Glenohumeral joint total rotation range of motion in elite tennis players and baseball pitchers

TODD S. ELLENBECKER, E. PAUL ROETERT, DAVID S. BAILIE, GEORGE J. DAVIES, and SCOTT W. BROWN

Physiotherapy Associates Scottsdale Sports Clinic, Scottsdale, AZ; USA Tennis High Performance, Key Biscayne, FL; The Orthopaedic Clinic, Phoenix, AZ; Gunderson Lutheran Sports Medicine & University of Wisconsin–LaCrosse, LaCrosse, WI; and Department of Educational Psychology, University of Connecticut, Stoors, CT

ABSTRACT

ELLENBECKER, T. S., E. P. ROETERT, D. S. BAILIE, G. J. DAVIES, and S. W. BROWN. Glenohumeral joint total rotation range of motion in elite tennis players and baseball pitchers. *Med. Sci. Sports Exerc.*, Vol. 34, No. 12, pp. 2052–2056, 2002. The amount of glenohumeral joint internal and external rotation used during overhead sport activities has been measured experimentally by sports scientists. Clinical measurement of glenohumeral joint internal and external rotation using goniometry is an integral part of a shoulder evaluation after injury or surgery or during preseason or preventative musculoskeletal screenings. **Purpose**: This study measured glenohumeral joint internal and external rotation in two groups of unilaterally dominant upper extremity athletes to compare the total arc of rotational range of motion between the dominant and nondominant extremities. **Methods**: A total of 163 elite athletes (117 male junior tennis players and 46 male baseball pitchers) were measured for glenohumeral joint internal and external rotation at 90° of abduction. Total rotation range of motion was calculated by summing internal and external rotation measures in each extremity. **Results:** An ANOVA with *post hoc* testing revealed no significant difference ($P > 0.05$) between extremities in baseball pitchers for total rotation range of motion (145.7 vs 146.9), whereas significantly less ($P < 0.001$) dominant arm total rotation range of motion was identified in the elite junior tennis players (149.1 vs 158.2). **Conclusion:** This study has identified unique glenohumeral joint rotational patterning in unilaterally dominant upper extremity athletes that has ramifications for rehabilitation after injury and for both injury prevention and performance enhancement. **Key Words:** SHOULDER, GONIOMETRY, EXTERNAL ROTATION, INTERNAL ROTATION

Biomechanical research has defined the amount of external rotation inherent in the abducted glenohumeral joint during arm cocking in the overhead throwing motion (12) and tennis serve (11). This research has similarly described the explosive internal rotation required to gain endpoint velocity before ball release in throwing and ball contact in the tennis serve (7,11,12,23). Concomitant to this biomechanical research are the clinical descriptions of glenohumeral joint pathology that occur secondary to adaptive changes, in rotational range of motion from repeated external rotation in the abducted position, and potentially can lead to subtle anterior instability and ultimately rotator cuff and labral pathology (5,18).

The intricate balance between glenohumeral joint mobility and stability is one of the greatest current clinical challenges for orthopaedic surgeons and rehabilitation professionals. The evaluation of glenohumeral joint mobility typically consists of both accessory and physiological joint mobility. Assessment of accessory mobility of the glenohumeral joint measures the amount of humeral head translation relative to the glenoid (1,14). Accessory mobility is defined as movements that occur during normal physiological movement patterns that are not under volitional control (1,14). Recent research describing the *in vivo* characteristics of humeral head translation has assisted the clinician in determining "normal" patterns of translation (9,14,15) but has not demonstrated a statistical relationship between translation and physiological motion (9,24).

Assessment of physiological mobility of the glenohumeral joint measures the amount of active or passive range of motion typically with a universal goniometer. Traditionally, the movements of internal and external rotation have been measured with stabilization of the scapulothoracic joint recommended to obtain a more isolated and accurate presentation of true glenohumeral joint physiological movement (10). Accurate measurement and identification of specific glenohumeral joint range of motion limitations are of paramount importance in shoulder rehabilitation because of the implications created by specific capsular hypomobility and the resultant abnormal humeral head kinematics outlined by Harryman et al. (16). Increases in external rotation range of motion have been documented in patients with glenohumeral joint instability (25). Significant decreases in

Address for correspondence: Todd S. Ellenbecker, MS, PT, SCS, OCS, CSCS, Physiotherapy Associates, Scottsdale Sports Clinic, 9449 N. 90th Street, Suite 100, Scottsdale, AZ 85258; E-mail: todd.ellenbecker@physio.strykercorp.com.
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glenohumeral joint internal rotation have been identified in patients with impingement (25).

Recent research (19,22) has outlined a combined measurement of internal and external rotation in 90° of glenohumeral joint abduction called total rotation range of motion. This measure portrays the total arc of rotational range of motion of the glenohumeral joint. Kibler et al. (19) and Roetert et al. (22) found decreases in the total rotation range of motion with increasing year of competitive tennis play in elite-level players. The purpose of this study was to measure total rotation range of motion in male elite junior tennis players and male baseball pitchers to determine whether bilateral differences exist in total rotation range of motion between extremities and between these two groups of unilaterally dominant upper extremity athletes.

FIGURE 1—Measurement technique used for glenohumeral joint internal rotation with 90° of abduction and scapular stabilization.

METHODS

Participants. A total of 163 participants were measured for glenohumeral joint internal and external rotation in this investigation. All participants were free from any musculoskeletal shoulder injury and had no history of shoulder injury in the previous year that prevented practice or competition. Participants also had no previous surgical history in their bilateral shoulders. Participants signed a written informed consent before involvement in this research. The participants consisted of samples of 46 male professional baseball pitchers with a mean age of 22.6 ± 2.0 yr taken from major league organizations with spring training complexes in Arizona and 117 elite junior male tennis players with a mean age of 16.4 ± 1.6 yr participating in Player Development programs with the United States Tennis Association. The classification of these junior tennis players as elite was determined by their respective competitive rankings and level of skill achievement. The number of years of competitive activity in each group was similar with tennis players starting competitive play 3–4 yr earlier than the baseball pitchers on average. The research protocol was approved by an institutional review board (Stryker Physiotherapy Associates, Memphis, TN).

Instrumentation. A standard universal goniometer was used for measurement with scales marked in one-degree increments.

Procedure. Participants were tested in the supine position on the examination table with 90° of glenohumeral joint abduction. The glenohumeral joint was placed in the coronal plane and remained so throughout the duration of testing. The universal goniometer axis was aligned with the long axis of the humerus, with the distal most tip of the olecranon being the superficial landmark for alignment. The stationary arm of the goniometer was placed in a vertical position. The moving arm of the goniometer was aligned with the lateral aspect of the ulna (20). The forearm was placed and remained in a pronated position for the duration of the testing. From the anatomical zero rotation position in 90° of abduction, the participants were asked to externally rotate their shoulder maximally. Stabilization of the scapulothoracic joint was provided by the examiner via a posteriorly directed containment force exerted by the tester's hand on the coracoid process and anterior aspect of the shoulder. No allowance for scapular protraction or elevation was permitted. Once the participant achieved a stable end point position, the angle was recorded from the universal goniometer. No passive overpressure was applied. The weight of the arm provided a consistent factor to achieve the stable end point. All measures of glenohumeral joint motion taken and analyzed in this research were active range of motion

Internal rotation was measured using identical landmarks for goniometer alignment and stabilization (Fig. 1). Total rotation range of glenohumeral joint motion was calculated by adding the external and internal rotation measurements together for each extremity (19). Testing order of the dominant and nondominant extremity was random. Care was taken not to measure the right arm first on all right-handed participants. Neither the examiner nor the participants were blinded to the goniometric results during measurement. All participants were measured by the lead author (T.S.E.) to negate interrater error. The reliability of this testing protocol has been subjected to a test-retest paradigm and has been published previously (10).

Data Analysis. Descriptive statistics were calculated using SPSS (SPSS, Chicago, IL) software. Total rotation range of motion data were submitted to a 2 (dominance) × 2 (sport) ANOVA. *Post hoc* tests using dependent *t*-tests were used when main effect differences were identified. The alpha level for statistical significance was set at 0.01. For determining whether there was an age effect for glenohumeral joint internal, external or total rotation an ANCOVA was run. This test was chosen for its ability to detect, after accounting for age differences, whether there are any statistically significant differences in any of the dominant and nondominant shoulder rotation measures based on sport.

RESULTS

Tables 1 and 2 display the descriptive and statistical data from the professional baseball pitchers and the elite junior tennis players. Data are displayed for external rotation,

TABLE 1. Bilateral comparison of isolated and total rotation range of motion from professional baseball pitchers and elite junior tennis players.

Subjects	Dominant Arm	Nondominant Arm	*t*	*P* Value
Baseball pitchers				
External rotation	103.2 ± 9.1 (1.34)	94.5 ± 8.1 (1.19)	7.135	0.000
Internal rotation	42.4 ± 15.8 (2.33)	52.4 ± 16.4 (2.42)	−7.922	0.000
Total rotation	145.7 ± 18.0 (2.66)	146.9 ± 17.5 (2.59)	−.981	NS
Elite junior tennis players				
External rotation	103.7 ± 10.9 (1.02)	101.8 ± 10.8 (1.01)	2.238	NS
Internal rotation	45.4 ± 13.6 (1.28)	56.3 ± 11.5 (1.08)	−8.977	0.000
Total rotation	149.1 ± 18.4 (1.73)	158.2 ± 15.9 (1.50)	−6.472	0.000

All measurements are expressed in degrees. Standard error of the mean in parentheses.

internal rotation, and total rotation range of motion. Table 3 summarizes the results of the repeated measures ANOVA. Significant main effect differences were found for both dominance (dominant vs nondominant extremity) and sport (baseball vs tennis), as well as in the (dominance × sport) interaction (Table 2). *Post hoc* testing using dependent *t*-tests revealed no significant bilateral difference in total rotation range of motion in the baseball pitchers in this study. Total rotation range of motion values measured on the dominant and nondominant arms in the baseball pitchers differed by only 1.2° (145.7 vs 146.9, respectively). Significantly less dominant arm total rotation range of motion was measured, however, in the elite junior tennis players when compared with the nondominant extremity. Values differed by 9.1° between the dominant and nondominant extremities in the elite junior tennis players. No significant difference was measured between the dominant arm total rotation range of motion value in baseball pitchers and that measured in male elite junior tennis players; however, nondominant arm total rotation range of motion values differed significantly between the two groups. Results of the ANCOVA showed no significant ($P > 0.01$) effects of age on dominant and nondominant internal, external, and total rotation range of motion measures. The ANCOVA furthermore did not identify any differences ($P > 0.01$) between sports in any of the range-of-motion variables based on age.

DISCUSSION

Evaluation of an athlete after a glenohumeral joint injury or surgery involves the measurement of bilateral physiological range of motion. The uninjured extremity in injured athletes and the nondominant extremity in healthy athletes who undergo preventive evaluations or screenings serve as the baseline extremity for determination of the individual's inherent "normal" range of motion (8,13). Therefore, specific information regarding the bilateral comparisons of normal range of motion in healthy, uninjured athletes is of importance as these comparisons often are used in clinical decisions on the extent and magnitude of range of motion loss and subsequent strategies to regain motion after injury or surgery.

TABLE 2. Comparison of total rotation range of motion between professional baseball pitchers and elite junior tennis players.

Extremity	Baseball Pitchers	Tennis Players	*t*	*P*
Dominant arm				
Total rotation	145.7 ± 18.0	149.1 ± 18.4	−1.306	NS
Nondominant arm				
Total rotation	146.9 ± 17.5	158.2 ± 15.9	−4.478	0.000

All measurements are expressed in degrees.

In a previous report of glenohumeral joint range of motion in professional baseball pitchers, similar findings were reported. Brown et al. (3) measured significantly greater dominant arm external rotation in professional baseball pitchers (141° dominant arm vs 132° nondominant) with significant decreases in internal rotation in the dominant arm (83° dominant vs 98° nondominant). Similar to the findings of the present study, Brown et al. (3) found increases in dominant arm external rotation with concomitant decreases in dominant arm internal rotation. Although Brown et al. (3) did not formally evaluate total rotation range of motion, summing the measures of internal and external rotation produced few differences between extremities in the total rotation range of motion measurement (224° dominant vs 230° nondominant). The range of motion values in the Brown et al. (3) study are markedly larger because passive range of motion was measured, versus the active range of motion measures taken in our research. No mention of glenohumeral joint isolation was reported by Brown et al. (3), adding the possibility of scapulothoracic motion to their internal and external rotation measures with 90° of glenohumeral joint abduction.

In another study that examined range of motion in professional baseball pitchers, Bigliani et al. (2) measured 72 pitchers with 90° of glenohumeral joint abduction. External rotation on the dominant arm was again significantly greater (118° vs 103°) than the nondominant arm in their research. Internal rotation was also reported to be less on the dominant arm but was measured as the maximal vertebral level reached in a combined pattern and cannot be compared to the present research.

On the basis of the results of these studies, it seems apparent that greater external rotation can be expected on the dominant extremity in the professional baseball pitcher while similar amounts of internal rotation range of motion loss occur on the dominant extremity. This apparent shift backward into a more externally rotated position on the dominant arm is accompanied by a nearly equal amount of internal rotation loss. This range-of-motion pattern preserves the total rotation range of motion on the dominant extremity similar to that measured on the nondominant side.

Explanations for the range-of-motion adaptation in unilaterally dominant upper extremity athletes include capsular, musculotendinous, and osseous factors. Jobe et al. (17) postulated that repetitive throwing gradually stretches out the anterior capsuloligamentous structures, which can lead to increased anterior-superior humeral head migration during throwing and cause rotator cuff pathology. Pappas et al. (21) reported reactive fibrous tissue formation in the posterior capsule as well as musculotendinous tightness of the posterior rotator cuff as primary factors that lead to dominant arm internal rotation loss in the throwing shoulder.

TABLE 3. ANOVA for the dependent variable of total rotation range of motion.

Source	Sum of Squares	df	Mean Squares	F	*P* Value
Dominance	4462.18	1	4462.18	98.25	0.000
Error (dominance)	1816.53	40	45.41		
Sport	10310.64	1	5155.32	10.90	0.000
Error (sport)	37812.09	40	472.65		
Dominance × sport	1343.60	1	671.80	11.84	0.000
Error (dominance × sport)	4536.26	40	56.70		

Recent research has implicated osseous factors in the apparent range-of-motion alteration in the dominant arm in the overhead-throwing athlete. Crockett et al. (6) compared 25 professional baseball pitchers with 25 age-matched individuals who had never played baseball and measured humeral retroversion with a CAT scan. Results showed a bilateral difference of 16° between the dominant and nondominant extremities with the dominant arm possessing 16° greater humeral retroversion. No bilateral difference in humeral retroversion was reported between extremities in the nonbaseball group. Thus, greater external rotation and limited internal rotation on the dominant extremity in professional baseball pitchers may be caused by osseous adaptations that occur with repetitive throwing during developmental years in addition to the capsular and musculotendinous factors described in earlier reports.

In contrast to the total rotation range of motion in professional baseball pitchers, this study did find a significant difference between extremities in the male elite junior tennis players in total rotation range of motion. Total rotation range of motion was significantly less, by 9.1°, on the dominant extremity in the elite junior tennis players. This reflects an actual decrease in the total rotational excursion on the dominant extremity, unlike the shift measured in the baseball pitchers. A statistically significant decrease in dominant arm internal rotation in the elite junior tennis players was measured. This finding supports previous studies that measured rotational range of motion in elite tennis players (19,22) in whom progressive losses in both internal rotation and total rotation range of motion occurred as players aged (19).

The clinical importance of this data is best illustrated when interpreting range-of-motion measurements in injured and uninjured overhead athletes. Adaptations in rotational range of motion related to sport seem to be multifactorial. Knowledge of "normal" bilateral range-of-motion patterning is essential to assist the clinician in determining whether range-of-motion restrictions are present and to guide rehabilitation professionals in determining range-of-motion values needed before initiation of functional activity programs after glenohumeral joint injury or surgery.

Wide variations of glenohumeral joint range of motion occur among athletes that may jeopardize clinical decision making regarding the application of stretching or capsular protection programs during rehabilitation. Athletes who routinely present with 110–120° of external rotation and as little as 30° of internal rotation may approach normal total rotational range-of-motion values when compared with the contralateral side. This study provides normative data on two populations of overhead athletes suggesting that total rotation range of motion is bilaterally symmetrical in the professional baseball player and not more than 10° deficient in elite junior tennis players. This baseline descriptive data can assist clinicians in determining optimal rotational range-of-motion patterns in athletes from these populations. Despite using techniques to minimize measurement error, such as stabilization of the scapulothoracic joint, single examiner for all participants, supine measurement position, and the use of active range of motion, limitations in the application of this research secondary to human error and the inherent characteristics of the universal goniometer do exist.

Clinical consequences of internal rotation range-of-motion loss have been reported experimentally in cadavers (16) in the form of abnormal anterosuperior humeral head shear. Burkhart and Morgan (4) clinically outlined the "peel-back" sign as a prime indicator of dysfunction of the biceps-labral complex. In their report, all throwers who presented with SLAP lesions had marked internal rotation deficits, measured with the arm in 90° of glenohumeral joint abduction. Burkhart and Morgan (4) attribute this lack of internal rotation to acquired posterior-inferior capsular tightness and implicated this as a primary factor in causing the SLAP lesions.

CONCLUSION

Measurement of glenohumeral joint total rotation range of motion in male elite junior tennis players and male professional baseball pitchers has produced different findings. Total rotation range of motion was not significantly different between extremities in baseball pitchers, despite alterations in isolated dominant arm external rotation and internal rotation relative to the nondominant extremity. Total rotation range of motion measures in elite junior tennis player were significantly less on the dominant extremity as compared with the nondominant extremity. These data have clinical ramifications for rehabilitation of unilaterally dominant upper extremity athletes and provide a normative database for glenohumeral joint total rotation range of motion.

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