American Journal of Sports Medicine

http://ajs.sagepub.com

Reliability, Precision, Accuracy, and Validity of Posterior Shoulder Tightness Assessment in Overhead Athletes

Joseph B. Myers, Sakiko Oyama, Craig A. Wassinger, Robert D. Ricci, John P. Abt, Kevin M. Conley and Scott M. Lephart

Am. J. Sports Med. 2007; 35; 1922 originally published online Jul 3, 2007;
DOI: 10.1177/0363546507304142

Reliability, Precision, Accuracy, and Validity of Posterior Shoulder Tightness Assessment in Overhead Athletes

Joseph B. Myers,* PhD, ATC, Sakiko Oyama, MS, ATC, Craig A. Wassinger, PhD, PT,
Robert D. Ricci, MS, ATC, John P. Abt, PhD, ATC, Kevin M. Conley, PhD, ATC, and
Scott M. Lephart, PhD, ATC
From the Neuromuscular Research Laboratory, Sports Medicine and Nutrition,
School of Health and Rehabilitation Sciences, University of Pittsburgh,
Pittsburgh, Pennsylvania

Background: Posterior shoulder tightness with subsequent loss of humeral internal rotation range of motion has been linked to upper extremity lesions in overhead athletes. A valid clinical assessment is necessary to accurately identify posterior shoulder tightness as a contributor to injury.

Purpose: To describe a modified supine assessment of posterior shoulder tightness by establishing the reliability, precision, clinical accuracy, and validity of the assessment.

Study Design: Cohort study (diagnosis); Level of evidence, 2.

Methods: Intrasession, intersession, and intertester reliability and precision were established by comparing the commonly used side-lying assessment of posterior shoulder tightness and the described modified supine assessment. Clinical accuracy of both methods was obtained using an electromagnetic tracking device to track humeral and scapular motion. Construct validity was established by identifying posterior shoulder tightness in a group of overhead athletes (baseball pitchers and tennis players) reported in the literature to have limited humeral internal rotation and posterior shoulder tightness.

Results: The side-lying intrasession intraclass correlation coeffecient (standard error of measurement), intersession intraclass correlation coeffecient (standard error of measurement), and intertester intraclass correlation coeffecient (standard error of measurement) were 0.83 cm (0.9), 0.42 cm (1.7), and 0.69 cm (1.4), respectively. The supine intrasession intraclass correlation coeffecient (standard error of measurement), intersession intraclass correlation coeffecient (standard error of measurement), and intertester intraclass correlation coeffecient (standard error of measurement) were 0.91° (1.1°), 0.75° (1.8°), and 0.94° (1.8°), respectively. In side-lying, the clinical accuracy expected was 0.9 ± 0.6 cm of error while, when measured supine, it was 3.5° ± 2.8° of error. Both assessments resulted in minimal scapular protraction (~3.5°). Between groups, baseball pitchers and tennis players had significantly less internal rotation range of motion ($P < .0001$) and greater posterior shoulder tightness ($P = .004$) when measured in supine, but not in side-lying ($P = .312$).

Conclusion: Both methods resulted in good clinician accuracy and precision, suggesting that both can be performed accurately. The supine method can be assessed more reliably than side-lying between both sessions and testers.

Clinical Relevance: Clinicians may want to consider use of the supine method given the higher reliability, validity, and similar precision and clinical accuracy.

Keywords: baseball; tennis; shoulder injury; clinical; overhead

---

The dominant shoulder of throwing and racket-sport athletes consistently demonstrates adaptive glenohumeral internal and external rotation range of motion when compared with the nondominant limb.[†] Based on a review of the literature, it appears that throwers demonstrate significantly greater glenohumeral external rotation and significantly less internal glenohumeral rotation in the throwing arm.[4,8,11,14,32,33] Loss of internal rotation has received the most attention of these 2 adaptations as it relates to injury in the throwing shoulder.

---

*Address correspondence to Joseph B. Myers, PhD, ATC, Neuromuscular Research Laboratory, UPMC Center for Sports Medicine, 3200 South Water Street, Pittsburgh, PA 15203 (e-mail: myersjb@upmc.edu).

No potential conflict of interest declared.

[†] References 1, 2, 5, 6, 8, 10, 11, 14, 26, 29, 32, 38, 41.

The American Journal of Sports Medicine, Vol. 35, No. 11
DOI: 10.1177/0363546507304142

Uncompensated loss of internal rotation without an accompanying increase in external rotation is believed to result from contracture and thickening of the posteroinferior portion of the glenohumeral joint capsule due to the repetitive microtrauma imparted during the deceleration phase of the throwing motion.[9,30,38] Burkhart et al[9] reported in their review of surgical observations that throwers who exhibited glenohumeral internal rotation deficits showed a severely contracted and thickened posteroinferior recess in the posterior band of the inferior glenohumeral ligament. Ticker et al[37] reported similar results, demonstrating thickened posterior capsules in patients diagnosed with limited internal rotation in conjunction with subacromial impingement. In addition to these arthroscopic findings, cadaveric research has demonstrated how biomechanical adaptations can result from posterior capsular tightening. These studies demonstrated altered humeral migration on the glenoid or loss of humeral internal rotation in cadaveric models with a plicated posterior capsule.[16,17] Pathomechanically, this change in glenohumeral arthokinematics may compromise the posterosuperior rotator cuff, bicipital insertion, and labrum, contributing to the subacromial impingement, pathologic internal impingement, or superior labral anterior posterior (SLAP) lesion commonly seen in overhead athletes.[3,9,16,26,36,38,40] While often described as posterior capsular tightness, it must be acknowledged that posterior shoulder tightness (PST) might better describe the ailment given the involvement of the other anatomical structures such as the posterior rotator cuff and deltoid.[23] The actual soft-tissue contributors to posterior capsular tightness have yet to be identified. Thus, this article adopts the term "posterior shoulder tightness" to describe this adaptation.

Clinically, PST is typically measured by passively assessing the amount of humeral internal rotation deficit (percentage difference in the amount of internal rotation between the dominant and nondominant limb) or horizontal adduction. In the current study, we operationally defined PST as the percentage difference in the amount of horizontal adduction. Warner et al[40] quantified PST by measuring passive humeral adduction of the patient in a supine position. The amount of horizontal adduction measured before scapular movement represented PST. One criticism of this assessment was that scapular motion was difficult to detect during the assessment.[39] Pappas et al[30] advocated measuring PST by manually stabilizing the scapula, while horizontal adduction was measured with a goniometer. The potential inconsistency in the scapular starting position between trials has been criticized with this technique.[39] A scapula stabilized in a more protracted position in a retest trial could result in more horizontal adduction and be mistaken for more posterior shoulder flexibility.[39] Additionally, neither reliability nor precision has been established for the supine methods of assessment. Tyler et al[39] advocated measuring PST by measuring passive humeral horizontal adduction in a side-lying position. The side-lying position provides the advantage of being able to monitor scapulothoracic motion during the assessment and standardizing the scapular starting position in a fully retracted position. Tyler et al[38,39] demonstrated this assessment to be valid, reliable (intrasession and intertester), and capable of detecting shoulder pathologic changes (subacromial impingement). Myers et al[26] demonstrated good reliability using the side-lying method as well and showed that it was able to identify excessive PST in baseball players diagnosed with pathologic internal impingement. This side-lying method has been adopted as the assessment of choice in the recent literature[13,24,26,38,42] (also E. L. Sauers et al, unpublished data, 2004).

Given the suggested role that PST plays in injury to the shoulder of the overhead athlete, it is important that clinicians use the best measurement technique available. While the side-lying assessment described by Tyler and colleagues[39] provides a reliable, valid means to assess PST, a common complaint is that the assessment can be difficult to perform. Specifically, it is difficult to stabilize the scapula in patients who are large in stature or by testers who are small in stature or have small hands. Additionally, it is critical to maintain the torso perpendicular to the treatment table during the side-lying method. Often, patients have difficulty relaxing the periscapular muscles while maintaining an erect torso. Thus, we hypothesized that a modified supine assessment that includes the benefits of scapular positioning and stabilization described by Tyler et al[39] and addresses the criticisms associated with the assessments described by Warner et al[40] and Pappas et al[30] might provide an alternative to the side-lying method for assessment. Specifically, we advocated using the treatment table to assist in stabilizing the scapula. For the modified supine assessment to be an effective clinical option, it must (1) be reliably performed between trials, sessions, and testers; (2) be performed with good accuracy and precision; (3) control scapular position and movement; and (4) be a valid measure of PST. The purpose of this study was to describe a modified supine assessment of PST and establish the reliability, precision, clinical accuracy, and construct validity of the assessment. Additionally, this assessment will be compared with the side-lying assessment that is currently the tool of choice for determining PST in the clinical setting.

MATERIALS AND METHODS

Participants

In the current study, 4 groups of individuals participated. Those groups included 1 group of 15 healthy male university students to establish reliability, precision, and clinical accuracy and 3 groups of intercollegiate male athletes to establish construct validity. The intercollegiate athlete groups included 15 intercollegiate male athletes who participate in nonoverhead activity sports (track or soccer), 15 male intercollegiate baseball pitchers, and 13 competitive (intercollegiate and university club) male tennis players. All participants were free of injury at the time of testing with no significant history of injury to the upper extremities tested. Complete demographics for all participants appear in Table 1.

TABLE 1
Patient Demographics[a]

	University Participants[b] (n = 15)		Baseball Pitchers[c] (n = 15)		Tennis Players[c] (n = 13)		Nonoverhead Athletes[c] (n = 15)	
Variable	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Age, y	25.3	4.7	20.0	1.1	21.8	2.8	20.1	1.1
Height, cm	166.1	14.7	181.5	7.1	177.4	5.6	177.7	5.3
Mass, kg	78.9	10.4	88.1	14.8	78.9	8.2	72.4	8.6

[a] SD, standard deviation.
[b] Participants used to establish reliability, precision, and clinical accuracy.
[c] Participants used to establish construct validity.

Instrumentation

Scapula and humerus kinematic data were collected using the MotionMonitor (Innovative Sports Training Inc, Chicago, Ill) electromagnetic tracking device. The MotionMonitor software uses data conveyed by electromagnetic receivers for the calculation of receiver position and orientation relative to an electromagnetic transmitter. The specific hardware used in this investigation consisted of an extended range direct-current transmitter and 5 receivers. The instrumentation sampling frequency used for all kinematic assessments in the current study was 100 Hz. In a pilot study, we determined the accuracy of our electromagnetic instrumentation and the optimal location within our measurement space for participant positioning and testing. Initially, the root mean square error for both position and orientation were calculated for the 8 ft × 8 ft (2.44 m × 2.44 m) measurement space allocated for our electromagnetic tracking device. The overall position error for the 64 ft^2 (17.87 m^2) measurement space was 3.3 mm, while the orientation error was 0.57°. Given that electromagnetic accuracy is compromised when measurements are taken too close to or too far from the transmitter, we determined the location within the measurement space that yielded the lowest amount of error. It was determined that the region of the measurement space that is between 0.91 m (3 ft) and 1.2 m (4 ft) directly in front of the transmitter demonstrated the least amount of position (0.7 mm) and orientation (0.27°) error. Thus, all scapular and humeral kinematic assessments in the current study were performed with the participants positioned 0.91 m away from the transmitter. Additionally, reliability and precision for scapulohumeral motion have been established by our laboratory and yielded an intrasession intraclass correlation coeffecient (ICC) of 0.967 with 0.94° of error (SEM, standard error of measurement) and intersession ICC of 0.889 with 2.11° of error.[25]

Clinically, humeral motion was assessed with both a standard goniometer (Model 01135, Lafayette Instrument Co Inc, Lafayette, Ind) and with an anthropometer. These instruments were used because of their availability in clinical sports medicine settings.

Procedures

All testing in the current study was performed in a university-based medical center human-movement research laboratory. Before testing, each participant provided informed consent as required by the University Institutional Review Board.

Establishing Reliability and Precision

Intrasession, intersession, and intertester reliability and precision were established with the group of 15 healthy university students. Posterior shoulder tightness was measured in both side-lying and supine positions. To measure PST in the side-lying position, the participant was asked to side-lie with the thorax aligned perpendicular to the treatment table and the spine in neutral flexion, extension, and rotation. With the tester facing the participant, excessive scapular movement was restricted by stabilizing the lateral border of the scapula in a retracted position. Starting from a position of 90° of humeral abduction and neutral humeral rotation, the tester passively lowered the arm into horizontal adduction by gripping the participant's forearm just distal to the humeral epicondyles. The arm was lowered until the humeral horizontal adduction end range was reached or until the humerus started to internally rotate.[38,39] At the end range of motion, the second tester recorded the distance, in centimeters, between the medial epicondyle and the surface of the treatment table using an anthropometer (Figure 1). This distance quantified the amount of horizontal adduction, which reflected the degree of tightness in the posterior shoulder structures. Measurements of 3 trials were taken by the same testers.

For the supine PST assessment, the participant lay supine on the treatment table. One tester was positioned beside the treatment table of the shoulder being tested, while the participant was asked to maximally retract his scapula. The tester then placed one hand under the scapula, pressing their thenar eminence against the lateral border of the scapula, stabilizing the scapula in the maximally retracted position. The tester then used the other hand to passively move the participant's arm into

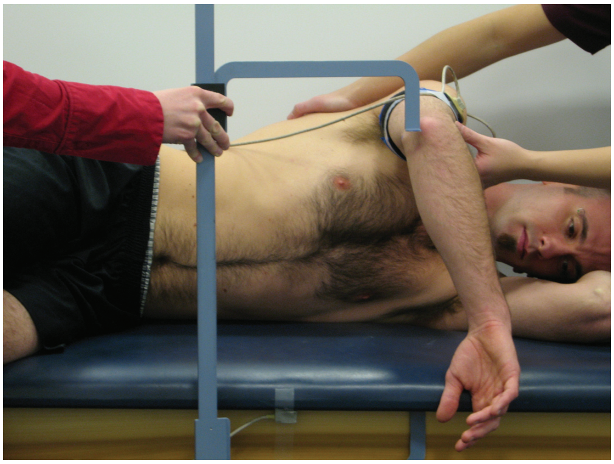

Figure 1. Side-lying posterior shoulder tightness assessment.

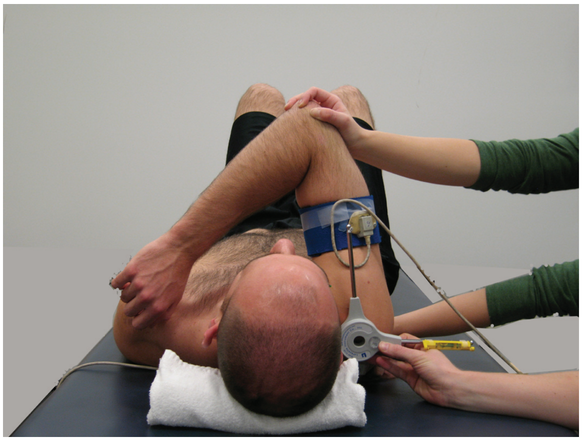

Figure 2. Supine posterior shoulder tightness assessment.

horizontal adduction while maintaining neutral humeral rotation. At the end range of horizontal adduction, the second tester recorded the angle formed between the humerus and the horizontal plane from the superior aspect of the shoulder (Figure 2). The fulcrum of the goniometer was placed over the estimated glenohumeral joint center, and the movement arm was aligned with the humerus. The stationary arm was kept parallel to the floor guided by a bubble level attached to the arm. A total of 3 trials were recorded by the same tester.

Intrasession reliability was established by using the 3 trials of each PST assessment for the dominant limb of each participant. Intraclass correlation coefficients, using the (3,1) model described by Shrout and Fleiss,[35] were calculated to determine reliability between trials. Additionally, from the obtained ICC and the standard deviation of each variable, precision was established by calculating the SEM between the 3 measurements.

Intersession reliability was established by retesting all participants using the identical methods described above 3 to 7 days after the initial measurements were taken. The means of the measures on each day were used to establish the intersession reliability and precision. Intraclass correlation coefficients using a (3,K) model were performed to determine reliability between sessions. Additionally, from the obtained ICC and the standard deviation of each variable, precision was established by calculating the SEM between sessions.

Intertester reliability and precision were established between 2 separate testers who were blinded to the other tester's results. Given the criticism that these tests can be hard to perform by examiners small in stature, one tester was large in stature (height, 197 cm; mass, 92 kg), while the other was small (height, 163 cm; mass, 61 kg). Both testers had at least 5 years of orthopaedic clinical experience. Each tester conducted 3 trials using both assessments on each study participant. The average of 3 trials for each tester on each participant was used to calculate intertester reliability using a (3,K) ICC model. Additionally, from the obtained ICC and the standard deviation of each variable, precision was established by calculating the SEM between testers.

Clinical Accuracy Assessment

In addition to establishing the reliability and precision of the PST measurements, an additional purpose of this study was to establish the amount of accuracy that is feasible clinically and how much scapular movement one could expect when performing the assessments. Minimizing scapular movement and isolating humeral motion on a fixed scapula are paramount to obtaining accurate PST measurement.

Clinical accuracy was assessed with the 15 healthy student participants. Each participant had 4 electromagnetic receivers secured to various anatomical landmarks for kinematic analysis of the scapula and humerus. Two electromagnetic receivers were secured with double-sided adhesive disks (3M Health Care, St Paul, Minn) and hypoallergenic tape (to further reduce receiver-to-skin movement) with 1 receiver attached superficial to the seventh cervical vertebra and 1 receiver attached on the flat, broad portion of the acromion on the scapula at a point one third the distance from the angulus acromialis to the acromioclavicular joint. An electromagnetic receiver was secured on the humerus using a Neoprene cuff and elastic tape at the midpoint between the angulus acromialis and the lateral humeral epicondyle. The receiver positions on the scapula and humerus were previously validated using bone-fixed markers and shown to accurately represent movement of their respective segments.[18,21] A fourth receiver was fixed to the undersurface of the wooden treatment table used for testing to allow accurate representation of the table surface for assessing PST in a side-lying position. A fifth receiver was attached to a stylus, which was used for the digitization of thoracic, humeral, and scapular landmarks that allowed for transformation of the receiver data from a global coordinate system to anatomically based local coordinate systems.[19,25,27] The electromagnetic tracking device was chosen to determine clinical accuracy because of the established accuracy of our device (0.7 mm and 0.27°).

A side-lying assessment of PST was performed as described above. One tester recorded the distance (in centimeters) between the medial epicondyle and the surface of the treatment table using an anthropometer, while simultaneous measurement was performed with the electromagnetic tracking device. Using the electromagnetic tracking device, the examiner calculated the distance between the medial epicondyle (digitized and derived from the humeral receiver) and the table surface (derived from the receiver placed on the treatment table) in centimeters. The mean difference and mean absolute difference between the clinical and electromagnetic tracking measurements were calculated for each trial, and the values from the 3 trials were averaged.

A supine assessment of PST was performed as described above. One tester recorded the amount of humeral horizontal adduction with a goniometer, while a simultaneous measurement was performed with the electromagnetic tracking device. With the electromagnetic tracking device, the amount of horizontal adduction was derived from the humeral receiver data. The absolute difference between the clinical and electromagnetic tracking measurements was calculated for each trial, and the 3 measurements were averaged. The average difference between the clinician and instrumentation-obtained measurements represents the clinician error.

During both assessments, the amount of scapular protraction that occurred during the test was calculated from data derived from both the scapular and thorax receivers. Scapulothoracic movement does not involve direct articulation with the thorax. The only attachment of these 2 segments is via the clavicle, a rigid body with a fixed length. As such, the position of the scapula can be described by 2 degrees of freedom as if in spherical space, by both elevation/depression and protraction/retraction.[18,22] The positions of the acromioclavicular joint (AC) and incisura jugularis (IJ) points with respect to the global coordinate system (tracked by the scapular and thoracic receivers, respectively) were used to calculate a vector from the IJ point to the AC point. For protraction/retraction, this vector was projected onto the transverse plane bisecting the IJ and was calculated as the angle between this projection and the frontal plane that bisects the IJ. The amount of scapular protraction (defined as the difference in scapular protraction position between the start and end position of each assessment) during the 3 trials was calculated and averaged for each position of assessment.

Establishing Construct Validity

Construct validity was established with the 43 healthy, male, collegiate athletes (15 baseball pitchers, 13 tennis players, and 15 nonoverhead athletes [soccer or track and field]). Both baseball pitchers and tennis players were chosen because each group exhibits unilateral decreases in humeral internal rotation range of motion (IRROM) and increased PST.[‡] Thus, we wanted to see which method of PST would better demonstrate differences in PST in a group of overhead athletes with decreased humeral internal rotation from overhead sports participation.

TABLE 2
Posterior Shoulder Tightness Reliability and Precision[a]

	Intrasession		Intersession		Intertester	
Assessment	ICC	SEM	ICC	SEM	ICC	SEM
PST side-lying	0.83	0.9 cm	0.42	1.7 cm	0.69	1.4 cm
PST supine	0.91	1.1°	0.75	1.8°	0.94	1.8°

[a] ICC, intraclass correlation coefficient; SEM, standard error of measurement; PST, posterior shoulder tightness.

Posterior shoulder tightness was assessed as described above in both side-lying and supine positions. Because of the bilateral asymmetries in shoulder flexibility of the dominant shoulder in overhead athletes,[§] the amount of PST measured in the dominant shoulder was normalized to the amount of PST in the nondominant shoulder and was reported as a percentage (dominant shoulder/nondominant shoulder × 100). In addition to both assessments of PST, passive glenohumeral rotation range of motion was measured. The participants lay supine on the treatment table with the testing shoulder placed in 90° of abduction and the elbow slightly off the edge of the table. A rolled towel was placed under the arm to align the humerus level with the acromion process.[28] The first tester stabilized the shoulder against the table with one hand to prevent any accessory motion, while using the other hand to passively move the humerus into maximal internal/external rotation. The second tester measured the amount of humeral rotation using a goniometer. The angle of the forearm, with respect to the plane parallel to the floor, was recorded as glenohumeral internal and external rotation. A level was attached to the stationary arm of the goniometer to ensure that it was kept parallel to the ground. The amount of humeral internal and external rotation measured in the dominant shoulder was normalized to the amount of humeral rotation in the nondominant shoulder and reported as a percentage (dominant shoulder/nondominant shoulder × 100). Before performing this study, we established the reliability and precision of performing the humeral rotation range of motion assessments. Intrasession reliability and precision for the goniometric measurements obtained from the pilot study were high for both internal rotation (ICC [3,1] = 0.985, SEM = 1.51°) and external rotation range of motion (ICC [3,1] = 0.942, SEM = 1.75°) (C. A. Wassinger et al, unpublished data, 2006).

The 3 groups' humeral rotation and PST were analyzed with 1-way ANOVA models. Tukey post hoc analyses were performed to determine where significant differences were present when the ANOVA indicated statistical significance. Additionally, the statistical relationship between humeral IRROM and both the side-lying and supine methods of PST assessment were established with Pearson product moment correlation analyses. An alpha level of .05 was set a priori.

[‡] References 1, 2, 5, 6, 8-11, 14, 26, 29, 30, 32, 38, 39, 41.

[§] References 1, 2, 4-6, 8, 10, 11, 14, 26, 29, 32, 33, 38, 41.

TABLE 3
Clinical Accuracy Descriptive Statistics[a]

	Side-Lying PST Assessment		Supine PST Assessment	
	Mean	SD	Mean	SD
Clinical measurement	35.6 cm	3.2	94.4°	10.6
Instrumentation measurement	35.4 cm	3.0	95.5°	11.4
Clinician/instrumentation Δ	–0.2 cm	1.0	–1.1°	3.9
Clinician/instrumentation absolute Δ	0.9 cm	0.6	3.5°	2.8
Amount of scapular protraction	4.1°	2.4	3.1°	3.5

[a] PST, posterior shoulder tightness; SD, standard deviation; Δ, difference.

RESULTS

Intrasession, intersession, and intertester ICC and SEM for both assessments appear in Table 2. The clinical accuracy and amount of scapular protraction during each test are presented in Table 3. The construct validity, descriptive statistics, and correlational analyses for the overhead group comparisons are presented in Tables 4 and 5. From the ANOVA and Tukey post hoc analyses, both the baseball and tennis players had significantly more humeral internal rotation deficits in their dominant limb ($F(2,42) = 11.00$; $P < .0001$) than nonoverhead control athletes. No differences were present between the baseball and tennis players. Additionally, the baseball pitchers and tennis players demonstrated significantly more PST in the dominant limb only when measured using the supine assessment ($F(2,42) = 6.38$; $P = .004$); however, no differences were noted with the side-lying assessment ($F(2,42) = 1.20$; $P = .312$). No differences existed between the baseball pitchers and tennis players. No differences were present between any groups in the amount of dominant limb external rotation. In addition, only the PST when measured in the supine position positively correlated ($r = 0.347$; $P = .023$) with internal rotation deficit. As PST increased when the participant lay supine, so also did the amount of internal rotation deficit.

DISCUSSION

Reliability and Precision

In the current study, intrasession, intersession, and intertester reliability were established with ICC for both the supine and side-lying methods. Intraclass correlation coefficients provide a numeric means of assessing the agreement between 2 trials or sets of data, thus providing an indication of the repeatability. As a general guideline, Portney and Watkins[31] suggest that ICC values above 0.75 are indicative of good reliability, while those below 0.75 indicate moderate to poor reliability. The results of this study suggest that both the side-lying (ICC = 0.83) and supine (ICC = 0.91) assessments demonstrated good intrasession reliability, thus indicating both assessments can be performed with good repeatability between trials. Intersession reliability was lower for both assessments. Only the supine assessment (ICC = 0.75) resulted in good repeatability between sessions. As such, the supine assessment may be more suited for measuring when multiple sessions of measurement are necessary, as commonly seen in the clinical setting when rehabilitation and treatment outcomes are documented over time. For intertester reliability, only the supine assessment demonstrated good reliability

TABLE 4
Construct Validity: Overhead Athlete Group Differences[a]

	Baseball Pitchers		Tennis Players		Nonoverhead Athletes		
	Mean	SD	Mean	SD	Mean	SD	*P* Value
Side-lying PST assessment							
Dominant limb, cm	31.8	4.1	33.3	3.8	30.7	2.8	
Nondominant limb, cm	29.7	3.6	31.0	3.6	30.2	3.8	
Dominant/nondominant × 100, %[b]	108.5	18.1	107.4	6.7	102.1	7.6	.312
Supine PST assessment							
Dominant limb, deg	105.9	5.9	103.9	7.6	107.0	6.8	
Nondominant limb, deg	114.1	9.2	111.9	6.5	107.4	10.3	
Dominant/nondominant × 100, %[b]	93.2	5.5	92.9	5.3	100.1	7.6	.004[c]
Humeral rotation range of motion							
Dominant limb internal rotation, deg	41.7	5.9	34.7	7.5	46.3	13.1	
Nondominant limb internal rotation, deg	54.3	8.3	45.7	7.5	47.5	13.0	
Dominant/nondominant internal rotation × 100, %[b]	77.9	13.1	76.1	12.8	98.8	16.9	<.0001[c]
Dominant limb external rotation, deg	132.0	10.4	129.6	12.4	120.3	7.0	
Nondominant limb external rotation, deg	119.7	6.5	120.7	12.7	114.0	6.1	
Dominant/nondominant external rotation × 100, %[b]	110.5	7.1	107.6	7.4	105.6	6.4	.179

[a] SD, standard deviation; PST, posterior shoulder tightness.
[b] Represents the percentage deficit between the dominant and nondominant limbs.
[c] Significantly different from both the baseball pitchers and tennis players.

TABLE 5
Relationship Between Posterior Shoulder Tightness and Humeral Rotation Range of Motion (N = 43)[a]

	Side-Lying PST Assessment[b]		Supine PST Assessment[b]	
	r	*P*	*r*	*P*
Internal rotation[b]	–0.164	.295	0.347	.023
External rotation[b]	0.166	.287	–0.002	.989

[a] PST, posterior shoulder tightness.
[b] Dominant/nondominant × 100.

(ICC = 0.94). These results suggest that the supine assessment may be more appropriate when multiple testers are making the assessments. We suspect that the discrepancy in intertester reliability between the 2 assessments is a result of differences in stature of the testers used in this study and that the supine assessment may provide a better means of performing the PST with better agreement between testers of all statures and sizes. The only other study we are aware of that assesses reliability of the supine assessment is by Laudner et al.[20] Unlike the current study where standard goniometry is used, Laudner et al[20] advocate the use of an inclinometer for the horizontal adduction measurements. An inclinometer might provide a more accurate means of measuring the joint motions. Like the current study, they demonstrated that the supine assessment can be done both within session and between testers with good reliability.[20]

Intraclass correlation coefficients provide a unitless estimate of reliability of measurement but do not provide an estimate of the precision one can expect from the measurement.[12] Standard error of measurement provides an indication of precision and represents the expected unit-based standard deviation for the particular measurement. Intrasession, intersession, and intertester precision were established for each assessment. Both assessments demonstrated good precision with less than 2° (supine assessment) or 2 cm (side-lying assessment) of error to be expected when comparisons are made between trials, sessions, or testers. Similarly, Laudner et al[20] demonstrated that the supine assessment can be performed with a low standard of error.

Clinical Accuracy

Clinical accuracy was established by comparing PST data collected manually by a clinician with simultaneous collection by highly accurate motion analysis instrumentation. The mean difference and mean absolute difference between the clinician and instrumentation-obtained data were calculated. The results suggest that both assessments can be performed clinically with little error. This is not surprising given the strong precision demonstrated during the reliability assessments described above. In addition, our testers were well versed in performing the 2 assessments.

The amount of scapular protraction that occurred during each assessment was measured because it is imperative that the tester limit the amount of compensatory protraction motion that can occur during humeral adduction. In the current study, the results suggest that both the side-lying and supine assessments are effective in limiting the amount of protraction that occurs. The primary tester in the current study was large in stature, making scapular stabilization easier to achieve regardless of the assessment method used. It would have been interesting to perform this same experiment with our tester who is small in stature. We suspect that more protraction would occur with the side-lying method because assistance in scapular stabilization is not achieved with the treatment table.

Construct Validity

Like the work by Tyler et al,[39] construct validity was established by assessing PST in a group of overhead athletes demonstrated in the literature to have decreased dominant limb IRROM and PST.[4,7,13-15,26,34] Our results support the reported literature in that both the baseball pitchers and tennis players had significantly decreased IRROM deficits in the dominant limb (normalized to the nondominant limb) compared with nonoverhead athletes. Internal rotation range of motion in the dominant limb was decreased by approximately 23% in the 2 overhead athlete groups.

Posterior shoulder tightness was assessed with both methods in the current study. Despite approximately 23% deficits in dominant limb internal rotation, only the supine assessment demonstrated significant differences between groups in PST. No group differences were identified with the side-lying method. Additionally, only the PST identified with the supine assessment significantly correlated with the amount of internal rotation deficits for all participants.

Unlike the current study, Tyler et al[39] demonstrated significant differences in PST when assessed side-lying between a group of 22 baseball pitchers and a nonoverhead control group. The discrepancy in results between the 2 studies was surprising given that the amount of PST reported was similar. The nonsignificant findings in the current study might be a result of the higher variability we observed when assessing PST, especially in the baseball players.

CONCLUSION

The results of this study suggest that the modified supine assessment of PST might be a viable alternative to the side-lying method of assessment. Both the side-lying and supine methods resulted in low clinician error and good precision, suggesting that both can be performed with good clinical accuracy. Both resulted in minimal scapular protraction, suggesting that scapular stabilization can be achieved, which is essential for accurate measurements. The supine method can be assessed more reliably than side-lying, especially when assessments are taken over several sessions or between several testers. Unlike the side-lying assessment, the supine assessment was able to identify differences between overhead and control athletes. Considering the significant correlation between IRROM and PST, the supine method may be more sensitive to detect changes in a population known to exhibit these PST characteristics.

Given these recommendations, the authors must acknowledge some limitations of the current study. The current study only used 2 testers. While these testers had varying backgrounds, clinical experience, and body stature, the results may be ultimately dependent on how well these 2 individuals were able to perform the 2 assessments. Our hope was to control this by choosing 2 individuals who both have extensive clinical experience evaluating the upper extremity and performing the assessments successfully. Additional testers should be included in further evaluations of the assessments outlined. Secondly, the supine assessment as described in the current article has yet to identify PST in shoulders with pathologic changes. This is an area of ongoing study. Warner et al[40] demonstrated PST (when measured supine similar to the described assessment in the current study) in patients with subacromial impingement. Both Tyler et al[38] and Myers et al[26] demonstrated the presence of PST using this side-lying method in patients with subacromial and internal impingement, respectively. We suspect that the supine method will be equally capable of identifying PST in individuals with pathologic abnormalities given the key components of both methods are identical (ie, stabilized scapula in a retracted position, isolated passive humeral adduction motion, etc). The supine method may make these components easier to standardize and to be performed by clinicians. Finally, only male participants were used in the current study. Potentially, the results may not be generalizable to female participants. However, there is no published research suggesting that assessment of PST is not appropriate to be performed on female overhead athletes.

In conclusion, both the side-lying and supine methods resulted in low clinician error and good precision. Both resulted in minimal scapular protraction, suggesting that scapular stabilization can be achieved, which is essential for accurate measurements. However, the supine method can be assessed more reliably between sessions and testers than side-lying. Additionally, the supine assessment was able to identify differences between overhead and control athletes and significantly correlated with the amount of IRROM, suggesting the supine method may be more sensitive to detect changes in a population known to exhibit these characteristics. From these results, clinicians may want to consider use of the supine method given the higher reliability and similar clinician accuracy and scapular stabilization.

REFERENCES

1. Andrews JR, Fleisig GS. Preventing throwing injuries. *J Orthop Sports Phys Ther.* 1998;27:187-188.
2. Baltaci G, Johnson R, Kohl H 3rd. Shoulder range of motion characteristics in collegiate baseball players. *J Sports Med Phys Fitness.* 2001;41:236-242.
3. Barber FA, Morgan CD, Burkhart SS, Jobe CM. Current controversies. Point counterpoint. Labrum/biceps/cuff dysfunction in the throwing athlete. *Arthroscopy.* 1999;15:852-857.
4. Bigliani LU, Codd TP, Connor PM, Levine WN, Littlefield MA, Hershon SJ. Shoulder motion and laxity in the professional baseball player. *Am J Sports Med.* 1997;25:609-613.
5. Borsa PA, Dover GC, Wilk KE, Reinold MM. Glenohumeral range of motion and stiffness in professional baseball pitchers. *Med Sci Sports Exerc.* 2006;38:21-26.
6. Borsa PA, Scibek JS, Jacobson JA, Meister K. Sonographic stress measurement of glenohumeral joint laxity in collegiate swimmers and age-matched controls. *Am J Sports Med.* 2005;33:1077-1084.
7. Borsa PA, Wilk KE, Jacobson JA, et al. Correlation of range of motion and glenohumeral translation in professional baseball pitchers. *Am J Sports Med.* 2005;33:1392-1399.
8. Brown LP, Niehues SL, Harrah A, Yavorsky P, Hirshman HP. Upper extremity range of motion and isokinetic strength of the internal and external shoulder rotators in major league baseball players. *Am J Sports Med.* 1988;16:577-585.
9. Burkhart SS, Morgan CD, Kibler WB. The disabled throwing shoulder: spectrum of pathology. Part I: pathoanatomy and biomechanics. *Arthroscopy.* 2003;19:404-420.
10. Burkhart SS, Morgan CD, Kibler WB. The disabled throwing shoulder: spectrum of pathology. Part III: the SICK scapula, scapular dyskinesis, the kinetic chain, and rehabilitation. *Arthroscopy.* 2003;19:641-661.
11. Crockett HC, Gross LB, Wilk KE, et al. Osseous adaptation and range of motion at the glenohumeral joint in professional baseball pitchers. *Am J Sports Med.* 2002;30:20-26.
12. Denegar CR, Ball DW. Assessing reliability and precision of measurement: an introduction to intraclass correlation and standard error of measurement. *J Sport Rehabil.* 1993;2:35-42.
13. Downar JM, Sauers EL. Clinical measures of shoulder mobility in the professional baseball player. *J Athl Train.* 2005;40:23-29.
14. Ellenbecker TS, Roetert EP, Bailie DS, Davies GJ, Brown SW. Glenohumeral joint total rotation range of motion in elite tennis players and baseball pitchers. *Med Sci Sports Exerc.* 2002;34:2052-2056.
15. Ellenbecker TS, Roetert EP, Piorkowski PA, Schulz DA. Glenohumeral joint internal and external rotation range of motion in elite junior tennis players. *J Orthop Sports Phys Ther.* 1996;24:336-341.
16. Grossman MG, Tibone JE, McGarry MH, Schneider DJ, Veneziani S, Lee TQ. A cadaveric model of the throwing shoulder: a possible etiology of superior labrum anterior-to-posterior lesions. *J Bone Joint Surg Am.* 2005;87:824-831.
17. Harryman DT, Sidles JA, Clark JM, McQuade KJ, Gibb TD, Matsen FA. Translation of the humeral head on the glenoid with passive glenohumeral motion. *J Bone Joint Surg Am*. 1990;72:1334-1343.
18. Karduna AR, McClure PW, Michener LA, Sennett B. Dynamic measurements of 3-dimensional scapular kinematics: a validation study. *J Biomech Eng.* 2001;123:184-190.
19. Laudner KG, Myers JB, Pasquale MR, Bradley JP, Lephart SM. Scapular dysfunction in throwers with pathologic internal impingement. *J Orthop Sports Phys Ther.* 2006;36:485-494.
20. Laudner KG, Stanek JM, Meister K. Assessing posterior shoulder contracture: the reliability and validity of measuring glenohumeral joint horizontal adduction. *J Athl Train.* 2006;41:375-380.
21. Ludewig PM, Cook TM. Translations of the humerus in persons with shoulder impingement symptoms. *J Orthop Sports Phys Ther.* 2002;32:248-259.
22. McClure PW, Michener LA, Sennett BJ, Karduna AR. Direct 3-dimensional measurement of scapular kinematics during dynamic movements in vivo. *J Shoulder Elbow Surg.* 2001;10:269-277.
23. Michener LA, McClure PW, Karduna AR. Anatomical and biomechanical mechanisms of subacromial impingement syndrome. *Clin Biomech.* 2003;18:369-379.
24. Mourtacos SL, Sauers EL, Downar JM. Adolescent baseball players exhibit differences in shoulder mobility between the throwing and nonthrowing shoulder and between divisions of play. *J Athl Train.* 2003;38(Suppl):S72.
25. Myers JB, Jolly JT, Nagai T, Lephart SM. Reliability and precision of in vivo scapular kinematic measurements using an electromagnetic tracking device. *J Sport Rehabil.* 2006;15:125-143.
26. Myers JB, Laudner KG, Pasquale MR, Bradley JP, Lephart SM. Glenohumeral range of motion deficits and posterior shoulder tightness

in throwers with pathologic internal impingement. *Am J Sports Med.* 2006;34:385-391.

27. Myers JB, Laudner KG, Pasquale MR, Bradley JP, Lephart SM. Scapular position and orientation in throwing athletes. *Am J Sports Med.* 2005;33:263-271.
28. Norkin CC, White DJ. *Measurement of Joint Motion: A Guide to Goniometry.* 2nd/spiral ed. Philadelphia, Pa: FA Davis Company; 1995:241.
29. Osbahr DC, Cannon DL, Speer KP. Retroversion of the humerus in the throwing shoulder of college baseball pitchers. *Am J Sports Med.* 2002;30:347-353.
30. Pappas AM, Zawacki RM, McCarthy CF. Rehabilitation of the pitching shoulder. *Am J Sports Med.* 1985;13:223-235.
31. Portney LG, Watkins MP. *Foundations of Clinical Research Applications to Practice.* 2nd ed. Upper Saddle River, NJ: Prentice Hall Health; 2000.
32. Reagan KM, Meister K, Horodyski MB, Werner DW, Carruthers C, Wilk K. Humeral retroversion and its relationship to glenohumeral rotation in the shoulder of college baseball players. *Am J Sports Med.* 2002;30:354-360.
33. Safran MR, Borsa PA, Lephart SM, Fu FH, Warner JJ. Shoulder proprioception in baseball pitchers. *J Shoulder Elbow Surg.* 2001;10:438-444.
34. Schmidt-Wiethoff R, Rapp W, Mauch F, Schneider T, Appell HJ. Shoulder rotation characteristics in professional tennis players. *Int J Sports Med.* 2004;25:154-158.
35. Shrout PE, Fleiss JL. Intraclass correlations: uses in assessing rater reliability. *Psychol Bull.* 1979;86:420-428.
36. Tibone JE, McMahon PJ, Shrader TA, Sandusky MD, Lee TQ. Glenohumeral joint translation after arthroscopic, nonablative, thermal capsuloplasty with a laser. *Am J Sports Med.* 1998;26:495-498.
37. Ticker JB, Beim GM, Warner JJ. Recognition and treatment of refractory posterior capsular contracture of the shoulder. *Arthroscopy.* 2000;16:27-34.
38. Tyler TF, Nicholas SJ, Roy T, Gleim GW. Quantification of posterior capsule tightness and motion loss in patients with shoulder impingement. *Am J Sports Med.* 2000;28:668-673.
39. Tyler TF, Roy T, Nicholas SJ, Gleim GW. Reliability and validity of a new method of measuring posterior shoulder tightness. *J Orthop Sports Phys Ther.* 1999;29:262-269; discussion 270-274.
40. Warner JJ, Micheli LJ, Arslanian LE, Kennedy J, Kennedy R. Patterns of flexibility, laxity, and strength in normal shoulders and shoulders with instability and impingement. *Am J Sports Med.* 1990;18:366-375.
41. Wilk KE, Meister K, Andrews JR. Current concepts in the rehabilitation of the overhead throwing athlete. *Am J Sports Med.* 2002;30:136-151.
42. Witwer A, Sauers E. Clinical measures of shoulder mobility in the collegiate water polo player. *J Sport Rehabil.* 2006;15:45-57.