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Preseason screening in high school pitchers Preseason Screening of Shoulder Range of Motion and Humeral Retrotorsion Does Not Predict Injury in High School Baseball Players

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Abstract

Background—Shoulder and elbow injuries are commonplace in high school baseball. While altered shoulder ROM and humeral retrotorsion angles have been associated with injuries, efficacy of preseason screening of these characteristics remains controversial.

Methods—We conducted preseason screenings for shoulder internal and external rotation range of motion (ROM) and humeral retrotorsion on a total of 832 high school baseball players, and tracked their exposure and incidence on throwing-related shoulder and elbow injuries over a subsequent season. Poisson regression with robust error variance was used to determine if preseason screening could identify injury risk in baseball players, and whether the injury risk was higher for pitchers compared to players who do not pitch.

Results—Shoulder rotation ROM or humeral retrotorsion at preseason did not predict risk of throwing-related upper extremity injury ($p=0.15-0.89$). Injury risk was 3.84 higher for baseball players who pitch compared to those who do not (95% CI =1.72–8.56, $p=.001$).

Discussion—Preseason measures of shoulder ROM and humeral retrotorsion may not be effective in identifying players who are at increased injury risk. Since shoulder ROM is a measure that fluctuates under variety of influence, future study should investigate if taking multiple measurements over a season can identify at-risk players. The usefulness of preseason screening

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may also depend on rigor of participation in sports. Future studies should investigate how preseason shoulder characteristics and participation factors (i.e. pitch count and frequency, competitive level, pitching in multiple leagues) interact to predict injury risk in baseball players.

Level of evidence—Level I, Prospective Design, Prognosis Study

Keywords

Screening; injury risk; evaluation; physical characteristics; baseball; humeral retrotorsion

Throwing-related upper extremity injuries comprise a large portion of all injuries occurring in baseball, making them a common place amongst competitive baseball players.^{4, 10, 13, 14, 16–18, 27, 31, 38, 39} Alternations in shoulder range of motion (ROM) have been long considered a contributing factor to these injuries,^{1, 2, 9, 21, 39, 40, 43, 46, 47} and thus significant emphasis is placed on evaluating shoulder ROM characteristics by clinicians who are working with baseball players. Specifically, glenohumeral internal rotation deficit (GIRD),^{5, 9, 21, 37, 39} adaptive gain in external rotation ROM,⁴⁷ and loss of total rotation ROM^{9, 35, 39, 46} and horizontal adduction ROM,³⁹ on the dominant limb have been linked to throwing-related upper extremity injuries. Additionally, humeral retrotorsion angle that influences shoulder rotation ROM has also been linked to injuries in some studies.^{24, 26, 44, 45}

While there is mounting evidence linking alterations in shoulder ROM characteristics to injury,^{1, 2, 5, 9, 21, 35, 43} it remains unclear whether screening of these characteristics in preseason can help identify baseball players with increased injury risk. The studies by Shanley et al^{37, 39} indicated that greater loss of total rotation ROM, deficit in horizontal adduction ROM, and GIRD at preseason are associated with increased risk of injury in high school baseball players. Contrarily, Tyler et al⁴² reported that having >20° GIRD at baseline was protective of injury in a study of high school baseball players, and Wilk et al^{46, 47} reported GIRD to be unrelated to injury risk in two studies on professional baseball pitchers. Greater dominant-limb humeral retrotorsion angle has been linked to lower risk of shoulder injuries²⁶ and few days lost from participation,³² but with greater risk of elbow injury²⁶ in professional baseball pitchers. Additionally, decreased non-dominant-limb humeral retrotorsion angles have also been linked to an increased risk of throwing-related injuries among high school and collegiate pitchers in a small prospective study.⁴⁵

Based on the inconsistent findings from the previous studies,^{37, 39, 42, 46, 47} it remains inconclusive whether preseason shoulder ROM characteristics and humeral retrotorsion can predict in-season injury risk. Investigating whether the data collected in preseason can predict injury risk during the season is clinically meaningful, as it can help us determine how to best utilize the clinical data. Therefore, the purpose of this study was to prospectively evaluate whether the shoulder ROM and humeral retrotorsion characteristics affect the risk of throwing-related shoulder and elbow injury that occur during a baseball season in a large sample of high school baseball players.

MATERIALS AND METHODS

Procedures

All participants ($n = 832$, age = 16.4 ± 1.1 years; height= 179.9 ± 6.5 cm; mass = 77.5 ± 12.3 kg) in the current study were junior varsity or varsity level, male baseball players who participated on one of 28 high schools from across the state of North Carolina, over three spring baseball seasons. Parental consent was obtained from all participants following the university institutional review board guideline. Additionally, assent was obtained from the minor participants on the day of testing.

All testing was conducted at an Athletic training room, dugout, or classroom at participating high schools. All preseason data collections were completed at the beginning of the spring baseball season, before the start of any competitions. At the beginning of the testing session, each participant provided information on amount of participation, current and past playing positions, and brief throwing-related upper extremity injury history by completing a survey. After completing a survey, each player was asked to lie supine on a portable treatment table for an assessment of shoulder ROM (internal rotation, external rotation, and horizontal adduction) using a digital inclinometer (The Saunders Group, Inc. Chaska, MN) and humeral retrotorsion using a digital inclinometer and a diagnostic ultrasound. The methods used to assess shoulder ROM were consistent with what has been used by clinicians and researchers. All measurements were taken three times bilaterally, and the average of the three trials were used for statistical analysis.

The shoulder internal and external rotation ROM was assessed with the participant's arm placed in 90° of shoulder abduction and elbow flexion (Figure 1a). A small towel roll was placed under the humerus to maintain its position in the frontal plane. Examiner applied a posteriorly directed force at the acromion to stabilize the scapula while passively rotated the limb into internal and external rotation to end range. The second examiner recorded the rotation angles. A total rotation ROM was calculated by adding the internal and external rotation ROM. Reliability and precision of the shoulder rotation ROM assessment had been established (Intrasession and intersession $ICC_{2,k}$: .911–.988, $SEM = 1.2 - 2.6^\circ$).^{21, 23, 25, 28}

To measure the horizontal adduction ROM, the examiner placed one hand under the scapula, while the participant lifted his shoulder off the table (Figure 1b). The examiner pressed the palm against the lateral border of the scapula to stabilize the scapula in a maximally retracted position, before using the other hand to move the participant's arm into horizontal adduction. At the end range, the second examiner recorded the angle formed between the humerus and the horizontal plane. The investigators have previously established the reliability ($ICC = .91$), precision ($SEM = 1.1^\circ$), and construct validity of this assessment method.²⁵

Humeral retrotorsion was assessed utilizing the technique previously validated against a measurement using a CT scan (Figure 1c).^{22, 23, 45, 48} While the participants' shoulder was placed in 90° of shoulder abduction and elbow flexion, an examiner positioned a 4cm linear array ultrasound transducer (LOGIQe, General Electric, Milwaukee, WI, USA) on the participant's anterior shoulder. The ultrasound transducer was aligned vertically (verified

with a bubble level) and positioned perpendicular to the long axis of the humerus. The second examiner rotated the humerus so that the bicipital groove appeared in the center of the ultrasound image, with the line connecting the apexes of greater and lesser tubercles parallel to the horizontal plane, using a grid placed over the ultrasound unit display as a guide. Once the humerus was positioned properly, a digital inclinometer, which was pressed firmly against the ulna, was used to record the forearm inclination angle relative to horizontal plane.

Side-to-side differences in internal rotation (glenohumeral internal rotation deficit), horizontal adduction (horizontal adduction motion deficit), and total rotation motion (total rotation motion deficit) were calculated by subtracting the dominant limb values from the non-dominant limb values. Side-to-side difference in external rotation (external rotation gain) and humeral retrotorsion (humeral retrotorsion difference) were calculated by subtracting the non-dominant limb values from the dominant limb values.

Injury Surveillance

Over the course of a baseball season, the exposures and injuries sustained by each participant were tracked with the aid of the Certified Athletic Trainer employed at each high school. During each week of the season, a web link for the online surveillance was emailed to the athletic trainers. Using this link, the athletic trainers reported any new injuries that occurred during the week, the number of practices and games the team had, and any participants who missed or had limited participation in each game/practice. When a participant missed or had a limited participation, additional information was obtained, including reason for the missed exposure (either because of injury or another reason). When an injury was listed as the reason for a missed or limited exposure, the injury specific data including diagnosis (made by the athletic trainer and/or physician), and injury mechanism were obtained.

The information captured from the athletic trainers was used to calculate athlete exposure and injury incident. An exposure was defined as full participation in a practice or a game. Injury was defined as any shoulder or elbow injury that resulted from the act of throwing/pitching and resulted in at least 1 missed or limited exposure. All exposure and injury data were verified at the end of the season with the help of each high school's athletic trainer and coach.

Statistical Analysis

Mean and standard deviation was calculated for shoulder ROM and humeral retrotorsion variables. For each variable, participants were categorized into below normal, normal, and above normal group using the values representing mean $\pm$ 1 standard deviation as cutoffs (Table 1).⁴² This method of using a standard deviation to define cutoff values was adopted from the previous study.⁴² The cutoff values seemed to generally coincide with the values that previous research and clinicians use to identify players with ROM values that deviate from normal.³⁷ For example In order to determine whether having below normal or above normal shoulder ROM or humeral retrotorsion values would result in increased injury risk, risk ratios were estimated using Poisson regression with robust error variance and player

game/practice exposures as an offset.⁵¹ The outcome variable was whether or not the participant sustained an injury during the season. The analyses were repeated with a subset of participants who pitch for the team. We also compared injury risk between participants who pitch for the team and do not by estimating the risk ratio between groups using the same similar Poisson regression model with pitching entered as a predictor variable. An a priori alpha level was set for 0.05 for all analyses. SAS Studio (SAS Institute Inc. Cary, NC) was used for all statistical analyses.

RESULTS

A total of 832 high school baseball players participated in the study. A total of 41 injuries were reported over the study period. This included 14 elbow injuries, 25 shoulder injuries, and 2 injuries involved both the shoulder and the elbow, resulting in injury rate of 1.1 injuries/1000 Athlete-Exposures. The injuries to the elbow included 5 injuries to the ulnar collateral ligament, 6 tendinosis/strain of the flexor pronator mass, 1 posterior impingement, and 2 non-specific joint pain. The injuries to the shoulder included 13 cases of tendinosis/strain, 6 impingements, a labral tear, stress fracture, pain from neural tension, and 4 non-specific joint pain. Among our participants, 55.5% (n = 462) reported that they would be pitching for their high school team. Of all recorded shoulder and elbow injuries, 75.6% (n=31) were sustained by the participants who pitched for their high school team. The injury rate among these players was 1.29 injuries/1000 Athlete-Exposures. Demographic information for the injured and uninjured participants is summarized in Table 2. Means and standard deviations of the dependent variables for the injured and uninjured participants are presented in Table 3. There were no significant differences in any demographics or dependent variables between participants who were injured and were not injured.

None of the shoulder range of motion or humeral retrotorsion variables from the pre-participation screening was predictive of injury risk during the season. The risk of injury was not significantly higher or lower for participants who demonstrated above normal or below normal values for all variables ($p>0.05$) (Table 4). The same could be said for the subset of participants who pitch for the team ($p>0.05$) (Table 5). Playing the position of pitcher during the season was associated with an increased risk of injury. Participants who pitch for the team were 3.84 times more likely to get injured compared to the participants who do not pitch (Risk ratio=3.84, 95% CI=1.72–8.56, $p=.001$).

DISCUSSION

The current study is the largest prospective study to date that investigated whether the preseason shoulder ROM and humeral retrotorsion characteristics in baseball players can be used to predict injury risk. Our results demonstrated that shoulder ROM or humeral retrotorsion measured at preseason does not identify high school baseball players with increased risk of injury over the subsequent season. Additionally, we also observed that pitchers had higher risk of injury compared to non-pitchers.

The challenge in using preseason ROM values to predict injury risk in baseball players is that shoulder ROM is not a static value. Range of motion can be acutely affected by variety

of factors and also change over the course of a season. Shoulder ROM can acutely increase by after warm up⁸ and stretches,^{15, 30, 36} and decrease after pitching⁶, and remain altered for more than 24 hours.⁴⁹ Decrease in shoulder ROM over the course of the season has not been demonstrated in high school pitchers,⁷ but has been demonstrated in collegiate pitchers.¹⁹ The fluidity of the shoulder ROM makes it difficult to capture the value that is representative of the pitcher's physical condition. Perhaps, measurement of ROM at a single time point in the preseason may not be sufficient to capture injury risk. Testing ROM repeatedly at preseason, and over the course of the season to capture the natural variability in the players shoulder ROM, and detecting significant deviation beyond the normal range may be needed, especially for pitchers whose injury rate was higher compared to non-pitchers. Those athletes who have significant deviations can be targeted for interventions to restore range of motion.

Humeral retrotorsion is greatest at birth, continues to decrease (i.e. unwind) during youth and early adolescence, and stabilize by the time baseball players enter high school.²⁹ Baseball players tend to present with increased humeral retrotorsion on the dominant arm, because repetitive torsional load on their throwing arm while playing youth baseball, interfere with the rewinding process, causing it to remain more "twisted" relative to the non-dominant arm.^{11, 12} Previous studies suggest that increased humeral retrotorsion on the dominant limb protects pitchers from shoulder injuries,²⁶ but increases the risk of elbow injuries in college²⁴ and professional²⁶ baseball pitchers. Although the mechanistic link is still unclear, the effect of dominant humeral retrotorsion on injury risk is likely attributed to the way humeral retrotorsion affects shoulder ROM,^{3, 23} and thereby loads at shoulder and elbow joints. On the other hand, lower non-dominant limb humeral retrotorsion has been linked to injuries among high school pitchers.^{20, 33, 45} The humeral retrotorsion angle of the non-dominant limb reflects the "default" humeral retrotorsion angle that the dominant limb would have if it were not subjected to repetitive torsional loading. The dominant limbs with lower "default" humeral retrotorsion angle have the potential to go through greater adaptation in humeral retrotorsion, and thus are theorized to be more susceptible to injuries.^{20, 45} On the contrary to these studies, we observed that the humeral retrotorsion was not predictive of shoulder or elbow injury in high school baseball players of pitchers.

The lower incidence proportion in our study compared to others may in part explain why preseason ROM or humeral retrotorsion characteristics were predictive of injury risk in previous studies,^{37, 39, 42} but not in ours. The rates of upper extremity injuries in our study were 1.1 injuries/1000 athlete-exposures for all baseball players and 1.29 injuries/1000 athlete-exposures for pitchers. These injury rates are much higher compared to what was reported for high school baseball players in the study by Krajnik et al (0.17 injuries/1000 athlete-exposures), but is lower compared to what was reported for high school softball/baseball players in the study by Shanley et al (2.5 injuries/1000 athlete-exposures). In our study, 4.9% of our players and 6.7% of our pitchers sustained injury during a baseball season. These numbers are also lower compared to incidence proportion previously reported for high school softball/baseball players (10.9%),⁴² and for high school pitchers (23.5–54.3%).^{37, 42, 45}

The discrepancy in incidence proportion between our study and others^{21,26,27} is puzzling, since all of these studies used similar definition of injury, and followed participants for a similar length of time (i.e. a season). One possible explanation is the difference in competitiveness of the baseball pitchers included in the studies. The more competitive pitchers tend to pitch more, pitch in lessons outside of school, and play for outside leagues simultaneously, increasing their risk of injury.^{34, 50} In fact, some of the players in one previous study were recruited from pitching academies and higher-level teams.^{37, 45} Our sample of players was recruited from 28 high schools, with less than 20% of them playing baseball in all three seasons (spring, summer, and fall) leading up to the season. We hope that sampling from a large number of schools resulted in representative sample of high school baseball players. The fact that preseason physical characteristics were not associated to injury risk in our study, but were linked to injury risk in other studies with potentially more competitive pitchers^{37, 45} suggest that altered preseason shoulder ROM may be a risk factor for baseball players and pitchers who participate in baseball above certain competitive level.

Since the operational definition of injury used in all studies were “any throwing-related upper extremity injuries that resulted in at least one missed participation”, we must also consider clinicians’ judgment to remove or keep players in participation, as possible extraneous factors that affects reported injury incidence. The athletic trainers who reported the injuries, in our study were not directly associated with the investigation, and thus had no study-related motivation to remove players from practice/game. Additionally, the injuries reported by the athletic trainers weekly were later verified by the coaches to ensure we capture all injuries.

One of the limitations of this study is that we used participation in a game or practice as a measure of exposure. Collecting pitch count data during games and recording types of pitching and fielding drills completed by each baseball players would have provided a more precise measure of exposure. This is a challenge for all future studies that investigate the effects of participation factors on injury risk in baseball players. As discussed earlier, shoulder ROM fluctuates under various influences, including warm up,⁸ stretching,^{15, 30, 36} pitching activity within a few days before assessment,⁶ and thoracic spine mobility.⁴¹ It is likely not possible to capture the “representative” shoulder ROM values for all pitchers during a single screening. Future study must investigate feasibility and efficacy of taking multiple baseline measurements to identify pitchers with increased injury risk. Another possible limitation is the relatively low number of injuries that was reported during the seasons compared to what was reported in the other studies. However we were in contact with the Athletic Trainers to gather injury data on a weekly basis, and verified the injury and exposure records with the coaches at the end of the season to capture all injuries.

CONCLUSIONS

Pitchers are at a greater risk of developing throwing-related arm injuries compared to those players who do not pitch. Injury prevention effort and resources should be directed to prevent injuries in pitchers. A one-time preseason assessment of shoulder ROM and humeral retrotorsion did not predict injury risk in our group of high school baseball players or

pitchers. However, given that various altered shoulder characteristics has been demonstrated as a risk factor for injuries in sample of pitchers from other studies, future studies should investigate whether taking multiple measurements over the season can better identify players at risk of injury, and how shoulder ROM characteristics and participation factors (i.e. pitch count and frequency, competitive level, pitching in multiple leagues) interact to predict injury risk in baseball players.

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Figure 1.
Assessment of shoulder range of motion and humeral retrotorsion

Table 1

Means and standard deviation of dependent variables and cut off values for grouping

Variables	Mean $\pm$ SD	Below normal	Above normal
Shoulder range of motion ($^{\circ}$)			
Dominant limb internal rotation	43.3 $\pm$ 9.5	33.8	52.8
Dominant limb external rotation	117.5 $\pm$ 13.3	104.2	130.8
Dominant limb horizontal adduction	94.2 $\pm$ 6.6	87.6	100.8
Dominant limb total rotation	160.8 $\pm$ 16.7	144.0	177.5
Glenohumeral internal rotation deficit *	7.6 $\pm$ 9.9	-2.3	17.5
External rotation gain †	4.1 $\pm$ 10.6	-6.4	14.7
Horizontal adduction deficit *	5.9 $\pm$ 6.9	-1.0	12.9
Total rotation motion deficit *	3.3 $\pm$ 12.0	-8.7	15.4
Humeral retrotorsion ($^{\circ}$)			
Dominant-limb humeral retrotorsion	77.3 $\pm$ 10.5	66.9	87.8
Non-dominant limb humeral retrotorsion	64.0 $\pm$ 10.6	53.4	74.7
Humeral retrotorsion difference †	13.3 $\pm$ 9.9	3.4	23.2

SD = Standard deviation

* Calculated as non-dominant limb value - dominant limb value

† Calculated as dominant limb value - non-dominant limb value

Table 2

Participant demographics

	Injured	Uninjured
All participants	n = 41	n = 791
Age (years)	16.4 ± 1.2	16.5 ± 1.1
Mass (kg)	78.2 ± 12.2	76.6 ± 12.4
Height (cm)	180.1 ± 6.0	179.8 ± 7.0
Baseball experience (years)	11.3 ± 1.6	11.0 ± 2.2
Participants who pitch for the team	n = 31	n = 462
Age (years)	16.4 ± 1.3	16.5 ± 1.1
Mass (kg)	79.4 ± 12.3	77.2 ± 12.1
Height (cm)	181.1 ± 5.7	181.4 ± 6.8
Baseball experience (years)	11.2 ± 1.7	11.3 ± 1.9
Pitching experience (years)	6.8 ± 1.9	7.0 ± 2.4

Table 3

Means and standard deviations for dependent variables by injury

Variables	<u>All participants</u>		<u>Participants who pitch</u>	
	Injured (n=41)	Uninjured (n=791)	Injured (n=31)	Uninjured (n=462)
Shoulder range of motion (°)				
Dominant limb internal rotation	43.2 ± 9.1	43.3 ± 9.5	44.3 ± 9.0	43.0 ± 9.3
Dominant limb external rotation	119.3 ± 14.3	117.4 ± 13.3	119.1 ± 15.4	117.5 ± 13.3
Dominant limb horizontal adduction	94.0 ± 7.6	94.2 ± 6.5	94.2 ± 7.3	94.7 ± 6.6
Dominant limb total rotation	160.7 ± 16.6	161.4 ± 19.7	160.5 ± 16.8	162.1 ± 21.0
Glenohumeral internal rotation deficit *	7.0 ± 9.0	7.6 ± 10.0	7.8 ± 8.0	7.9 ± 9.5
External rotation gain †	3.2 ± 10.1	4.2 ± 10.6	3.7 ± 10.7	4.7 ± 10.1
Horizontal adduction deficit *	5.0 ± 6.6	6.0 ± 6.9	5.2 ± 7.3	5.6 ± 7.3
Total rotation motion deficit *	3.4 ± 11.5	3.6 ± 12.1	160.5 ± 16.8	162.1 ± 21.0
Humeral retrotorsion (°)				
Dominant-limb humeral retrotorsion	77.6 ± 10.4	77.3 ± 10.5	76.7 ± 9.9	77.8 ± 10.6
Non-dominant limb humeral retrotorsion	65.0 ± 8.9	64.0 ± 10.7	64.4 ± 8.7	63.5 ± 10.9
Humeral retrotorsion difference †	12.6 ± 9.5	13.4 ± 10.0	12.2 ± 9.6	14.3 ± 10.3

SD = Standard deviation

* Calculated as non-dominant limb value - dominant limb value

† Calculated as dominant limb value - non-dominant limb value

Table 4

Risk ratios for proposed risk factors

	Below normal			Above normal		
	Risk ratio	95%CI	p	Risk ratio	95%CI	p
Shoulder range of motion (°)						
Dominant limb internal rotation	0.94	0.40–2.21	.88	0.93	0.39–2.20	.87
Dominant limb external rotation	1.10	0.49–2.48	.81	1.09	0.49–2.46	.82
Dominant limb horizontal adduction	1.22	0.52–1.93	.65	1.74	0.81–3.74	.15
Dominant limb total rotation	1.32	0.61–2.84	.48	1.11	0.47–2.63	.81
Glenohumeral internal rotation deficit	1.17	0.53–2.60	.69	0.54	0.17–1.75	.31
External rotation gain	0.58	0.21–1.62	.87	0.93	0.40–2.19	.87
Horizontal adduction deficit	1.36	0.63–2.90	.43	0.69	0.25–1.94	.49
Total rotation motion deficit	1.40	0.65–3.01	.39	1.18	0.50–2.78	.71
Humeral retrotorsion (°)						
Dominant-limb humeral retrotorsion	1.03	0.48–2.21	.94	0.79	0.31–2.00	.62
Non-dominant limb humeral retrotorsion	0.75	0.32–1.77	.51	0.94	0.40–2.23	.89
Humeral retrotorsion difference	1.08	0.50–2.32	.84	0.82	0.32–2.09	.68

Table 5

Rate ratios for proposed risk factors for pitchers

	Below normal			Above normal		
	Risk ratio	95%CI	p	Risk ratio	95%CI	p
Shoulder range of motion (°)						
Dominant limb internal rotation	0.77	0.28–2.16	.62	1.24	0.53–2.95	.61
Dominant limb external rotation	1.51	0.66–3.44	.32	1.50	0.66–3.41	.34
Dominant limb horizontal adduction	1.05	0.38–2.94	.92	1.53	0.68–3.43	.30
Dominant limb total rotation	1.38	0.61–3.13	.44	1.34	0.26–3.19	.51
Glenohumeral internal rotation deficit	1.07	0.43–2.67	.89	0.65	0.20–2.07	.46
External rotation gain	0.70	0.25–1.96	.50	1.09	0.43–2.74	.85
Horizontal adduction deficit	1.15	0.51–2.59	.74	0.82	0.29–2.30	.71
Total rotation motion deficit	1.15	0.49–2.72	.75	0.97	0.35–2.71	.96
Humeral retrotorsion (°)						
Dominant-limb humeral retrotorsion	1.13	0.50–2.55	.77	0.75	0.26–2.11	.59
Non-dominant limb humeral retrotorsion	0.85	0.36–2.03	.71	1.14	0.45–2.88	.79
Humeral retrotorsion difference	0.97	0.43–2.19	.94	0.98	0.35–2.74	.96