variables that demonstrated a significant result on analysis of variance.

RESULTS

Participants' demographic data are presented in Table 2**.** The mean values for GIRD, ERG, total-ROM difference, and humeral-retrotorsion difference for each group are presented in Table 3.

We found group differences in humeral-retrotorsion difference ($F_{3,131} = 6.2$, $P = .001$; Figure 3). Post hoc testing revealed differences between baseball players and male controls (mean difference [md] = 7.8; $t_{76} = 3.1$, $P =$

Table 3. Descriptive Statistics, Mean ± SD

Group	Humeral-Retrotorsion Difference	Glenohumeral Internal-Rotation Deficit	External-Rotation Gain	Total Range-of-Motion Difference
Baseball players	14.1 ± 9.8°	9.9 ± 9.5°	3.0 ± 9.8°	6.9 ± 10.8°
Softball players	7.9 ± 9.0°	2.5 ± 6.4°	1.0 ± 7.4°	1.5 ± 7.0°
Male controls	6.3 ± 12.3°	4.7 ± 9.3°	4.5 ± 5.5°	0.2 ± 9.8°
Female controls	6.9 ± 7.9°	−0.5 ± 12.8°	−6.4 ± 9.8°	5.9 ± 12.4°

.001; 95% confidence interval [CI] = 2.8, 12.9) and baseball and softball players (md = 6.2; t_{86} = 3.4, P = .001; 95% CI = 2.5, 9.8), indicating that baseball players had a greater humeral-retrotorsion difference than both male controls and softball players. We noted no difference between softball players and female controls (md = 0.24; t_{59} = 0.12, P = .909; 95% CI = –4.12, 4.60).

Group differences were demonstrated in GIRD ($F_{3,132}$ = 8.0, $P < .0005$; Figure 4). Post hoc testing revealed differences between baseball players and male controls (md = 5.2; t_{77} = 2.4, P = .017; 95% CI = 1.0, 9.5) and baseball and softball players (md = 7.4; t_{87} = 4.1, $P < .0005$; 95% CI = 3.8, 11.1), indicating that baseball players had greater GIRD than both male controls and softball players. We found no difference between softball players and female controls (md = 3.3; t_{59} = 1.24, P = .220; 95% CI = –2.05,8.71).

Group differences were demonstrated in ERG ($F_{3,132}$ = 6.4, $P < .0005$; Figure 5). Post hoc testing revealed a difference in ERG between softball players and female controls (md = 7.5; t_{59} = 3.31, P = .002; 95% CI = 2.96, 12.03), indicating that softball players had greater ERG than female controls. We saw no differences between baseball players and male controls (md = –1.5; t_{77} = –0.3, P = .51; 95% CI = –6.1, 3.1) or baseball and softball players (md = 2.0; t_{87} = 1.0, P = .334; 95% CI = –2.1, 6.1).

Group differences were evident in total-ROM difference ($F_{3,167}$ = 3.7, P = .013; Figure 6). Post hoc testing revealed differences between baseball players and male controls (md = 6.8; t_{77} = 2.8, P = .006; 95% CI = 2.03, 11.5) and baseball and softball players (md = 5.4; t_{87} = 2.6, P = .010; 95% CI = 1.3, 9.5), indicating that baseball players had a greater total-ROM difference than both male controls and softball players. No difference was noted between softball players and female controls (md = –4.2; t_{59} = –1.49, P = .142; 95% CI = –9.78, 1.44).

DISCUSSION

Our goal was to directly compare ROM and humeral retrotorsion of the shoulder among softball players, baseball players, and sex-matched controls. Our results were consistent with those in the previous literature when baseball players were compared with male controls.[8–13] Interestingly, we found differences between baseball and softball players on GIRD, humeral retrotorsion, and total ROM, with baseball players having greater GIRD and humeral-retrotorsion and total-ROM differences. This indicates that although baseball and softball are similar sports, the physical adaptations and potential injury mechanisms are different. Further, softball players did not differ from female control participants on GIRD, humeral-retrotorsion difference, or total-ROM difference. The GIRD, humeral-retrotorsion difference, and total-ROM difference are expected physical adaptations in overhead athletes because of the repetitive stress on the dominant arm during the throwing motion; however, our results do not suggest that these adaptations occur in softball players when compared with controls. Our findings were consistent with those in the previous literature evaluating ROM adaptations and humeral retrotorsion in baseball players.[10,11,13,24,26] Although these observations are consistent

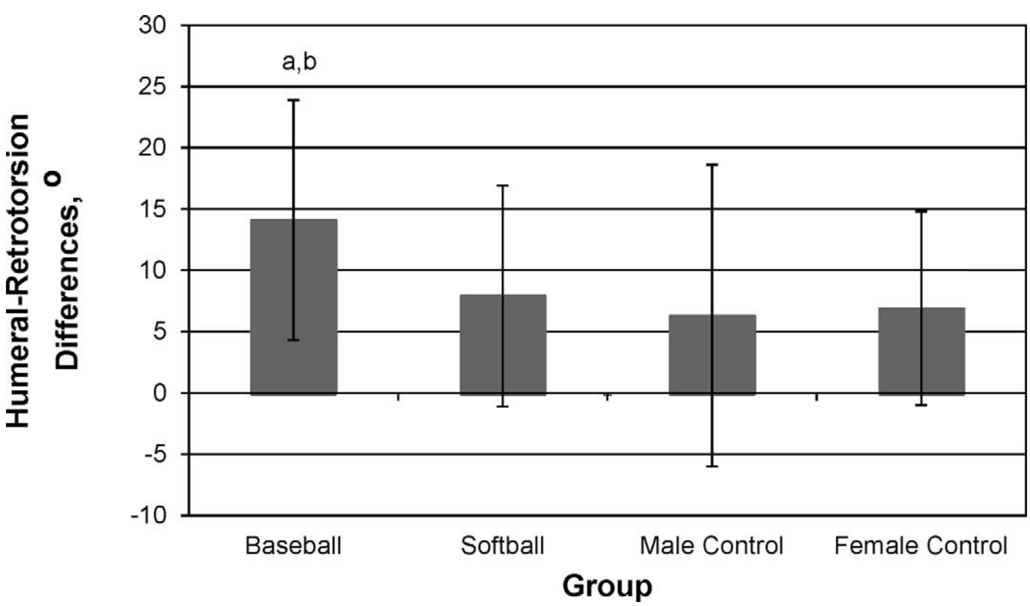

Figure 3. Humeral-retrotorsion differences. [a]Difference between baseball and softball position players. [b]Difference between baseball players and male controls.

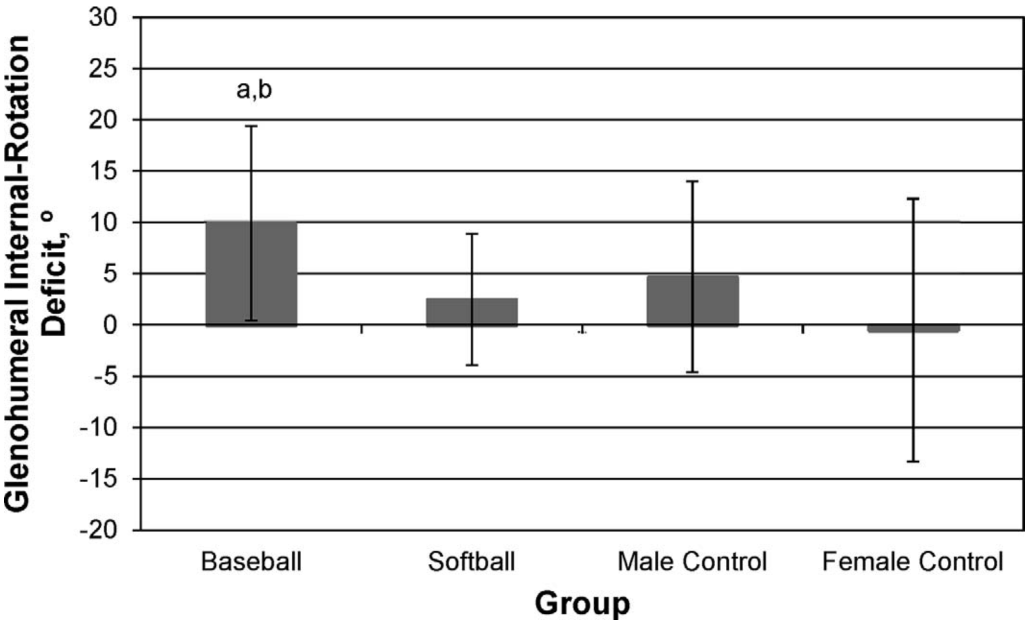

Figure 4. Glenohumeral internal-rotation deficits. [a]Difference between baseball and softball players. [b]Difference between baseball players and male controls.

with those in the previous literature, little research on the same variables has been conducted in softball players.[19,27]

Baseball and softball players perform similar overhead throwing motions, but many variations between the groups may explain group differences. Anthropometrically, the female softball player is generally smaller in height, body mass, size, and muscle mass compared with the male baseball player, with an associated decrease in absolute muscle strength and lower absolute torque and power generation.[20] In addition, a softball weighs approximately 20% more than a baseball, and the softball field is much smaller than the baseball field (shorter distance between the bases), which could influence the joint torques during the throwing motion.[21,22] These differences in the forces and angular velocities at the shoulder may affect physical adaptations of the shoulder-stabilizing musculature and posterior capsule that are responsible for the greater decrease in the dominant-arm internal-rotation ROM in baseball players when compared with softball players.

Our results are consistent with those in the previous literature evaluating ROM adaptations and humeral retrotorsion in baseball players.[10,11,13,24,26] Little research on the same variables has been recorded in softball players.[19,27] We noted less pronounced variations in the physical characteristics of softball players when compared with baseball players.

Furthermore, our results indicate the male baseball players had a greater humeral-retrotorsion side-to-side difference than the softball players (approximately 6°). Alterations in humeral retrotorsion are created through opposing torques

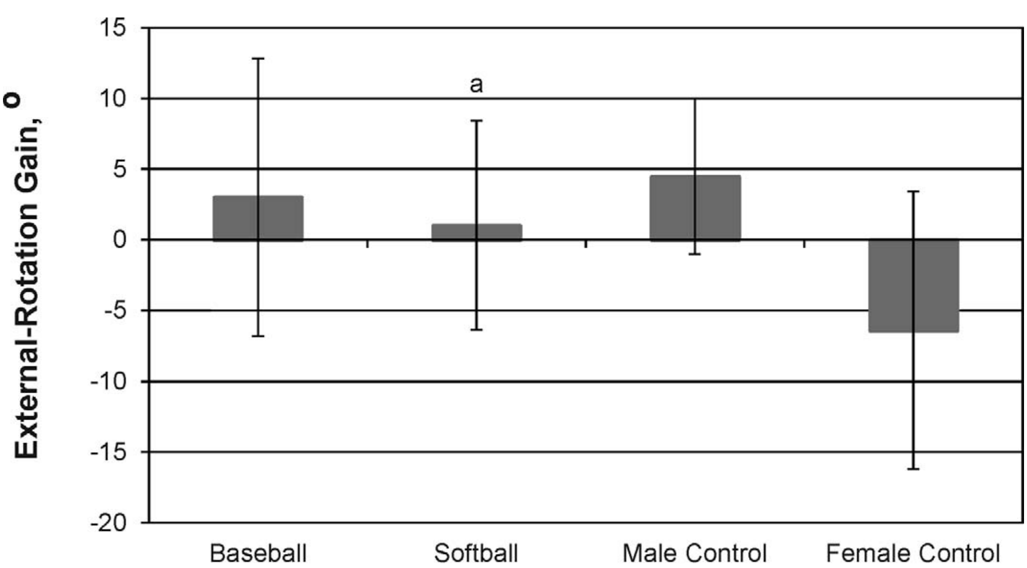

Figure 5. External-rotation gains. [a]Difference between softball players and female controls.

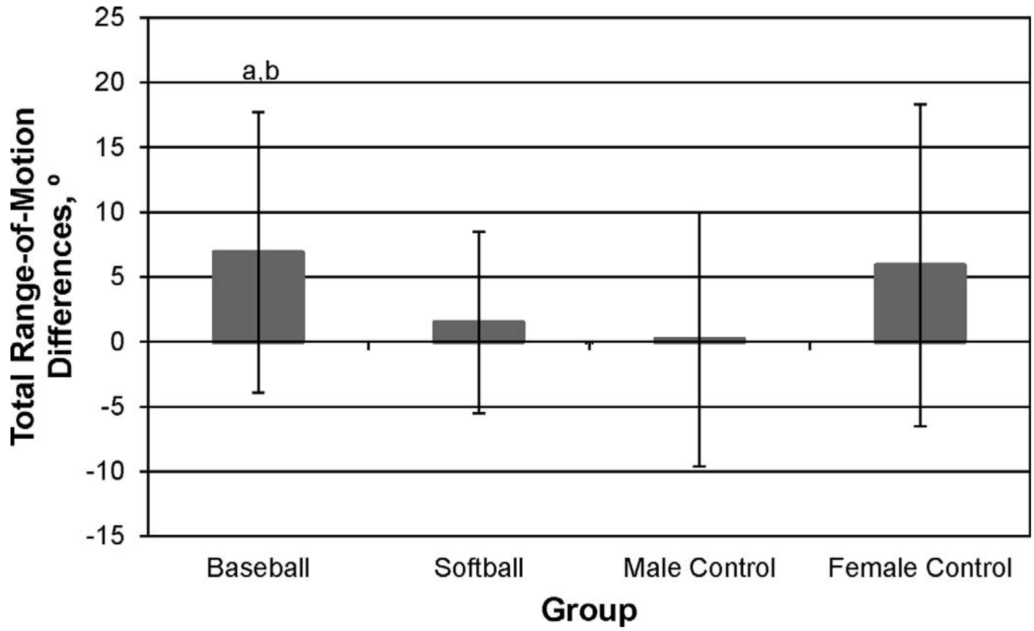

Figure 6. Total range-of-motion differences. [a]Difference between baseball and softball players. [b]Difference between baseball players and male controls.

acting upon the proximal humerus as the arm moves into maximum external rotation before accelerating to ball release during the overhead throw. These opposing torques create a twisting effect upon the long axis of the humerus, increasing the amount of humeral retrotorsion over time as this motion is repeated excessively. The previously discussed factors that influence the joint torques and stress on the shoulder-stabilizing musculature and posterior capsule could also influence the development of humeral retrotorsion and thus the interpretation of rotational ROM measures.[16] In addition, the female growth spurt is generally shorter than that of the male,[28] allowing a longer period of time for the open epiphyseal plates of the male to be manipulated by humeral torques and for humeral retrotorsion to develop. Finally, as we learned from our experience with youth baseball teams, the majority of children participating on these teams are expected to pitch at some point. Because of guidelines for pitch limits paired with the large number of games, most players on many teams practice pitching in case they are needed. The additional stress at the shoulder from pitching in games and practice may be another reason why humeral retrotorsion is greater in baseball players.[29]

Previous authors[16,30,31] have identified the osseous component of humeral retroversion as a major contributor to ROM measures and suggested using a corrected-ROM measure to better assess the soft tissue restriction that is present. This adjustment has been proposed to isolate the total-ROM alterations in the shoulder that are attributed to soft tissue contracture or lengthening, as opposed to the traditional thought that all variations in ROM are caused by soft tissue differences.[16,30] The adjustment for humeral torsion redefines the point of neutral for measuring internal and external rotation such that the proximal humerus is placed in a standard position. The difference in humeral retrotorsion between baseball and softball players may be causing the ROM difference between the groups.

Several limitations in our research study should be acknowledged. First, the population studied was completely healthy. Therefore, we cannot determine if the measurements of ROM and humeral retrotorsion would be affected within a group with shoulder or elbow injury or if some values were associated with injury, as the groups were not followed prospectively.

In addition, only current pitchers were excluded from the study. It is possible that individuals pitched at younger ages and their measurements were influenced by their past history as pitchers; however, clinically, this is not a modifiable factor, and practitioners must develop injury-prevention programs for all athletes, regardless of their past experiences as a pitcher. In addition, the average age of the participants was 19.4 years. Although females have reached physical maturity by the age of 19, several of the males in this study may not have reached physical maturity. This indicates that these baseball players may experience a further alteration in humeral retrotorsion. If these players' epiphyseal plates had not closed, they could experience increased retrotorsion effects during the subsequent few years. Furthermore, the time frame during which physical maturation is experienced is generally longer for the male population[32] and may allow for a greater overall effect on humeral retrotorsion.

Future researchers should focus on prospectively tracking softball players to determine modifiable physical characteristics that may predict injury. In addition, few data exist that compare the kinematics and kinetics of the overhead softball throw with those of the baseball throw or the baseball pitch. An overall biomechanical analysis of overhead baseball and softball throwing may provide valuable insight into the differences in the development of physical characteristics between softball and baseball players and injury mechanisms in these groups.

CONCLUSIONS

We found few differences between softball position players and female control participants, as well as less-pronounced adaptations in softball position players' ROM and humeral retrotorsion when compared with those of the baseball position players in this study and the previous literature. Although the throwing motion is similar between baseball and softball, the decreased angular velocities and forces at the shoulder in female softball players may explain why the physical adaptations that are traditionally seen in baseball players when compared with controls were not seen in softball players. Despite the many similarities between baseball and softball, our findings suggest that athletes adapt to the demands of the sport differently. Because of this, injury risk factors and injury-prevention programs that are successful in baseball players may not be as effective for softball athletes. Future researchers should focus on evaluating specific injury mechanisms in softball players and developing an evidence-based injury-prevention program.

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