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Reliability of Measuring Humeral Retroversion Using Ultrasound Imaging in a Healthy Nonthrowing Population

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Context: Studies have reported the difference in humeral retroversion (HR) between the dominant and nondominant side in throwing athletes. However, there are few data concerning HR for the rest of the population. In addition, the relationship between HR and external (ER) and internal rotation (IR) at 90° shoulder abduction has not been thoroughly investigated. ***Objectives:*** To investigate the reliability of ultrasound methodology to measure HR. In addition, using ultrasonography, the authors compare HR between the dominant and nondominant sides in healthy adult men and determine the relationship between HR and ER and IR at 90° of shoulder abduction. ***Design:*** Descriptive study. ***Setting:*** Laboratory. ***Participants:*** Thirty-seven healthy male subjects (age 21.9 ± 2.4 y, height 172.9 ± 5.3 cm, weight 66.0 ± 7.2 kg) with no history of shoulder or elbow injury, recruited from a convenience sample, volunteered for the study. ***Main Outcome Measures:*** Subjects were bilaterally examined for HR, ER, and IR. HR was measured by ultrasonography. ***Results:*** The intrarater reliability of the ultrasound methodology was .91–.98, and the interrater reliability was .97. The HR angle on the dominant side (mean ± SD: 68.5° ± 10.0°) was significantly greater than that of the nondominant side (58.0° ± 8.4°; $P < .001$). ER on the dominant side was significantly greater than on the nondominant side ($P < .001$), whereas IR on the dominant side was significantly smaller than on the nondominant side ($P < .001$). Total arc of motion for the dominant side was not significantly different from that of the nondominant side ($P = .335$). ***Conclusion:*** In the current study, ultrasound methodology to measure HR showed high interrater reliability, as well as high intrarater reliability. In addition, this study indicates that healthy Japanese adult men have side-to-side differences in HR.

Keywords: range of motion, shoulder, humerus, torsion

Humeral retroversion is defined as the angle between the orientation of the humeral head and the distal humeral articular surface. The humeral-retroversion angle may be influenced by factors such as throwing activity,[1–5] age,[6] and gender.[7] In addition, there are various methods to measure the angle. As a result, a wide

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range of values has been reported for the humeral-retroversion angle, and taking into account anatomical and functional factors, no consensus has been reached concerning the reference value.

Currently, for side-to-side differences of external and internal rotation at 90° shoulder abduction in overhead athletes,[1–3,5] humeral retroversion has been a topic of focus. Using radiography, Osbahr et al[3] and Reagan et al[5] reported on the side-to-side difference in glenohumeral-rotation range of motion and humeral retroversion for college baseball players. Using computed tomography (CT), Crockett et al[2] and Chant et al[1] described side-to-side differences of glenohumeral-rotation range of motion and humeral retroversion in baseball players compared with control subjects. Several authors have documented that the throwing shoulder exhibits significantly more external rotation and significantly less internal rotation than the nonthrowing shoulder. These studies also emphasize that even though the range of external and internal rotation in the throwing shoulder is different from that of the nonthrowing shoulder, the total arc of motion (external rotation + internal rotation) is equal bilaterally. Currently, it is commonly believed that the humeral retroversion and soft tissues of the glenohumeral joint influence differences in external and internal rotation between the throwing and nonthrowing shoulders in throwing athletes.

Differences in humeral retroversion between the throwing and nonthrowing shoulders in throwing athletes have been well documented using radiography[3,5] or CT.[1,2] Means of the humeral-retroversion angle for overhead athletes ranged from 33° to 49° in previous studies. Most researchers[1,2,8–10] have found no side-to-side difference in control groups. On the other hand, Edelson[7] reported on side-to-side differences in 336 dry bones, and other anthropological writings have suggested the possibility of side-to-side differences in humeral retroversion. However, there appear to be few research reports or discussions that focus on side-to-side differences in control groups. Accordingly, it is important to confirm whether there are also side-to-side differences in humeral retroversion in healthy subjects who do not engage in habitual throwing activity.

To date, humeral retroversion has been measured using anthropometry,[6,7,11] radiography,[3–5,12] CT,[1,2,8] and ultrasonography.[13,14] Although the validity and reliability for each of these techniques have been established, a golden standard of methodology has not been established yet. Soderlund et al[12] reported that the intraobserver and interobserver coefficients of variation in radiography were 2.8% and 4.6%, respectively. The CT method of measuring humeral retroversion has been described as highly reliable (interclass correlation .9.) by Dias et al.[15]

On the basis of previous studies, the advantages of ultrasonography are that it is a noninvasive method that eliminates the risk of patients' being exposed to radiation and it is available to use repeatedly for various age groups in the clinical setting. Another advantage to using ultrasound is that it is a portable device and generally cheaper than X-ray and CT scans. However, there are few basic data measured by ultrasonography that can be compared with previous reports that used other methods of measurement such as anthropometry, radiography, or CT. Therefore, we need to determine the variability of the humeral-retroversion angle measured by ultrasonography and establish the basic data for the physical therapeutic approach in a clinical setting.

Using ultrasound methodology, Yamamoto et al[16] and Whiteley et al[14] reported good to high reliability between raters. In view of collecting humeral-retroversion data from a diverse sample, ultrasound methodology should be used to measure high reliability. In addition, when using ultrasound to measure humeral retroversion in the clinical setting, 1 person is preferable to 2 people because it is easy to use in a clinical setting.

Because humeral retroversion influences the shoulder's external and internal rotation, clinicians should assess the mobility of this rotation, including humeral retroversion. One purpose of this study is to investigate the reliability of ultrasound methodology when measuring humeral retroversion. In addition, we compare humeral retroversion between the dominant and nondominant sides, in healthy adult men who do not engage in habitual throwing activity, with ultrasound diagnostic equipment and determine the relationship between humeral retroversion and external and internal rotation at 90° shoulder abduction.

Methods

Subjects

Thirty-seven Japanese men recruited from a convenience sample volunteered for this study, the purpose of which was to investigate between-trials reliability, compare humeral retroversion between the dominant and nondominant sides, and determine the relationship between humeral retroversion and external and internal rotation at 90° shoulder abduction. All subjects were 20 to 29 years old (mean ± SD, 21.9 ± 2.4). Their height was 172.9 ± 5.3 cm and weight was 66.0 ± 7.2 kg. Inclusion criteria included asymptomatic shoulders, a normal range of active movement, and no history of shoulder or elbow injury. Exclusion criteria included a history of surgery, a history of musculoskeletal injury, and any participation in an organized sport involving an overhead shoulder motion. These sports included baseball, tennis, volleyball, European handball, and javelin throwing. Dominance was determined using the Edinburgh Handedness Inventory.[17] Thirty-five subjects were right-hand dominant, and 2 were left-hand dominant. In the second experiment, between-days reliability was determined. Eight male subjects (age 21.0 ± 0.5 years, height 170.5 ± 5.0 cm, weight 64.9 ± 5.2 kg) were assessed for humeral retroversion in 2 separate test sessions with ultrasonography. Seven subjects were right-hand dominant, and 1 was left-hand dominant. Test sessions were separated by 1 to 4 days. Institutional-review-board approval was granted in the spirit of the Helsinki declaration, and all subjects signed an informed-consent form before participation in this study.

Test Procedures

Measurement of Humeral Retroversion Using Ultrasound Diagnostic Equipment. Ultrasound diagnostic equipment (SSA-340A, Toshiba, Japan) with a 10-MHz linear-array probe was used to determine humeral retroversion. Subjects were examined in the supine position on an examination table with their arm locked using a fixed base to prevent any rotation of the humerus during the procedure (Figure 1). The probe was inserted into foam polystyrene, which was set in a fixed base to maintain the positional relation of the probe and humerus during real-time scanning. The measurement order for sides (dominant and nondominant) was randomized.

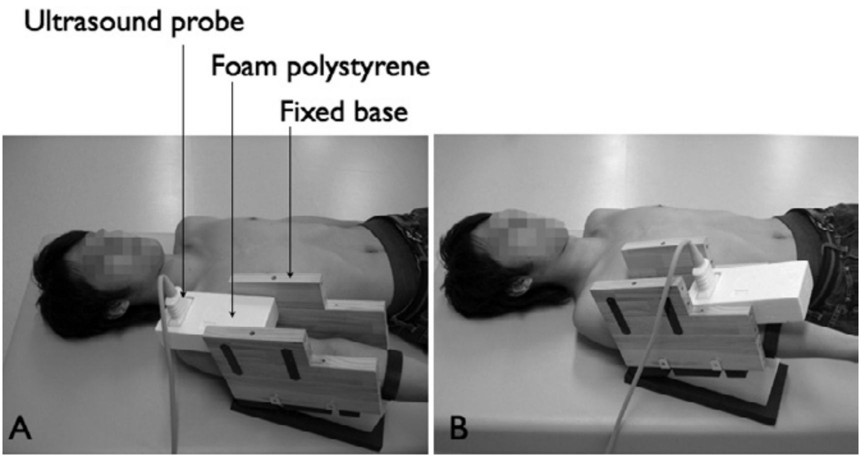

Figure 1 — Subject positioning for scanning ultrasonography of the (A) proximal and (B) distal humerus.

Two transverse ultrasound images using B mode were obtained to measure humeral retroversion. First, with the probe set in the fixed base, an image of the proximal humerus was taken at the level of the bicipital groove. Examiners carefully moved the probe along the arm to obtain the transverse ultrasound image that visualized the most prominent shapes of the greater and lesser tuberosities (Figure 2A). Next, the probe inserted into foam polystyrene was removed from the fixed base and then was replaced along the distal humerus. The transverse ultrasound image was provided with the distal humerus at the level of the trochlea and capitellum (Figure 2B). The measurements were carried out in 3 trials for each image of the proximal and distal humeral epiphysis. Each set of transverse ultrasound image data was saved on digital videotape connected to the ultrasound equipment.

The images were then analyzed on an Apple computer (Model G3 400MHz) using Adobe Photoshop version 5 (Figure 3). The baseline of the proximal humerus was determined to be perpendicular to the line that connected the greater tuberosity and the lesser tuberosity most prominently. The baseline of the distal humerus was determined as the line parallel to the plane of the articular surface of the trochlea and capitellum. The humeral-retroversion angle was defined as the angle between the baselines of the proximal humerus and the distal humerus. The mean value of the 3 trials was adapted as the humeral-retroversion angle.

Shoulder Range of Motion. Passive external rotation and internal rotation at 90° of abduction were measured using standard goniometric techniques. Subjects were positioned supine in 90° of shoulder abduction and 90° of elbow flexion. Care was taken to fix the scapula with one hand while the examiner's other hand rotated the shoulder into position. The goal was to standardize the technique by minimizing scapulothoracic contribution to motion, thus isolating glenohumeral rotation.

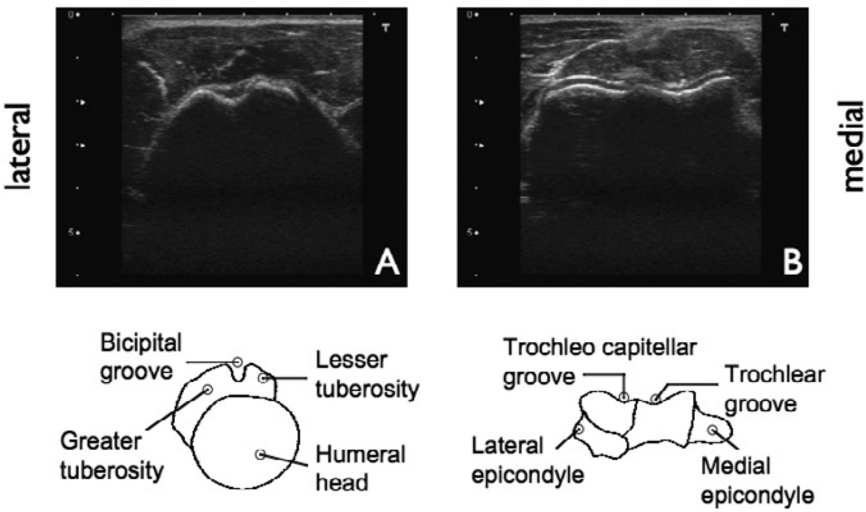

Figure 2 — Ultrasonography of the (A) proximal and (B) distal humerus.

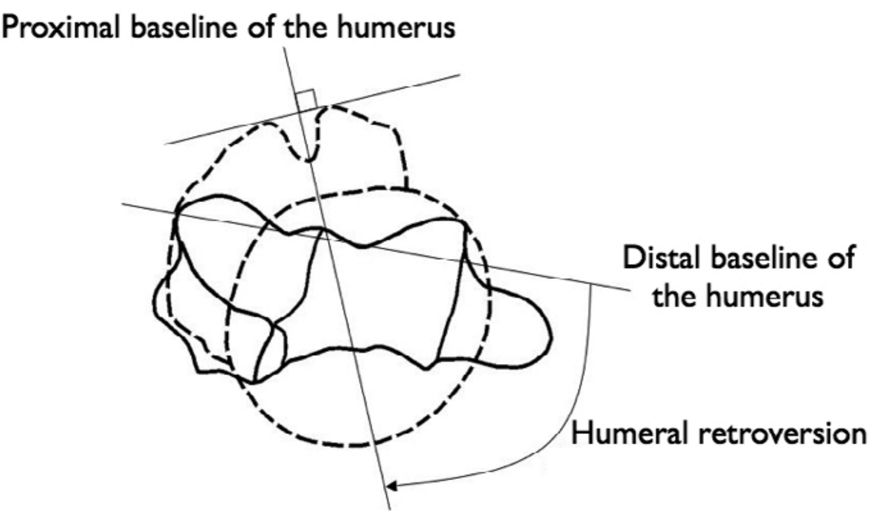

Figure 3 — Diagram demonstrating measurement of the humeral-retroversion angle in this study. This diagram of the right humerus is viewed from below, showing the humeral head (indicated by the dashed line) and the humeral epicondyles (solid line).

Statistical Analysis

The mean and standard deviation were recorded. An intraclass correlation coefficient was used to assess between-trials reliability among 3 trials with $ICC_{3,1}$ and between-days reliability with $ICC_{1,1}$.[18] In addition, consistency of measurement was examined across raters and trials by SEM calculation. Independent *t* tests were used to compare the difference between the dominant and nondominant sides for range of motion and humeral retroversion. In addition, the Pearson product–moment coefficient of correlation was used to assess the statistical relationship between humeral retroversion and external- and internal-rotation range of motion. The level of statistical significance was set at $P < .05$. All statistical analyses were performed using SPSS version 12.0J for Windows. A statistical power analysis indicated that a sample size of 16 was necessary to achieve a power of 80% at a significance level of $P < .05$.

Results

Descriptive statistics regarding humeral retroversion and range of motion are presented in Table 1. Between-trials reliability among 3 trials was .95 on the dominant side and .91 on the nondominant side. In addition, results for between-days reliability showed high repeatability ($ICC_{1,1} = .98$). Table 2 shows ICC values and SEM measured using ultrasound methodology in this study. Figure 4 shows a histogram of humeral-retroversion angles on dominant and nondominant sides. The humeral-retroversion angles were normally distributed on both sides according to a Levene test ($F = 0.428$, $P = .515$). As a result of analysis using an independent *t* test, the humeral-retroversion angle on the dominant side (68.5° ± 10.0°) was significantly greater than that on the nondominant side (58.0° ± 8.4°; $t = 6.8$, $P < .001$). For passive range of motion, external rotation at 90° of abduction on the dominant side (116.8° ± 7.7°) was significantly greater than on the nondominant side (107.8° ± 8.5°; $t = 6.4$, $P < .001$), whereas internal rotation at 90° of abduction on the dominant side (46.8° ± 11.2°) was significantly less than on the nondominant side (58.5° ± 11.4°; $t = –9.7$, $P < .001$). Total arc of motion (external rotation + internal rotation) for the dominant side (163.5° ± 11.5°) was not significantly different than that for the nondominant side (166.4° ± 13.5°; $t = –0.971$, $P = .335$).

Table 1 Comparison of Humeral Retroversion and Range of Motion Between Dominant and Nondominant Sides, Mean ± SD

	Side		
	Dominant (n = 37)	**Nondominant (n = 37)**	***P***
Humeral retroversion	68.5° ± 10.0°	58.0° ± 8.4°	<.001
95% confidence interval	65.1–71.8	55.2–60.8	
External rotation at 90° of abduction	116.8° ± 7.7°	107.8° ± 8.5°	<.001
Internal rotation at 90° of abduction	46.8° ± 11.2°	58.5° ± 11.4°	<.001
Total arc of motion	163.5° ± 11.5°	166.4° ± 13.5°	.335

Table 2 Reliability of Ultrasound Methodology

	ICC	95% CI	SEM	*P*
This Study				
Between-trials reliability ($ICC_{3,1}$)				
dominant (n = 37)	.95	.91–.97	1.57°	<.001
nondominant (n = 37)	.91	.85–.95	2.56°	<.001
Between-days reliability ($ICC_{1,1}$)				
day 1 to day 2 (n = 8)	.98	.94–.99	2.12°	<.001
Interrater reliability ($ICC_{2,1}$)				
tester 1 to tester 2	.97	.92–.99	1.51°	<.001
Whiteley et al[14] Interrater Reliability ($ICC_{2,1}$)				
Right arm	.98	.95–.99		
Left arm	.94	.82–.98		
Yamamoto et al[16] Interobserver Reliability		.60–.65[a]		

[a] Statistical technique was not described.

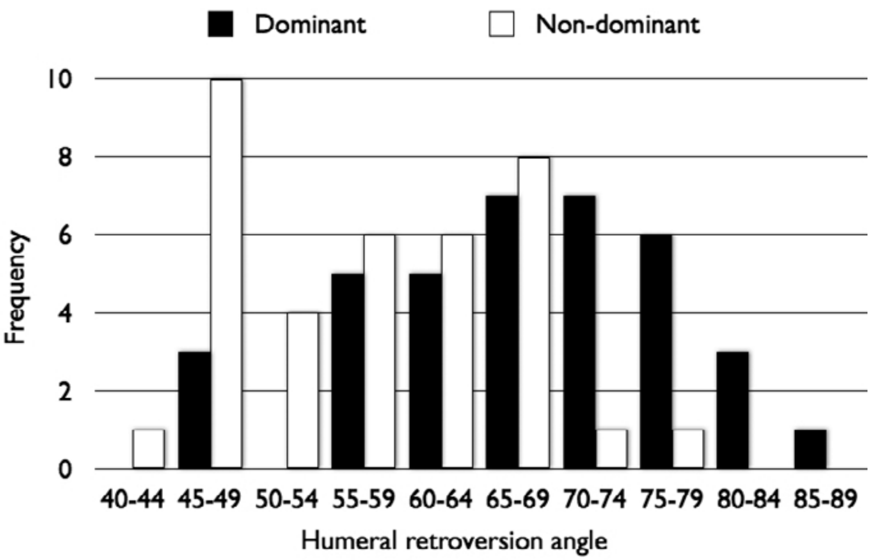

Figure 4 — Histogram of the humeral-retroversion angle on the dominant and nondominant sides.

For the dominant side, a significant relationship was found between humeral retroversion and external rotation at 90° of abduction ($r = .59$, $P < .001$). However, there was no significant correlation between humeral retroversion and internal rotation at 90° of abduction ($r = -.28$, $P = .098$). For the nondominant side, statistical analyses showed no significant correlation for either humeral retroversion and external rotation at 90° of abduction ($r = .26$, $P = .115$) or humeral retroversion and internal rotation at 90° of abduction ($r = -.28$, $P = .092$).

Discussion

We believe that the ultrasound methodology used in the current study has high between-trials reliability ($ICC_{3,1} = .91$ for the dominant side and $ICC_{3,1} = .95$ for the nondominant side), high between-days reliability ($ICC_{1,1} = .98$), and high interrater reliability ($ICC_{2,1} = .97$). The results of the current study are comparable to those of Whiteley et al[14] in regard to the ultrasound-assisted method of measuring humeral torsion (Table 2). In their study, interrater reliability ranged from .94 to .98. However, there are methodological differences between the study of Whiteley et al and our study. In the Whiteley et al study, measurement of humeral torsion required 2 examiners. One of the examiners used ultrasound to visualize the proximal bicipital groove while another examiner rotated the subject's humerus by moving the forearm until the bicipital groove was perceived to be at the uppermost region in the ultrasound image. The second examiner measured the angle of the bent forearm, using an electrical inclinometer, as the humeral torsion. During the measurement of humeral torsion in their method, the examiners had to pay strict attention to prevent rotation of the subject's humerus. In our method, however, the subject's arm is locked using a fixed base to prevent any rotation of the humerus during the procedure. Concerning the ultrasound methodology, we directly measured the humeral-retroversion angle from slices with the proximal and distal humeral epiphysis, despite the description of Yamamoto et al[16] of how the humeral-retroversion angle cannot be directly measured by ultrasonography. Therefore, our method has high reliability and may be useful and appropriate in clinical settings.

In the current study, we have shown that healthy adult men have a greater humeral-retroversion angle on the dominant side (68.5° ± 10.0°) than the nondominant side (58.0° ± 8.4°). The distribution of humeral-retroversion angles for healthy Japanese adult men varied widely. These results indicate that humeral retroversion differs among individuals. Next, for external and internal rotation at 90° of abduction, subjects had greater external rotation and less internal rotation on the dominant side than the nondominant side. On the other hand, the total arc of motion (external rotation + internal rotation) on the dominant side was equal to that of the nondominant side. Based on these results, it is possible to assume that humeral retroversion influences the phase shift of shoulder rotational range. Figure 4 shows a histogram of humeral-retroversion angles on dominant and nondominant sides. Standard deviations of dominant and nondominant sides in this study were 10.0° and 8.4°, respectively. These are consistent with data from previous reports.[2–5] That is, the value ranges from 58.5° to 78.5° on the dominant side and from 49.6° to 66.4° on the nondominant side. In addition, using the 95%

confidence interval, the range was from 65.1° to 71.8° on the dominant side and from 55.2° to 60.8° on the nondominant side. If we take standard deviation and the 95% confidence interval into consideration, the humeral-retroversion angles in this study's subjects vary widely by individual. Therefore, we cannot adopt a specific value for the humeral-retroversion angle.

For humeral retroversion, the mean difference between the dominant and nondominant side was 10.5° ± 9.4° for healthy adult men in this study. Our results indicate that healthy adult men have side-to-side differences in humeral retroversion, despite the fact that subjects in this study were not overhead-throwing athletes. We think there is not enough evidence to assume there are no side-to-side differences in humeral-head retroversion for the normal population, although overhead-throwing athletes such as baseball players certainly have side-to-side differences in humeral-head retroversion. In other words, our results demonstrate that side-to-side differences in humeral retroversion occur in healthy adult men, as well as the throwing athletes reported by previous studies.[2–5] Results from the current study are similar to those of other studies[2–5] concerning side-to-side differences of humeral retroversion for overhead-throwing athletes (Table 3). We believe that the subjects in our study are representative of the normal population. Some previous studies[1,2,4] define the normal population as those with no history of shoulder surgery or injury and no participation in any unilateral overhead sports. Exclusion criteria of subjects in our study included a history of any participation in an organized sport involving overhead shoulder motion. In our study, the sampling criteria of the subjects as representative of the normal population are also consistent with previous studies. Previous studies report that overhead-throwing athletes have greater humeral retroversion on the throwing side than on the nonthrowing side.[2–5] Pieper[4] reports the mean side-to-side difference in 38 handball players without any chronic shoulder pain as 14.39° ± 5.95°, although there was no significant difference in the control group of 37 male subjects. Crockett et al[2] report the mean side-to-side difference in 25 professional baseball pitchers as 17°, although there was no significant difference in the 25 male control-matched subjects. Previously, Osbahr et al[3] and Reagan et al[5] reported that the side-to-side differences for humeral retroversion were 10.1° ± 4.7° and 10.6°, respectively. Krahl and Evans[11] and Cowgill[19] have described how a muscle imbalance of medial and lateral rotators influences the humeral-retroversion angle. Habitual upper limb activities such as overhead throwing appear to occur in a muscle imbalance of medial and lateral rotators. Our findings suggest the existence of other habitual upper limb activities that affect the side-to-side difference in humeral retroversion. However, the purpose of this study was not to identify the other factors that affect humeral retroversion. Therefore, future studies should investigate any factors that affect humeral retroversion.

For external and internal rotation at 90° of abduction, subjects had greater external rotation and less internal rotation on the dominant side than the nondominant side. In addition, the total arc of motion (external rotation + internal rotation) on the dominant side was equal to that of the nondominant side ($P = .335$). Results from this study show that external and internal rotation at 90° of abduction in healthy adult men was similar to previous reports concerning characteristics of range of motion (ROM) for throwing athletes.[20,2,3,5] We believe that the phase shift of shoulder rotation is influenced by the change in humeral retroversion and also occurs in healthy adult men who do not necessarily participate in overhead-throwing

Table 3 Previous Studies' Results for Humeral Retroversion on Dominant and Nondominant Sides Compared With the Current Study (°), Mean ± SD

	Side		
	Dominant	Nondominant	Difference
Pieper[4]			
handball players (n = 38)	49.08 ± 9.78	34.68 ± 10.18	14.39 ± 5.95 ($P < .01$)
control group (n = 37)	41.46 ± 5.08	39.70 ± 6.76	NS
Crockett et al[2]			
baseball pitchers (n = 25)	40 ± 9.9	23 ± 10.4	17 ($P < .001$)
control group (n = 25)	18 ± 12.9	19 ± 13.5	NS
Osbahr et al[3]			
baseball pitchers (n = 19)	33.2 ± 11.4	23.1 ± 9.1	10.1 ± 4.7 ($P < .005$)
Reagan et al[5]			
baseball players (n = 54)	36.6 ± 9.8	26.0 ± 9.4	10.6 ($P < .001$)
Whiteley et al[14]			
baseball players (n = 35)	13.8 ± 8.6	25.0 ± 9.2	12.1 ± 9.4 ($P < .001$)
control group (n = 16)	n/a	n/a	NS
Chant et al[1]			
baseball players (n = 19)	44.9 ± 10.9	34.3 ± 6.9	10.6 ($P < .001$)
control group (n = 6)	35.9 ± 13.8	33.6 ± 14.1	NS
Current study			
healthy adult men (n = 37)	68.5 ± 10.0	58.0 ± 8.4	10.5 ± 9.4 ($P < .001$)

sports, as well as in throwing athletes. Individuals have isolated values because the humeral-retroversion angle differs according to individual. Therefore, clinicians should measure isolated humeral retroversion for individuals when measuring external and internal ROM of the shoulder by the conventional method of using a goniometer. Such assessment, including humeral retroversion and ROM measurement, leads clinicians to a more precise understanding of the limited factor and laxity factor of shoulder ROM.

The clinical relevance of this investigation provides the basic data of humeral retroversion measured with ultrasonography for healthy adult men and the reliability of the ultrasound method to measure the humeral-retroversion angle. The conventional ROM test does not take into account humeral retroversion when interpreting shoulder rotation. The commonly used ROM test expresses the relative positional relationship between the segments in space, but not the direct relationship between articular surfaces of the humeral head and scapular glenoid. Because humeral retroversion influences the external and internal rotation of the glenohumeral joint and differs according to individual, we should interpret the external and internal rotational range, including humeral retroversion, as something that varies for every individual measured. It is unclear at what age humeral retroversion develops and whether overhead throwing causes it. The ultrasound method of measuring humeral retroversion used in the current study is available for physical therapists to interpret the pathology of increasing, as well as restricting, the range of the glenohumeral rotation. In addition, the ultrasonography technique has the advantage of being a noninvasive method that eliminates the risk of exposure to radiation and can be used repeatedly in real time for various age groups in a clinical setting.

Conclusion

Ultrasound methodology to measure humeral retroversion shows high interrater reliability, as well as high intrarater reliability. In addition, this study indicates that healthy adult men have side-to-side differences in humeral retroversion. The dominant side has a greater humeral-retroversion angle and external rotation and less internal rotation than the nondominant side. The total arc of motion on the dominant side was equal to that of the nondominant side. Future studies should use the ultrasound methodology for various age groups in larger samples to establish the basic data for the physical therapeutic approach in a clinical setting.

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