

## [ Physical Therapy ]



# Reliability of a New Clinical Instrument for Measuring Internal and External Glenohumeral Rotation

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**Background:** The shoulder plays a critical role in many overhead athletic activities. Several studies have shown alterations in shoulder range of motion (ROM) in the dominant shoulder of overhead athletes and correlation with significantly increased risk of injury to the shoulder and elbow. The purpose of this study was to measure isolated glenohumeral joint internal/external rotation (IR/ER) to determine inter- and intraobserver reliability of a new clinical device.

**Hypothesis:** (1) Inter- and intraobserver reliability would exceed 90% for measures of glenohumeral joint IR, ER, and total arc of motion; (2) the dominant arm would exhibit significantly increased ER, significantly decreased IR, and no difference in total arc of motion compared with the nondominant shoulder; and (3) a significant difference exists in total arc between male and female patients.

**Study Design:** Case series.

**Level of Evidence:** Level 4.

**Methods:** Thirty-seven subjects (mean age, 23 years; range, 13-54 years) were tested by 2 orthopaedic surgeons. A single test consisted of 1 arc of motion from neutral to external rotation to internal rotation and back to neutral within preset torque limits. Each examiner performed 3 tests on the dominant and nondominant shoulders. Each examiner completed 2 installations.

**Results:** Testing reliability demonstrated that neither trial, installation, nor observer were significant sources of variation. The maximum standard deviation was 1.3° for total arc of motion and less than 2° for most other measurements. Dominant arm ER was significantly greater than nondominant arm ER ( $P = 0.02$ ), and dominant arm IR was significantly less than nondominant arm IR ( $P = 0.00$ ). Mean total rotation was 162°, with no significant differences in total rotation between dominant and nondominant arms ( $P = 0.34$ ). Mean total arc of motion was 45° greater in female subjects. Differences in total arc of motion between male and female subjects was statistically significant ( $P < 0.00$ ).

**Conclusion:** This simple, clinical device allows for both inter- and intraobserver reliability measurements of glenohumeral internal and external rotation.

**Keywords:** shoulder; glenohumeral range of motion; internal rotation deficit

The shoulder plays a critical role in many athletic activities, especially those requiring repetitive overhead motions such as throwing, swimming, hitting, and serving in tennis and volleyball. Several studies have shown the alterations in shoulder range of motion (ROM) in the dominant shoulder of overhead throwing athletes.<sup>7-9,13,15,30</sup> These studies exhibit significantly greater external rotation (ER) and a decrease in

internal rotation (IR) in the dominant shoulder in comparison with the nondominant shoulder.<sup>2-4,10,14,17,33</sup> Furthermore, these changes in ROM significantly increased risk of injury to the shoulder and elbow.<sup>11,23,27</sup>

The dominant shoulder is stretched to the extremes of ER during the late-cocking phase in baseball and in the backswing of the serve in tennis and volleyball. Repeated microtrauma

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Figure 1. Shoulder rotation device with an integrated backboard, arm cradle, and scapular stabilization.

causes fibrotic changes in the capsulo-ligamentous structures of the shoulder. These fibrotic changes may serve to maintain the overall stability of the joint by decreasing capsular distensibility posteriorly but concomitantly preventing full IR. The etiologies of this decreased IR include posterior capsular tightness,<sup>5-7</sup> osseous adaptation,<sup>3,10,26</sup> and muscular tightness.<sup>3,33</sup>

Although the importance of accurate measurement of glenohumeral joint rotation has been well established, there is no uniform method of measuring IR. Several techniques have been reported, including active ROM by assessing the vertebral level on the back that can be reached by the tip of the extended thumb<sup>2,19,24</sup> and passive ROM measured at 90° of shoulder abduction. Numerous authors have emphasized the importance of using scapulothoracic joint stabilization to restrict scapular movement.<sup>5,14,22</sup> Tremendous variability exists in published mean IR ROM values, from 83° in asymptomatic pitchers by Brown et al<sup>4</sup> to 62° in professional pitchers by Wilk and Andrews<sup>31</sup> to 36° in throwers by Meister et al.<sup>22</sup> This lack of a uniform method of measuring IR ROM makes it difficult to compare passive ROM data across studies.

The purpose of this study was to use a new clinical instrument to measure isolated glenohumeral joint IR/ER in healthy patients to determine inter- and intraobserver reliability. We hypothesized that inter- and intraobserver reliability would exceed 90% for measures of glenohumeral joint IR, ER, and total arc of motion. We further hypothesized

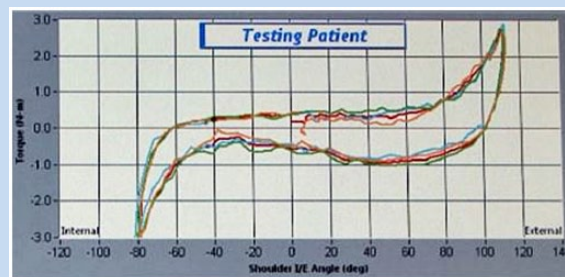


Figure 2. Hysteresis curve generated for each range of motion test. The curve reflects external rotation, internal rotation, and total arc of motion. The colored lines represent each of the trials performed in 1 installation.

that the dominant arm would exhibit significantly increased ER, significantly decreased IR, and no difference in total arc of motion compared with the nondominant shoulder. Finally, we hypothesized that there would be a significant difference in total arc between male and female patients.

## MATERIALS AND METHODS

### Shoulder Rotation Testing Instrument

The instrument we have designed for measuring shoulder rotation consists of an integrated backboard and arm cradle connected to force, torque, and angle sensors (Figure 1). The backboard rests on a standard examination table and is secured to the examination table through the use of a metal clamp. The patient's arm and forearm are placed into the foam padded arm cradle and secured with hook and loop straps. The hand and fingers are secured into a clamp to keep the metacarpophalangeal and proximal interphalangeal joints extended. A 5-pound weight is placed over the humeral head, in line with the arm and arm cradle, for stabilization during the ROM testing. Before testing, this 5-pound weight is locked into place. The force, torque, and angle transducers are connected to a laptop computer that records these values during testing in real time. A hysteresis curve is generated for each ROM test (Figure 2), which reflects ER/IR and total arc of motion. Force and angle sensor calibrations are performed prior to each testing installation. The 5 pounds of weight placed over the humeral head during ROM testing are zeroed out during these force and angle sensor calibrations.

### Measurement Protocol

The forearm is initially in the vertical position, which corresponds to neutral rotation. The examiner then manually rotates the arm of the device, first in ER, until a torque level of 2 N-m (1.5 ft-lbs) is indicated on the laptop screen. This level has been chosen based on the expected threshold of patient discomfort and the approximate forces used during clinical examination of the shoulder. External rotation, in

Table 1. The effects of trial, installation, and observer on external, internal, and total rotations in dominant and nondominant arms<sup>a</sup>

Factor	Dominant Arm			Nondominant Arm		
	ER	IR	Total	ER	IR	Total
Trial	0 ( <i>ns</i> )	0.10 (0.35)	0.91 (0.15)	0 ( <i>ns</i> )	0 ( <i>ns</i> )	1.66 (0.28)
Installation	0.06 (0.43)	1.85 (0.19)	0 ( <i>ns</i> )	0.18 (0.23)	1.41 (0.13)	0 ( <i>ns</i> )
Observer	1.09 (0.30)	0 ( <i>ns</i> )	1.40 (0.33)	0 ( <i>ns</i> )	0 ( <i>ns</i> )	1.66 (0.28)

ER, external rotation; IR, internal rotation.

<sup>a</sup>Values reported are estimated variance components with accompanying significance probabilities in parentheses. Note the absence of any trial, installation, or observer effects on selected rotations. The variance components shown are computed using a 4-factor random effects analysis of variance model. Zero variance components were estimated as negative and hence automatically set to 0, indicating nonsignificance (*ns*).

degrees, is recorded at this 2 N-m torque level. Upon reaching this torque level, the arm of the device is then rotated in the opposite direction, into IR, and past neutral, until a torque level of 2 N-m is indicated on the laptop screen. Again, the angle of IR is recorded at this torque level. The arm of the device is then brought back to neutral rotation. This comprises 1 measurement on the tested arm. This process is repeated for a total of 3 measurements on the tested arm. The patient is then placed back into the device, and 3 measurements are performed on the contralateral arm. One measurement on both arms constitutes a trial, and 3 trials comprise an installation.

### Experimental Protocol

Thirty-seven subjects were tested (13 male patients, 24 female patients) for this study. Two orthopaedic surgeons (T.N.L., A.D.P.) performed measurements on both shoulders of each subject. One test consisted of 1 arc of motion from neutral to ER to IR and back to neutral within the preset torque limits. Three tests were performed, by each examiner, on the dominant and nondominant shoulders, which comprised 1 installation. The process was repeated for each subject, to produce 2 installations from each examiner.

### Statistical Methods

Initially, we used 6 random effects 4-factor analysis of variance models (1 for each combination of arm-dominance status [ie, dominant vs nondominant] and rotational measurement [ie, external, internal, and total]) to test for significant sources of variation (variance components) in rotation due to subjects, examiners, installations, trials, and other interactions. These initial 6 linear statistical methods indicated that trials were not a significant source of variation for all measures of rotation (minimum  $P > 0.15$ ; Table 1). Furthermore, it was anticipated that clinicians would record multiple external, internal, or total rotation measurements for a given patient and treat the average measurement as a single representative value. Therefore, to reflect this anticipated use, we modified the statistical models

in 2 ways: 3 models, 1 for each rotation type, namely, external, internal, and total, to exclude trial as a factor in the model, with the average measurement of the 3 trials treated as a single test for a specific installation and observer, and another 3 models, 1 for each rotation type, to further exclude installations with the average measurement of the 3 trials and 2 installations treated as a single test for observers. Both of these latter sets of statistical models included arm dominance/nondominance as a fixed effects factor as well as the interaction terms. From the second set of 3 models, the dominant and nondominant arms were significantly different for ER and IR when averaged over subjects and observers ( $P = 0.00$  in each case) but not significant for total ( $P = 0.07$ ). From the last 3 models, the dominant and nondominant arms were significantly different when averaged over subjects, observers, and installations ( $P = 0.00$  for ER,  $P = 0.00$  for IR) but not significant for total ( $P = 0.34$ ).

## RESULTS

Our testing of instrument reliability demonstrated that neither trial, installation, nor observer were significant sources of variation (Table 1). The maximum standard deviation was 1.3° for total arc of motion and less than 2° for most other measurements.

With respect to our second hypothesis, dominant arm ER was significantly greater than nondominant arm ER (mean difference, 6.8903°;  $P = 0.02$ ), and dominant arm IR was significantly less than nondominant arm IR (mean difference, -9.1665°;  $P = 0.00$ ; Table 2). Total rotation in both arms averaged 162°, with no significant differences in total rotation between dominant and nondominant arms (mean difference, -2.1096;  $P = 0.34$ ; Table 2).

Total arc of motion averaged 45° greater in female subjects (Table 3). The greatest arc of motion measured in a male patient was 169.5°. This was 17.4° less than the average female patient. Total arc of motion differences between male and female subjects were statistically significant ( $P < 0.00$ ).

Table 2. Internal rotation, external rotation, and total arc comparisons in dominant versus nondominant shoulders

	Dominant Arm			Nondominant Arm		
	ER	IR	Total	ER	IR	Total
Observer 1	106.4	54.7	161.5	98.5	63.6	162.2
Observer 2	105.6	55.6	161.3	99.7	65	164.8

ER, external rotation; IR, internal rotation.

Table 3. Total range of motion (degrees)

Male Patients			Female Patients		
Minimum	Maximum	Mean	Minimum	Maximum	Mean
116.6	169.5	141.9	132.1	227	186.9

## DISCUSSION

Several methods have been used to assess glenohumeral joint ROM, but certain deficiencies limit their use as both clinical and research tools. Measuring shoulder IR by vertebral level has low reliability<sup>12,16</sup> and does not test posterior capsular function, since it is also influenced by scapulothoracic and elbow motions. Edwards et al<sup>12</sup> looked at inter- and intraobserver reliability of measuring IR by vertebral level. This method has been criticized for not measuring pure IR of the glenohumeral joint; it is affected by concurrent conditions in the elbow, wrist, or thumb, and it may not be easy to determine bony landmarks in the spine.<sup>19-21</sup> They found the interobserver reliability to be poor and intraobserver reliability reasonable. There was a >1 vertebral error in the upper thoracic and lumbar spine and a 1 to 2 level error in the lower thoracic spine, with a mean actual measurement error of 1 vertebral level. They concluded that measurement of IR by vertebral level was not readily reproducible between observers.

The supine cross-chest adducted position has also been used and is reported to have moderate to high reliability.<sup>29,30</sup> However, this method appears to lack validity as it is significantly influenced by chest width, chest and arm muscle bulk, and the position in which the scapula is stabilized, which is occasionally difficult to achieve.

Awan et al<sup>1</sup> looked at inter- and intraobserver reliability of 3 techniques to measure passive IR of the glenohumeral joint at 90° of shoulder abduction. They noted previous studies that showed scapulothoracic motion can confound shoulder ROM measurements by using standard techniques in which the scapula was relatively free to move.<sup>12</sup> They studied the nonstabilized method, the visual inspection method, and the manual scapular stabilization method.

The visual inspection method for scapular motion was first described by Kibler et al.<sup>18</sup> They concluded that manual scapular stabilization may not be necessary if the limit of passive shoulder IR can be reliably defined as the point at which the scapula begins, visually, to lift from the examining table surface (ie, tilt anteriorly).

Awan et al<sup>1</sup> found that ER and IR obtained with the visual inspection/scapular stabilization methods were significantly less than with the nonstabilized method. They purported that the visual inspection/scapular stabilization methods may represent a more valid measure of glenohumeral joint IR. The dominant arm, in their study, showed increased ER and less IR compared with the nondominant arm. Intraobserver reliability was judged to be good for all 3 methods. Interobserver reliability was fair to good for all 3 methods. The standard deviation reported for the best method was 8.8° for ER and 7.7° for IR. This compares with the approximately 1° standard deviation we reported for total arc.

Wilk et al<sup>34</sup> also examined 3 different methods of measuring passive IR of the glenohumeral joint at 90° of shoulder abduction. These methods included providing stabilization of the scapula, stabilization of the humeral head, or the visual inspection method with no stabilization. They found significantly decreased IR in the dominant shoulder for each method and between each method compared with the nondominant shoulder. The visual inspection method allowed the most IR, while the humeral head method allowed the least IR. They found that all 3 methods produced similar interobserver reliability, with the scapula stabilization method producing the highest intraobserver reliability. These authors concluded that the scapula stabilization method allowed normal, unrestricted glenohumeral joint motion while preventing excessive scapulothoracic motion and



recommended this technique for glenohumeral joint ROM measurement. Wilk and Andrews<sup>31</sup> reported standard deviation for IR only, but these were relatively high at 8.1°.

Other shoulder instruments by Novotny et al,<sup>25</sup> Marko et al, Watkins and Sachs, and Guanche and Hale exhibit reasonable reliability for rotational measurements, but are often expensive, not portable, cumbersome, and thus have limited widespread use among shoulder clinicians and investigators.

Most clinicians agree that a significant decrease in glenohumeral joint IR may lead to several pathologies, such as subacromial impingement syndrome,<sup>30,31</sup> “dead arm syndrome,” superior labral anterior and posterior (SLAP) lesions, and elbow injuries.<sup>7,11</sup> The initial presentation of glenohumeral internal rotation deficit (GIRD) is often an overhead athlete who complains of decreased velocity and command, posterior stiffness, and trouble “loosening up.” This posterior shoulder pain without mechanical symptoms occurs during the late-cocking and early acceleration phases of throwing, causing a contracture of the posterior-inferior capsule. This causes a posterosuperior shift in the glenohumeral contact point, which may predispose the athlete to the subacromial impingement syndrome. Subsequently, the superior labrum and biceps anchor may fail in tension. Wilk et al<sup>32</sup> reported a correlation between GIRD and shoulder injuries in professional baseball pitchers followed over a 3-year period. Pitchers with GIRD exhibited a 2.4 times greater risk of shoulder injuries than pitchers without GIRD. All of these findings support the importance of accurately assessing ROM in the overhead athlete.

We found a 45° difference in mean total arc of motion between male and female patients. In our study, the mean total arc of motion for males was 141°, 40° less than the values published by Wilk et al.<sup>32</sup> This should be taken into consideration when setting ROM goals in physical therapy or in reporting surgical results.

## CONCLUSION

Although the importance of accurate measurement of glenohumeral joint rotation has been well established, there is no uniform method of measuring IR and ER. The dominant arm exhibits significantly increased ER, significantly decreased IR, and no difference in total arc of motion compared to the nondominant shoulder. Male and female patients have significantly different total arc of motions.

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