Evaluation of Clinical Assessment Methods for Scapular Dyskinesis

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Purpose: The purposes of this study were to (1) assess the inter-rater reliability and validity of 2 clinical assessment methods of categorizing scapular dyskinesis and (2) quantify the frequency of asymmetry of bilateral scapular motion in injured and uninjured shoulders by use of 3-dimensional (3D) kinematic analysis. **Methods:** We evaluated 56 subjects, 35 with shoulder injury and 21 with no symptoms. Two blinded evaluators categorized the scapular motion of all subjects to determine inter-rater reliability using 2 observational methods ("yes/no" and "4 type") to evaluate scapular dyskinesis. Subjects were also instrumented with electromagnetic receivers to assess bilateral 3D scapular kinematics to determine the presence of dyskinesis and establish criterion validity of the 2 methods. **Results:** The inter-rater percent agreement and the degree of this agreement as measured by κ statistic showed that the yes/no method produced a higher inter-rater percent agreement (79%, $\kappa = 0.40$) than the 4-type method (61%, $\kappa = 0.44$). The yes/no method had a higher sensitivity (76%) and positive predictive value (74%) when compared with the 3D criterion. A χ^2 analysis found significantly more multiple-plane asymmetries in symptomatic subjects (54%) in flexion compared with asymptomatic subjects (14%) ($P = .002$). **Conclusions:** The yes/no method allows multiple-plane asymmetries to be considered in clinical assessment and therefore renders this a good screening tool for the presence of scapular dyskinesis. Kinematic analysis shows that asymmetries are common in symptomatic and asymptomatic populations. Testing in flexion showed a higher frequency of multiple-plane scapular asymmetries in the symptomatic group. **Clinical Relevance:** Identification of scapular dyskinesis is a key component of the shoulder examination. The clinician's ability to establish the presence or absence of scapular dyskinesis by observation is enhanced using a simple yes/no method especially when testing subjects in shoulder forward flexion. Although scapular asymmetries appear to be a prevalent finding, dyskinesis in the presence of shoulder symptoms should be considered a potential factor contributing to the dysfunction in the presence of shoulder symptoms should be considered a potential factor contributing to the dysfunction. **Key Words:** Shoulder—Physical examination—Scapula—Biomechanics—Movement disorders.

Alterations in static scapular position and dynamic scapular motion, described as scapular dyskinesis, have been found in patients with various shoulder pathologies including impingement, instability, and labral and rotator cuff injuries.[1-5] It has been thought that these alterations affect normal scapulohumeral rhythm (SHR) and shoulder arthrokinematics and therefore play a role in producing the dysfunctions associated with these pathologies.[5-7] Since the original description of SHR,[8] clinicians and researchers have attempted to measure and quantify this relation to gain a better understanding of SHR in normal and injured shoulder function. Researchers have used 2-dimensional radiographs[9] or, recently, 3-dimensional (3D) radiographs[2,10] to describe the contribution of scapular motion during humeral elevation. Previous studies have identified normal and abnormal scapular motions during humeral motions using 3D electromagnetic kinematic motion analysis systems or other labora-

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tory methods[1-3,11,12] that are not available in most clinical settings.

A reliable method of clinical assessment of these scapular alterations has not been developed. Several problems contribute to this difficulty. First, it is challenging to accurately observe the motions of the scapula beneath the muscle and overlying soft tissues. Second, measurement methods must take into account the 3 rotational movements and 2 translations of the scapula.[11,12] A few of the first clinical assessment methods categorizing or quantifying scapular dyskinesis, such as the lateral scapular slide test,[6,13] posterior displacement test,[14] and scapular upward rotation measure,[15,16] used static measures that assessed scapular position in 1 plane or, at most, 2 planes. The third challenge is establishing clinical assessment criteria to define scapular dyskinesis. Clinicians commonly assess scapular function by observing bilateral scapular motion during repeated motions of arm elevation and lowering. Clinically significant scapular dyskinesis is often considered present if symptomatic patients show asymmetric position or motion compared with the opposite side.[3,4,17] A method using this definition categorizes scapular dyskinesis into 1 of 4 categories, with 3 types describing patterns of scapular asymmetry and 1 type describing symmetric scapular motion. This assessment method is based on observation of scapular border positions at rest and during elevation motions[17] (Fig 1). This clinical assessment method has shown only moderate reliability,[17] primarily limited by 2 factors. It requires clinicians to allocate the assessment of asymmetry into a single plane of motion, which may be too restrictive. In addition, using asymmetry as the clinical criterion for dyskinesis may be too sensitive a measure because the prevalence of scapular asymmetry in asymptomatic subjects is not

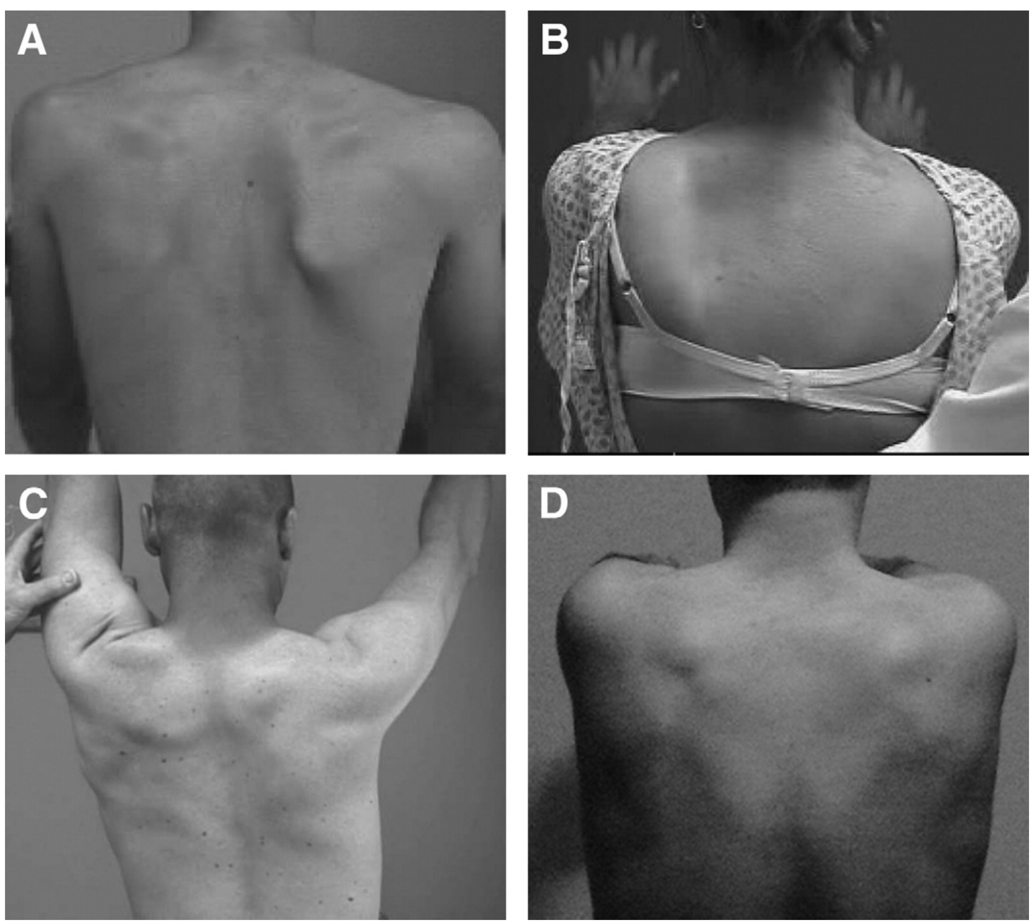

Figure 1. (A) Prominent inferior medial scapular border, classified as type I dyskinesis. (B) Prominent entire medial scapular border, classified as type II dyskinesis. (C) Excessive superior migration of superior medial scapular border, classified as type III dyskinesis. (D) Normal and symmetric scapular motion, classified as type IV.

well known.[18] The final challenge is that observational clinical assessment methods have not been compared with a reference standard, such as 3D kinematic analysis. To establish the validity and reliability of a clinical assessment method for scapular dyskinesis, the visual observations should be compared with a valid and reliable measure of scapular kinematics.[11,12]

The purposes of this study were to (1) assess the inter-rater reliability and validity of 2 clinical assessment methods of categorizing scapular dyskinesis by observation and (2) quantify the prevalence of asymmetry of bilateral scapular motion in individuals with and without shoulder symptoms by use of 3D kinematic analysis. The research hypotheses were as follows: (1) observation-based clinical assessment methods of scapular asymmetry can yield good inter-rater reliability and criterion validity, and (2) 3D kinematic analysis will show a greater prevalence of scapular asymmetry in subjects with symptomatic shoulders.

METHODS

Subjects

Fifty-six subjects participated in the study. The demographic information is presented in Table 1. The 35 symptomatic subjects were patients of 1 orthopaedic surgeon (W.B.K.). The right shoulder was involved in 16 of 35 patients (46%) in this group. Each subject underwent a standard orthopaedic shoulder examination including but not limited to ligamentous, labral, and rotator cuff testing with appropriate imaging. Subjects were excluded from the study if they presented with any of the following: bilateral shoulder pain; previous fracture of the scapula, humerus, or clavicle; and history or evidence of injury to the long thoracic, spinal accessory, or cervical root nerve. Diagnoses were determined by clinical examination and/or imaging and included rotator cuff tendinopathy without complete tear (n = 13), labral pathology (n = 7), unidirectional anterior glenohumeral instability (n = 6), and periscapular muscle weakness (n = 9). The 21 asymptomatic subjects were recruited from a convenience sample from the local community and had no pathology in either shoulder. Before participation, the intent and procedures were explained to the subjects, who then read and signed a consent form approved by the Institutional Review Boards of the University of Kentucky and the Lexington Clinic (Lexington, KY).

TABLE 1. *Demographic Comparison of Subjects in Both Groups*

	Asymptomatic	Symptomatic	*P* Value
Age [mean (SD)] (yr)*	24 (3)	32 (11)	< .001
Mass [mean (SD)] (kg)*	75 (18)	80 (16)	.62
Height [mean (SD)] (cm)*	172 (9)	175 (9)	.67
Gender (No. of subjects)†			.26
Male	11	24	
Female	10	11	
Dominance (No. of subjects)†			.7
Right	19	30	
Left	2	5	

*Independent *t* test used for comparison between groups.
†χ^2 Analysis used for comparison between groups.

Observational Clinical Assessment of Scapular Dyskinesis

Two blinded clinicians (W.B.K. and T.L.U.) performed independent assessments of scapular motion for each subject during the course of clinical assessment. Each assessment included observing the medial and superior scapular borders during 3 to 5 trials of arm elevation in the sagittal and scapular planes. The clinicians categorized the scapular motion into 1 of the 4 categories (4-type method) according to the "predominant pattern of scapular asymmetry observed" as previously described.[17] This clinical assessment method was based on altered scapular motion or resting position occurring in a single scapular kinematic plane.[11,12] A type I dyskinesis pattern is characterized by prominence of the inferior medial scapular angle and would be associated with excessive anterior tilting of the scapula (Fig 1A). A type II dyskinesis pattern is characterized by prominence of the entire medial border and would be associated with excessive scapular internal rotation (Fig 1B). A type III dyskinesis pattern is characterized by prominence of the superior scapular border and would be associated with excessive upward translation of the scapula (Fig 1C). A type IV pattern is characterized as "normal," indicating that no asymmetries were identified and no prominence of the medial or superior border was observed. Normal scapular motion is described as bilateral posterior tilting, external rotation, and slight superior translation during arm elevation and reversal of these during lowering relative to the opposite side[17] (Fig 1D). When clinicians observed asymmetry in multiple planes of motion, they were instructed to choose the single most predominant pattern. The second clinical assessment method described 2 types ("yes/no") and was a simplification of the 4-type method. All 3 dyskinesis categories (types I to III) were collapsed into a single category of "yes" (an abnormal dyskinesis pattern was observed), and type IV was relabeled "no" (normal scapular motion was observed). This removed the requirement of the clinician to decide on a single predominant pattern when multiple planes of asymmetry may have been observed.

Three-Dimensional Kinematic Analysis

The subjects were instrumented with receivers from a 3D electromagnetic tracking device, the Flock of Birds (Ascension Technologies, Burlington, VT). Motion Monitor software (Innovative Sports Programs, Chicago, IL) recorded 3D position and orientation of each subject's thorax and bilateral scapulae at 100 Hz. Three receivers were applied with two-sided adhesive tape and secured with CoverRoll (Beiersdorf, Norwalk, CT), one to the sternum, just inferior to the jugular notch, and one on each scapula at the flattest aspect of the posterior acromion in an attempt to reduce artifact produced by skin movement.[1] Placement of the scapular sensor on the acromion has been shown to optimally capture all directions of scapular motions and has been validated through a bone pin study.[12]

A global coordinate system was established by mounting a standard range transmitter (Ascension Technologies) on a rigid plastic and wooden base approximately 60 inches above the ground. The transmitter was aligned with the cardinal planes of the body (Fig 2). Subjects stood with their arms relaxed by their sides while bony landmarks on the thorax (jugular notch, xiphoid process, C7, T8, and T12) and both scapulae (inferior angle, root of scapular spine, and posterior acromial angle) were digitized to record motions. A standardized protocol was followed to define scapular and thoracic segment axes and convert the local coordinate system into meaningful angular rotations by use of the Euler angle sequence of rotations.[19,20] These procedures have produced reliable measures, with intraclass correlation coefficient (2,1) values ranging between 0.77 and 0.90 and standard error of measure values ranging from 1° to 2°.[21]

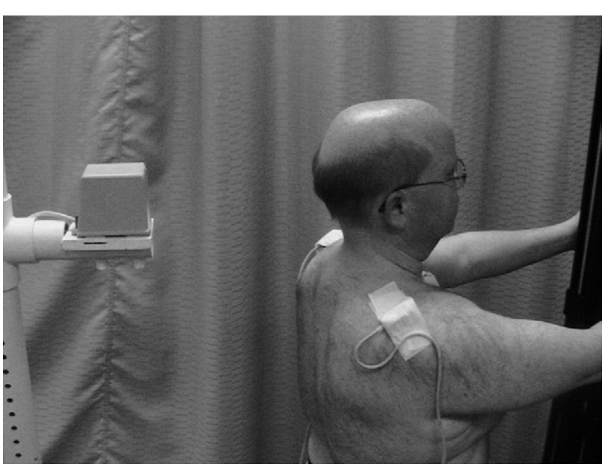

FIGURE 2. Position of subject standing in front of transmitter with receivers attached to bilateral scapulae and transmitter just behind subject. This setup and positioning were used for all subjects.

The subject stood facing an adjustable backdrop (Nimlok, Niles, IL) that served as a guide during elevation and lowering in each plane. Resting kinematic data were recorded for 5 seconds and served as a reference to determine zero offsets for bilateral scapular comparisons during dynamic measurements. The resting position was defined as the subject standing in his or her normal posture with the arms at the sides, elbows in full extension, hands on the seams of the pants, and thumbs pointing forward. This was the starting and finishing position for all repetitions. Subjects completed 8 repetitions of arm elevation and lowering with elbows in full extension in a sagittal plane in concert with a metronome at a rate of 75°/s. The backdrop was then moved to guide motion in the scapular plane, defined as 45° to the frontal plane. A physical block on the backdrop limited maximal arm elevation to 150°. Subjects unable to achieve 150° (n = 4) elevated both arms to the maximal angle achieved by the injured side. The final 5 of the 8 repetitions were used for data analysis.

Data Reduction

The 2 clinical assessment methods were compared to a criterion reference of 3D kinematic analysis to evaluate criterion validity. To determine asymmetry, 8 subjects with no previous injuries were identified and clinically assessed by both clinicians to have normal symmetry between scapulae at rest and during dynamic motion. A zero offset was determined from each subject's resting position. The mean difference in position between the right and left scapula at each data point was calculated for scapular posterior tilt (rotation about horizontal axis) and internal rotation (rotation about vertical axis). To determine symmetry of the superior borders, the differences in the amount of translation in the vertical plane of the scapular spine relative to T12 was determined by use of the same procedures. The mean difference was calculated for the 8 symmetric subjects. On the basis of the mean differences, the upper boundary of a 95% confidence interval for each respective plane of scapular motion was used to determine the threshold for symmetric motion. These threshold values for flexion and scaption were 8° and 7°, respectively, for scapular internal rotation and 9° and 8°, respectively, for posterior tilt. A threshold of 1.6 cm for both flexion and scaption was determined for superior scapular translation. Scapular kinematic data not exceeding any of these 3 thresholds were considered to indicate symmetric scapular motion, whereas differences exceeding these threshold values were categorized as asymmetric according to 3D kinematic analysis. Asymmetric scapular motion was considered present if the difference between scapulae exceeded threshold values for at least 50 consecutive data points (0.5 seconds) in at least 3 of the 5 trials. Figure 3 illustrates kinematic asymmetric scapular motion quantified by 3D kinematic analysis. These objective criteria from the 3D scapular kinematic analysis provided the standards to validate the 2 clinical assessment methods. The 3D kinematic analysis was used to determine prevalence of scapular asymmetry as either a single plane of asymmetry or multiple-plane asymmetry.

Statistical Analysis

The inter-rater reliability of both clinical assessment methods was determined by use of a κ correlation, which is used with categorical and nominal data, to determine the relative agreement between investigators.[20] The scores for κ range from 0 to 1, with a 1 representing perfect agreement.[22] To determine the criterion validity, each clinical assessment method was compared to the category derived from the objective 3D kinematic analysis to determine the sensitivity, specificity, positive predictive value, negative predictive value, and accuracy. The prevalence of asymmetric and symmetric occurrences between the symptomatic and asymptomatic groups were compared by use of a Pearson χ^2 analysis with significance set at $P \leq .05$.

RESULTS

The inter-rater reliability of the 4-type clinical assessment method yielded a 61% agreement between the 2 investigators, resulting in a κ correlation of 0.44 ($P < .01$). The yes/no assessment method yielded a 79% agreement, with a κ correlation of 0.41 ($P < .01$). The 2 assessment methods compared with the criterion of the 3D kinematic analysis resulted in an overall accuracy of the 2 evaluation methods ranging between 45% and 66%. The sensitivity of the 4-type method varied across the types of scapular patterns, ranging from 10% to 54%, and the specificity ranged from 62% to 94% (Table 2). The yes/no method resulted in sensitivity ranging from 74% to 78% but decreased specificity, ranging from 31% to 38% for scaption and flexion, respectively (Table 3).

Asymmetry by use of 3D kinematic analysis was described by categorizing the prevalence into 3 levels:

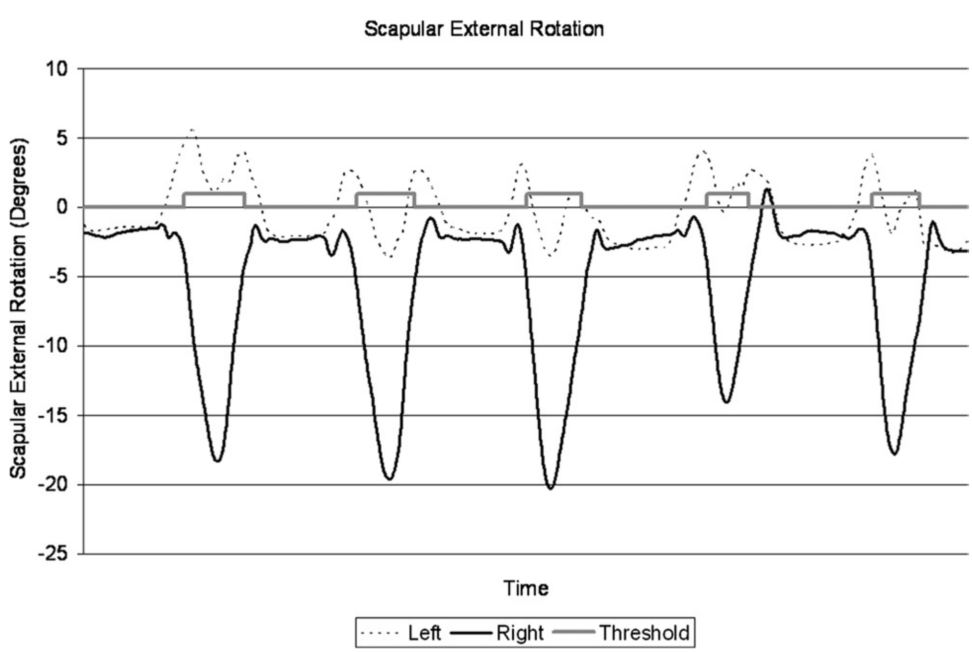

Figure 3. Quantification of asymmetric motion of left scapula during arm elevation. The right scapula externally rotates through elevation and then internally rotates during arm lowering. The left scapula attempts to externally rotate but is unable, which would produce a clinically observed prominent medial border (type II). The gray line indicates an asymmetric threshold, when the differences in rotation of the 2 scapulae exceed the symmetry criterion threshold of an 8° difference for internal rotation.

Table 2. *Validity of 4-Type Assessment Method of Scapular Dyskinesis Compared Against 3D Kinematic Analysis Performed During Humeral Scaption and Flexion*

	Type I	Type II	Type III	Type IV
Scaption				
Sensitivity	47%	10%	13%	31%
Specificity	62%	85%	80%	74%
Positive predictive value	58%	43%	20%	27%
Negative predictive value	50%	45%	70%	78%
Accuracy	54%	45%	61%	64%
Flexion				
Sensitivity	54%	20%	22%	38%
Specificity	67%	94%	84%	78%
Positive predictive value	58%	71%	40%	40%
Negative predictive value	63%	59%	70%	76%
Accuracy	61%	61%	64%	64%

no asymmetry, single-plane asymmetry, and multiple-plane asymmetries. The Pearson χ^2 analysis for flexion motion showed significant differences in the frequency of asymmetries between the 2 groups, with more multiple-plane asymmetries for the symptomatic group (54.3% [19 of 35]) compared with the asymptomatic group (14.3% [3 of 21]) ($P = .002$) (Table 4). There was no significant difference in the frequency of asymmetries between the 2 groups for elevation in scaption ($P = .97$). The overall prevalence of scapular asymmetry in any plane was not different for the asymptomatic and symptomatic subjects, with 27 of 35 (77%) and 16 of 21 (76%), respectively, in scaption ($P = .87$) and 25 of 35 (71%) and 15 of 21 (71%), respectively, in flexion ($P = .66$).

DISCUSSION

The results affirm the research hypotheses but raise a third clinically relevant question. The results show that the yes/no method increased the inter-rater agreement and increased the sensitivity and positive predictive value over the original 4-type method but the reliability was not improved. This study showed that scapular asymmetry in multiple planes, as determined by 3D kinematic analysis, is more prevalent in symptomatic subjects during humeral elevation in flexion but not in scaption. Asymmetry in 1 or more planes is seen with equal prevalence in both asymptomatic and symptomatic patients with a variety of shoulder pathologies. This occurrence poses a clinically relevant question as to how to interpret a clinical assessment of altered scapular motion. Is the observation "normal" and not significant to the shoulder injury? Do altered motions represent a specific process that always needs to be treated, or are they only important in the larger context of all the factors that may be contributing to shoulder dysfunction and symptoms?

Evaluation of Clinical Assessment Methods

It does not appear that the 4-type method of assessment, which is based on single-plane motion criteria, is representative of the more common multiple-plane asymmetries recorded in this study. The inter-rater agreement of 69% and reliability ($\kappa = 0.44$) yielded a moderate correlation.[22] This is similar to the inter-rater reliability in a previous study, where κ ranged from 0.31 to 0.43.[17] Our study had 2 experienced clinicians evaluate patients directly, which is likely the best-case scenario to enhance inter-rater reliability as compared with the previous study that used videotape recordings. The moderate reliability reflects the difficulty in detecting specific single-plane patterns of scapular dyskinesis due to frequent multiple-plane asymmetries, poor visualization of bony landmarks, and body morphology.

The 4-type assessment method validated against the 3D kinematic system yielded widely variable results. The sensitivity of the 4-type method was low (range, 10% to 54%), whereas the specificity ranged from moderate to good (range, 62% to 94%). It appears that a major factor influencing this outcome is the highly prevalent multiple-plane nature of scapular asymmetries. The 4-type method was designed to identify the predominant pattern of scapular motion in a single plane. However, on the basis of 3D kinematic analysis, multiple-plane asymmetries were commonly present when any asymmetries were identified clinically. Of 41 subjects identified clinically to have scapular asymmetry, 20 showed multiple-plane asymmetries with 3D kinematic assessment. Therefore the low validity of the 4-type method is affected by the constraints placed on the clinician to choose a single plane of asymmetric motion.

Table 3. *Validity of Yes/No Assessment Method of Scapular Dyskinesis Compared Against 3D Kinematic Analysis Performed During Humeral Scaption and Flexion*

	Flexion	Scaption
Sensitivity	78%	74%
Specificity	38%	31%
Positive predictive value	76%	78%
Negative predictive value	40%	27%
Accuracy	66%	64%

Table 4. χ^2 *Frequency Table Showing Differences in Number of Asymmetries, as Determined by 3D Kinematics, Between Two Groups in Humeral Flexion (P = .002)*

	No Asymmetries	Single-Plane Asymmetry	Multiple-Plane Asymmetries	Total
Asymptomatic				
No. of subjects	6	12	3	21
Percentage	28.6	57.1	14.3	100
Symptomatic				
No. of subjects	10	6	19	35
Percentage	28.6	17.1	54.3	100

The yes/no method improved the inter-rater agreement to 79% and improved the sensitivity to 76% without changing the reliability. These improvements may have reflected that the clinician was no longer limited to choosing single-plane categories and because the "yes" category is more inclusive. The positive predictive value, or the probability that 3D kinematic analysis showed that a subject had asymmetric motion when it was observed clinically, was improved to 74%. This indicates that the yes/no assessment method decreases the risk of false-negative findings by better identifying subjects who truly have scapular dyskinesis. The specificity of the yes/no method was 30%, indicating that there is a higher risk of false-positive findings. This combination of values indicates that the yes/no method is a good screening tool in the shoulder evaluation process and provides greater agreement among clinicians (inter-rater reliability) in their observational assessment of scapular dyskinesis.

The yes/no method displayed sensitivity, specificity, and κ values similar to those of other commonly used clinical tests for the shoulder. Clinical tests of SLAP tears showed a mean sensitivity of 57% (range, 32% to 91%) and specificity of 41% (range, 13% to 92%).[23-25] Tests evaluating shoulder laxity and instability display inter-rater agreement κ values of 0.3 to 0.5 and intra-rater reproducibility of 46% to 88%.[26,27] In the evaluation of subacromial impingement, a multitude of tests have shown varying results, with wide ranges of sensitivity (32% to 90%), specificity (25% to 97%), and diagnostic accuracy (33% to 72%).[28,29] These findings support the conclusion that although the criterion validity of the yes/no method is not optimal, it is similar to that of other clinical shoulder tests. These findings reinforce the inherent difficulty in creating highly accurate clinical assessment tools for the shoulder or scapula and underscores the need for further research.[30]

Prevalence of Scapular Asymmetry

This study showed a high prevalence of asymmetric scapular motions in both populations. The incidence of symmetry as quantified by 3D kinematic analysis was found to range between 71% and 77% for all subjects, regardless of symptoms. This suggests that the presence of asymmetry should not be the sole criterion determining the clinical significance of scapular dyskinesis. Objective kinematic analysis often shows asymmetries in bilateral human movement.[18,31,32] The observed scapular alterations, either based on side-to-side differences or compared with normative values, may have multiple causative factors, including ligamentous laxity, muscle imbalance, side dominance, and body alignment.[3,18,31,33-35] These alterations may be asymptomatic in individuals[18] or they may be associated with, but not always found to be causative in, various pathologies such as multidirectional instability[35] or impingement.[1,36]

The second hypothesis of increased prevalence in symptomatic subjects was partially supported through kinematic analysis that showed that symptomatic subjects (54%) had more multiple-plane asymmetries during forward flexion than asymptomatic subjects (14%). However, in scaption there was an equal distribution of multiple-plane scapular asymmetries of 45% in both groups, not supporting this hypothesis. This suggests that the task and the degree of asymmetry may be clinically relevant in distinguishing the scapular dyskinesis that is seen in a symptomatic patient. It is not clear why there were more asymmetries in flexion over scaption. Elevation in scaption appears to activate all the scapular musculature to a moderate degree, whereas forward flexion activities show a bias toward higher serratus anterior activity.[37] Inhibition of the serratus anterior has been identified in the presence of shoulder instability and pain.[1,38] It is feasible that decreased motor activity of the serratus anterior may account for the elevated prevalence in flexion, but because electromyographic data were not collected, this can only be speculation.

How to Interpret a Clinical Finding of Scapular Dyskinesis

Scapular alterations occur in the presence of shoulder pathology. There is ample literature that suggests that scapular alterations or asymmetries are associated with glenohumeral instability,[3,35] acromioclavicular separation,[39] and impingement syndrome.[1,36] These studies report various scapular alterations. Studies evaluating impingement have documented increases in scapular anterior tilt[1,36] and no increase in scapular anterior tilt.[40] One investigation identified increased scapular posterior tilt in patients with posterior impingement.[41] These results support that a single scapular pattern is not associated with a specific diagnosis. Scapular dyskinesis may be clinically compared with patellofemoral malpositioning in the knee[33] or sulcus sign in the shoulder.[31,35] It can exist in asymptomatic individuals, but it should be ruled in or out during the clinical assessment of patients with shoulder pain. The yes/no method's sensitivity would suggest that a "no" finding regarding asymmetry is helpful in ruling out dyskinesis as a contributing factor to shoulder pain. A "yes" finding in the symptomatic shoulder would potentially assist in directing treatment.

This study has several limitations. A potentially significant limitation is the narrow threshold criteria for symmetry. A 95% confidence interval to determine the threshold for symmetry was used based on a small population ($n = 8$) but has similar values to previous studies.[1,12] It is not clear at this time whether the thresholds used in this study are clinically meaningful as predictors of dysfunction. A second limitation is the inclusion of multiple shoulder pathologies. Limiting the symptomatic subjects to a specific diagnosis may have generated more precise findings. However, scapular dyskinesis is seen in association with multiple shoulder pathologies, and no evidence suggests an association between a specific injury and any pattern of scapular dyskinesis. Therefore patients with multiple diagnoses were included. A third limitation is the age difference between the 2 groups. The mean age of the symptomatic group was higher but showed a wide range (16 to 53 years), so the patients could be considered relatively young. The body mass, however, which likely has the most effect on visual and 3D kinematic analysis of scapular dyskinesis, was not significantly different between groups. Lastly, this study did not correlate clinical assessment findings with specific kinematic alterations of scapular motion. This should be a subject of future study.

CONCLUSIONS

The yes/no method allows multiple-plane asymmetries to be considered in clinical assessment, thus rendering it a good screening tool for the presence of scapular dyskinesis. Kinematic analysis shows that asymmetries are common in symptomatic and asymptomatic populations; however, when scapular dyskinesis is found in the presence of shoulder symptoms, it should be considered as a potential contributing factor to shoulder dysfunction. Assessment for scapular dyskinesis in symptomatic patients should include forward flexion motions because the prevalence of multiple-plane asymmetries was higher.

REFERENCES

1. Ludewig PM, Cook TM. Alterations in shoulder kinematics and associated muscle activity in people with symptoms of shoulder impingement. *Phys Ther* 2000;80:276-291.
2. Paletta GA, Warner JJP, Warren RF, Deutsch A, Altchek DW. Shoulder kinematics with two-plane x-ray evaluation in patients with anterior instability or rotator cuff tearing. *J Shoulder Elbow Surg* 1997;6:516-527.
3. Warner JJP, Micheli LJ, Arslanian LE, Kennedy J, Kennedy R. Scapulothoracic motion in normal shoulders and shoulders with glenohumeral instability and impingement syndrome.A study using Moiré topographic analysis. *Clin Orthop Relat Res* 1992:191–199.
4. Kibler WB, McMullen J. Scapular dyskinesis and its relation to shoulder pain. *J Am Acad Orthop Surg* 2003;11:142-151.
5. Burkhart SS, Morgan CD, Kibler WB. The disabled throwing shoulder: Spectrum of pathology. Part I: Pathoanatomy and biomechanics. *Arthroscopy* 2003;19:404-420.
6. Kibler WB. Role of the scapula in the overhead throwing motion. *Contemp Orthop* 1991;22:525-532.
7. 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.
8. Inman VT, Saunders M, Abbot LC. Observations of the function of the shoulder joint. *J Bone Joint Surg Am* 1944;26:1-30.
9. Poppen NK, Walker PS. Normal and abnormal motion of the shoulder. *J Bone Joint Surg Am* 1976;58:195-201.
10. Bey MJ, Zauel R, Brock SK, Tashman S. Validation of a new model-based tracking technique for measuring three-dimensional, in vivo glenohumeral joint kinematics. *J Biomech Eng* 2006;128:604-609.
11. Karduna AR, McClure PW, Michener LA, Sennett B. Dynamic measurements of three-dimensional scapular kinematics: A validation study. *J Biomech Eng* 2001;123:184-190.
12. 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.
13. Odom CJ, Taylor AB, Hurd CE, Denegar CR. Measurement of scapular asymmetry and assessment of shoulder dysfunction using the lateral scapular slide test: A reliability and validity study. *Phys Ther* 2001;81:799-809.

14. Plafcan DM, Turczany PJ, Guenin BA, Kegerris S, Worrell TW. An objective measurement technique for posterior scapular displacement. *J Orthop Sports Phys Ther* 1997;25:336-341.
15. Johnson MP, McClure PW, Karduna AR. New method to assess scapular upward rotation in subjects with shoulder pathology. *J Orthop Sports Phys Ther* 2001;31:81-89.
16. Su KP, Johnson MP, Gracely EJ, Karduna AR. Scapular rotation in swimmers with and without impingement syndrome: Practice effects. *Med Sci Sports Exerc* 2004;36:1117-1123.
17. Kibler WB, Uhl TL, Maddux JQ, McMullen J, Brooks PV, Zeller B. Qualitative clinical evaluation of scapular dysfunction. A reliability study. *J Shoulder Elbow Surg* 2002;11:550-556.
18. Oyama S, Myers JB, Wassinger CA, Ricci D, Lephart SM. Asymmetric resting scapular posture in healthy overhead athletes. *J Athl Train* 2008;43:565-570.
19. Wu G, van der Helm FC, Veeger HE, et al. ISB recommendation on definitions of joint coordinate systems of various joints for the reporting of human joint motion—Part II: Shoulder, elbow, wrist and hand. *J Biomech* 2005;38:981-992.
20. Karduna AR, McClure PW, Michener LA. Scapular kinematics: Effects of altering the Euler angle sequence of rotations. *J Biomech* 2000;33:1063-1068.
21. Tripp BL, Uhl TL, Mattacola CG, Srinivasan C, Shapiro R. A comparison of individual joint contributions to multijoint position reproduction acuity in overhead-throwing athletes. *Clin Biomech (Bristol, Avon)* 2006;21:466-473.
22. Landis JR, Koch GG. The measurement of observer agreement for categorical data. *Biometrics* 1977;33:159-174.
23. Gaunche C, Knatt T, Solomonow M, Lu Y, Barratta R. The synergistic action of the capsule and the shoulder muscles. *Am J Sports Med* 1995;23:301-306.
24. Morgan CD, Burkhart SS, Palmeri M, Gillespie M. Type II SLAP lesions: Three subtypes and their relationships to superior instability and rotator cuff tears. *Arthroscopy* 1998;14:553-565.
25. Stetson WB, Templin K. The crank test, the O'Brien test, and routine magnetic resonance imaging scans in the diagnosis of labral tears. *Am J Sports Med* 2002;30:806-809.
26. Levy AS, Lintner S, Kenter K, Speer KP. Intra- and interobserver reproducibility of the shoulder laxity examination. *Am J Sports Med* 1999;27:460-463.
27. McFarland EG, Torpey BM, Curl LA. Evaluation of shoulder laxity. *Sports Med* 1996;22:264-272.
28. Calis M, Akgun K, Birtane M, Karacan I, Calis H, Tuzun F. Diagnostic values of clinical diagnostic tests in subacromial impingement syndrome. *Ann Rheum Dis* 2000;59:44-47.
29. MacDonald PB, Clark P, Sutherland K. An analysis of the diagnostic accuracy of the Hawkins and Neer subacromial impingement signs. *J Shoulder Elbow Surg* 2000;9:299-301.
30. Bahk M, Keyurapan E, Tasaki A, Sauers EL, McFarland EG. Laxity testing of the shoulder: A review. *Am J Sports Med* 2007;35:131-144.
31. Lintner SA, Levy A, Kenter K, Speer KP. Glenohumeral translation in the asymptomatic athletes shoulder and its relationship to other clinically measurable anthropometric variables. *Am J Sports Med* 1996;24:716-720.
32. McBride ME. Evidence of biomechanical functional symmetry in the presence of lower extremity structural asymmetry during running (Masters of Physical Education). Vancouver: University of British Columbia, 1993.
33. Witvrouw E, Bellemans J, Lysens R, Danneels L, Cambier D. Intrinsic risk factors for the development of patellar tendinitis in an athletic population. A two-year prospective study. *The Am J Sports Med* 2001;29:190-195.
34. Cavanagh PR. The biomechanics of lower extremity action in distance running. *Foot Ankle* 1987;7:197-217.
35. Ogston JB, Ludewig PM. Differences in 3-dimensional shoulder kinematics between persons with multidirectional instability and asymptomatic controls. *Am J Sports Med* 2007;35:1361-1370.
36. Lukasiewicz AC, McClure P, Michener L, Pratt N, Sennett B. Comparison of 3-dimensional scapular position and orientation between subjects with and without shoulder impingement. *J Orthop Sports Phys Ther* 1999;29:574-586.
37. Ekstrom RA, Donatelli RA, Soderberg GL. Surface electromyographic analysis of exercises for the trapezius and serratus anterior muscles. *J Orthop Sports Phys Ther* 2003;33:247-258.
38. Scovazzo ML, Browne A, Pink M, Jobe FW, Kerrigan J. The painful shoulder during freestyle swimming, an electromyographic cinematographic analysis of twelve muscles. *Am J Sports Med* 1991;19:577-582.
39. Gumina S, Carbone S, Postacchini F. Scapular dyskinesis and SICK scapula syndrome in patients with chronic type III acromioclavicular dislocation. *Arthroscopy* 2009;25:40-45.
40. McClure PW, Bialker J, Neff N, Williams G, Karduna A. Shoulder function and 3-dimensional kinematics in people with shoulder impingement syndrome before and after a 6-week exercise program. *Phys Ther* 2004;84:832-848.
41. 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.