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original research

A Clinical Method for Identifying Scapular Dyskinesis, Part 2: Validity

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Context: Although clinical methods for detecting scapular dyskinesis have been described, evidence supporting the validity of these methods is lacking.

Objective: To determine the validity of the scapular dyskinesis test, a visually based method of identifying abnormal scapular motion. A secondary purpose was to explore the relationship between scapular dyskinesis and shoulder symptoms.

Design: Validation study comparing 3-dimensional measures of scapular motion among participants clinically judged as having either normal motion or scapular dyskinesis.

Setting: University athletic training facilities.

Patients or Other Participants: A sample of 142 collegiate athletes (National Collegiate Athletic Association Division I and Division III) participating in sports requiring overhead use of the arm was rated, and 66 of these underwent 3-dimensional testing.

Intervention(s): Volunteers were viewed by 2 raters while performing weighted shoulder flexion and abduction. The right and left sides were rated independently as normal, subtle dyskinesis, or obvious dyskinesis using the scapular dyskinesis test. Symptoms were assessed using the Penn Shoulder Score.

Main Outcome Measure(s): Athletes judged as having either normal motion or obvious dyskinesis underwent 3-dimensional electromagnetic kinematic testing while performing the same movements. The kinematic data from both groups were compared via multifactor analysis of variance with post hoc testing using the least significant difference procedure. The relationship between symptoms and scapular dyskinesis was evaluated by odds ratios.

Results: Differences were found between the normal and obvious dyskinesis groups. Participants with obvious dyskinesis showed less scapular upward rotation ($P < .001$), less clavicular elevation ($P < .001$), and greater clavicular protraction ($P = .044$). The presence of shoulder symptoms was not different between the normal and obvious dyskinesis volunteers (odds ratio = 0.79, 95% confidence interval = 0.33, 1.89).

Conclusions: Shoulders visually judged as having dyskinesis showed distinct alterations in 3-dimensional scapular motion. However, the presence of scapular dyskinesis was not related to shoulder symptoms in athletes engaged in overhead sports.

Key Words: shoulder, upper extremity, kinematics, assessment

Key Points

- Validity of the scapular dyskinesis test was demonstrated, because participants with and participants without dyskinesis displayed differences in scapular kinematics.
- Scapular kinematics in athletes identified as having dyskinesis were similar to those in athletes with other shoulder conditions, including impingement syndrome and the SICK scapula syndrome.

Scapular dyskinesis is the term given to visible alterations in scapular position and motion patterns, and alterations in scapular motion patterns have been associated with shoulder injury.[1] Compared with people having normal shoulders, differences in scapular kinematics have been found in people with instability, rotator cuff tears, and impingement syndrome.[1–8] Visually, these findings have been reported as scapular winging or asymmetry, although the visual assessments were not validated.

Findings of kinematic studies in individuals with shoulder injuries have been variable and include increased scapular superior translation,[3,9] reduced scapular posterior tilt,[3,4,10] reduced scapular upward rotation and internal rotation under loaded conditions,[4,11] altered glenohumeral-scapulothoracic ratios,[12,13] and changes in scapular kinematics with resistance or fatigue.[14–18] One group,[9] however, found alterations opposite to those reported above, including greater upward rotation during flexion and greater posterior tilt and upward rotation during scaption in those with subacromial impingement syndrome, which the authors cited as possible favorable compensatory responses to increase the subacromial space. Finally, Graichen et al[12] noted no alterations in shoulder girdle motion when comparing those having unilateral impingement with controls. Yet they found a subset of patients who had signs of "pathological scapulohumeral relationships (increased glenoid [upward] rotation)" and suggested that this subset may benefit from efforts to correct shoulder motion patterns rather than surgery.

We hypothesized that the variable findings from kinematic studies and the generally small differences found between asymptomatic and symptomatic participants (typically less than 5°) may be attributable to excessive variation among individuals. A validated method that can reliably identify people with scapular motion abnormalities

Table 1. Participant Characteristics

		Flexion[a]		Abduction[b]	
	All Participants (n = 66)	Normal (n = 31)	Dyskinesis (n = 31)	Normal (n = 36)	Dyskinesis (n = 11)
Age, y (mean ± SD)	20.7 ± 2.6	21.3 ± 2.7	20.0 ± 2.2	20.9 ± 2.6	19.7 ± 2.3
Height, cm (mean ± SD)	178.8 ± 9.5	179.7 ± 9.6	178.4 ± 9.3	180.4 ± 9.0	168.7 ± 9.1
Mass, kg (mean ± SD)	78.0 ± 12.7	80.7 ± 13.4	76.5 ± 12.1	79.1 ± 12.0	65.7 ± 8.6
Body mass index	24.3 ± 2.6	24.8 ± 2.7	23.9 ± 2.5	24.2 ± 2.6	23.0 ± 2.1
Side tested					
Right		12	13	18	6
Left		19	18	18	5
Dominant side					
Right	62	29	29	33	11
Left	4	2	2	3	0
Sex					
Male	50	26	22	30	2
Female	16	5	9	6	9
Sport					
Water polo	40	19	19	23	2
Swimming	12	8	3	5	4
Baseball	11	2	8	4	5
Other	3	2	1	4	
NCAA Division					
I	40	24	20	27	2
III	26	7	11	9	9

Abbreviation: NCAA, National Collegiate Athletic Association.

[a] The pooled kinematic data for flexion from the 31 shoulders rated as having obvious dyskinesis were compared with the data from 31 shoulders having normal motion.

[b] The pooled kinematic data from all 11 shoulders with obvious dyskinesia were compared with the data from 36 shoulders having normal motion.

and that is suitable for routine clinical use would be of great value, because it would allow us to screen those who may be at risk for developing shoulder injuries because of abnormal scapular motion. It would also allow us to direct specific interventions aimed at improving scapular muscle force and control in those with scapular injuries. Finally, it would assist future researchers in efforts directed at understanding the role of scapular dyskinesis in those with injuries.

Previous assessment measures of scapular motion have limitations. Some involve the use of sophisticated technology such as Moire topography,[1] electromagnetic tracking,[9,19–21] or magnetic resonance imaging,[12] which are impractical for routine clinical use. In 1998, a measurement of scapular stability, the lateral scapular slide test, was devised for use at static positions during arm elevation.[22] The lateral scapular slide test defines an ''abnormality'' as a 1.5-cm difference in side-to-side linear measurements between the scapula and spine with the arm placed in 3 test positions. However, because this technique uses only linear measures along the thorax, it does not address displacement of the scapula's medial border or inferior angle away from the thoracic wall (ie, winging). Additionally, in a study of 71 collegiate athletes who participated in 1-arm–dominant sports, 52 exhibited a difference of at least 1.5 cm on 1 or more of the 3 positions assessed for the lateral scapular slide test,[23] which brings into question the usefulness of asymmetry as an indicator of injury. Kibler et al[24] described a visual classification system using 3 types of dyskinesis or a normal (symmetrical) motion pattern, but the reported interrater reliability of the system ($\kappa = 0.4$) may be too low to support its use as described. Additionally, the validity of this system has not been established.

The purpose of our study was to determine the validity of a newly developed visually based test for scapular dyskinesis, the scapular dyskinesis test (SDT), by comparing kinematic measures obtained from a 3-dimensional (3-D) electromagnetic motion tracking system between those with normal motion and those with obvious dyskinesis as identified by the SDT. A secondary purpose was to identify any relationship between judgments of dyskinesis using the SDT and symptoms in athletes currently participating in sports requiring repetitive overhead movements.

METHODS

Participants

Volunteers for this kinematic validation study (n = 66) were collegiate athletes involved in overhead sports recruited from a larger reliability study sample (n = 142) described in part 1 of this 2-part study.[25] All 142 participants performed 5 repetitions of bilateral, active, weighted shoulder flexion and bilateral, active, weighted shoulder abduction (coronal plane), which constitute the tasks for the SDT. As the volunteers performed these shoulder elevation tasks, their scapular motion patterns were rated by 2 trained raters (a certified athletic trainer and a physical therapist or physical therapy student).[25] Only participants with 1 or both weighted test movements rated as having either normal motion or obvious dyskinesis by both raters during the visual assessment were invited to undergo instrumented 3-D testing. Although 104 volunteers met the criteria for instrumented testing, 66 agreed to undergo instrumented testing. The characteristics of these individuals are given in Table 1. Visual ratings and instrumented data were collected bilaterally, but data from only 1 shoulder of any single participant were used. Obvious dyskinesis was characterized by either scapular winging or dysrhythmia (or both) as operationally defined in part 1 of this study.[25] Athletes were not recruited for instrumented testing if their shoulders were rated as having a subtle abnormality or if the raters disagreed on the rating for a test movement.

To determine the relationship between visually determined scapular dyskinesis and the presence of symptoms, 104 participants were included from the larger sample of 142 if both raters agreed on the rating as being either normal or obvious dyskinesis. Data from only 1 shoulder were used from each volunteer, either the most painful shoulder or the dominant shoulder if no pain was reported. Before testing, all participants signed a consent form approved by Arcadia University and Temple University institutional review boards, which also approved the study.

Instrumentation

The Liberty electromagnetic-based motion capture system (Polhemus, Colchester, VT) was used with MotionMonitor software (Innovative Sports Training, Inc, Chicago, IL) for collection of 3-D kinematic data of the shoulder complex.[9,26,27]

A transmitter emits a low-frequency magnetic field that is detected by a digitizing stylus and receivers that serve as sensors to capture the position and orientation of the humerus, scapula, and thorax. The transmitter served as a global reference frame and was mounted to a rigid plastic base and oriented so that it was level, with its coordinate axes aligned with the cardinal planes of the human body.[27] The thoracic sensor was affixed to the manubrium of the sternum with double-sided tape. The humeral receiver was positioned over a neoprene elbow sleeve on the distal humerus with a hook-and-loop strap. The scapular receiver was applied to a custom-made, adjustable scapular-tracking jig machined from plastic, which was attached to the skin with hook-and-loop adhesive tape.[26] The accuracy of the electromagnetic tracking device has been reported as 0.8 mm and 0.15° by the manufacturer and has been previously verified.[28]

The arbitrary axis systems defined by the Liberty sensors were converted to anatomically appropriate axis systems by using a series of standardized axes embedded in each segment,[27] as recommended by the International Society of Biomechanics.[29] The data were converted to anatomically defined scapular rotations using a Euler angle sequence of external rotation, upward rotation, and posterior tilting.[29,30] In addition to the 3 scapular rotations used to describe scapular orientation, the position of the scapula with respect to the thorax was described using 2 clavicular rotations (Figure 1).[9,27] The surface-based electromagnetic tracking method has been validated by comparison with measures from a sensor mounted on bone pins attached directly to the scapula, with average errors ranging between 1.0° and 3.5° for scapular motions during humeral elevation, after a correction factor was used for measurement of upward rotation.[26] Intraclass correlation coefficients (2, 1) reflecting reliability among 3 testers for 9 participants ranged from 0.69 to 0.95 for scapular motions.[26]

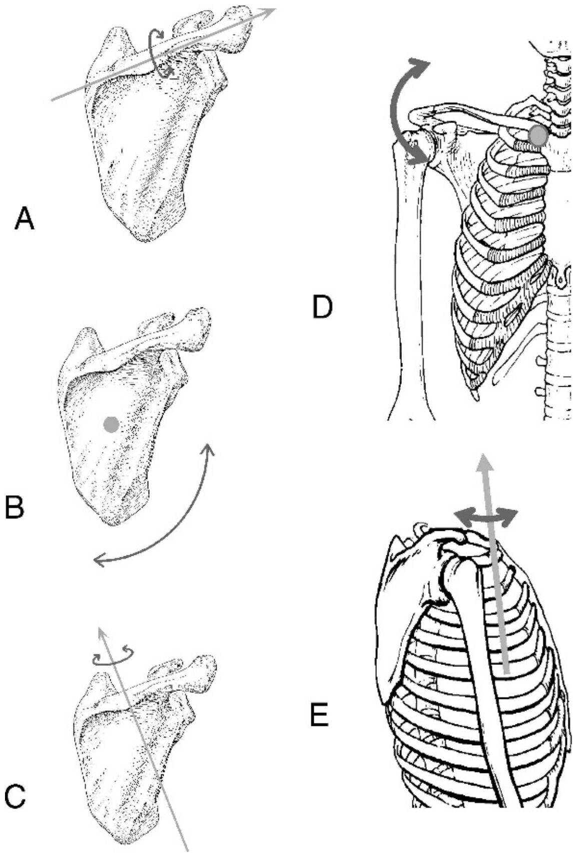

Figure 1. Individual axes and rotations used to describe scapular orientation and position. A, Scapular posterior tilting. Negative or decreasing values represent anterior tilting. B, Scapular upward rotation. Negative or decreasing values represent downward rotation. C, Scapular external rotation. Decreasing values represent scapular internal rotation. Because the scapula remains internally rotated relative to the frontal plane of the thorax, these values remain negative. D, Clavicular elevation. Negative or decreasing values represent clavicular depression. E, Clavicular protraction. Decreasing values represent retraction. Because the clavicle tends to remain retracted relative to the frontal plane of the thorax, these values typically remain negative. Reprinted with permission of the American Physical Therapy Association.[27] This material is copyrighted, and any further reproduction or distribution is prohibited.

Experimental Procedure

Male volunteers were asked to remove their shirts, and female volunteers were asked to wear halter tops during the study to allow visualization of the posterior thorax. The participants completed demographic and self-report measures, including the pain subscale of the Penn Shoulder Score.[31]

Instrumented testing occurred either on the same day or within 3 days of the initial testing. If volunteers did return at a later date, they were revideotaped and subsequently rated to assure that the movement pattern had not changed. Three-dimensional shoulder kinematic data were

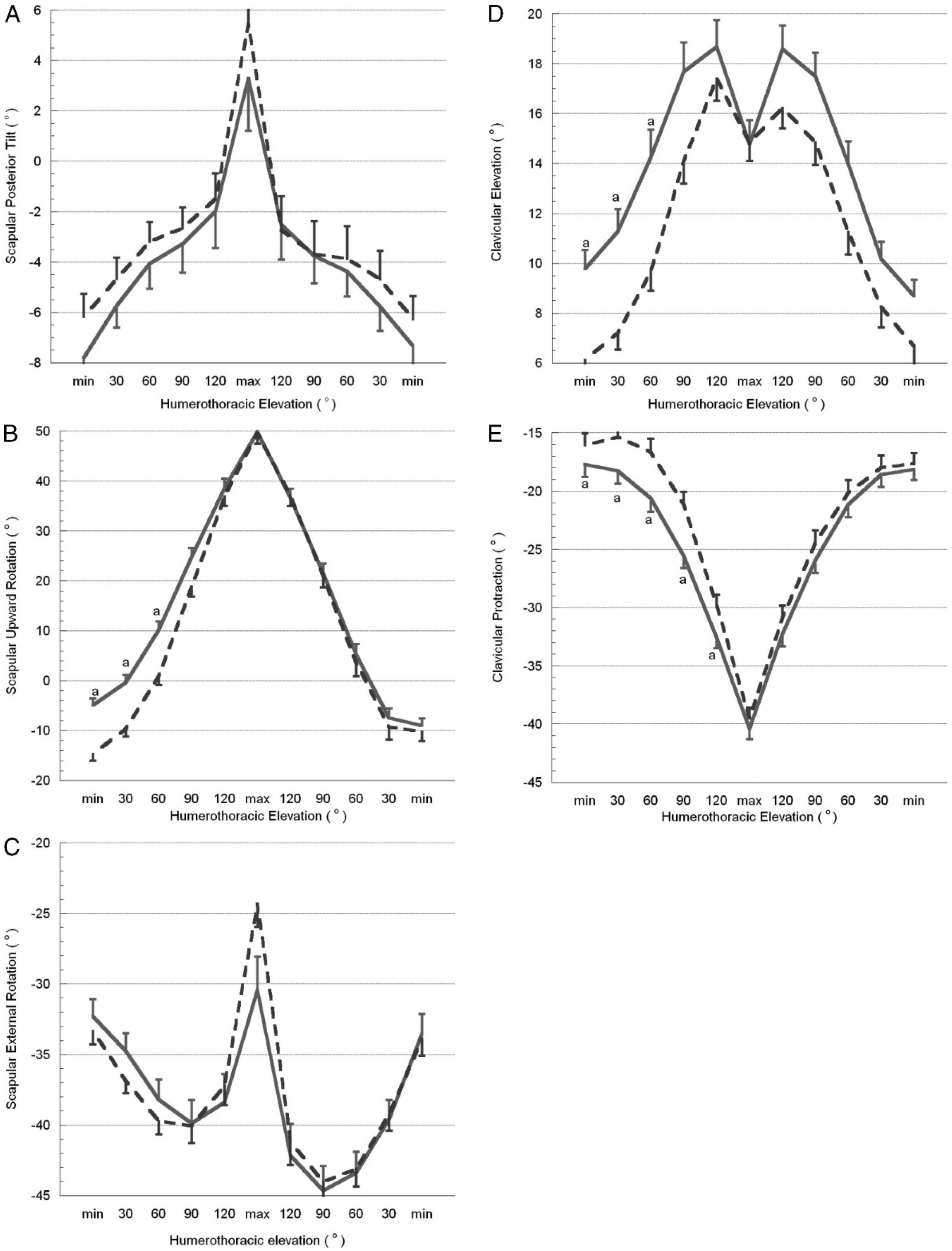

Figure 2. Mean scapular rotations during humerothoracic flexion during arm elevation (minimum [min] to maximum [max]) and lowering (max to min). The solid line represents the mean values of the participants with normal motion; the dashed line represents the mean values of the participants with obvious dyskinesis during weighted test movements. The minimum values for humerothoracic flexion for the normal and abnormal groups were 9.8 and 8.2, respectively; the maximal values were 149.6 and 150.0, respectively. A, Scapular posterior tilting, with negative or decreasing values representing anterior tilting. B, Scapular upward rotation, with decreasing values representing

collected on each individual as he or she performed 3 repetitions of bilateral weighted flexion and weighted abduction as previously described, with sensors fixed to the thorax, scapula, and humerus. The tests were performed with participants grasping dumbbells, using 1.4 kg (3 lb) for those weighing less than 68.1 kg (150 lb) and 2.3 kg (5 lb) for those weighing 68.1 kg or more. The same physical therapist set up and tested all volunteers and was blinded to the visually based rating of the athlete from the SDT.

The position and orientation of the scapula in relation to the thorax during humeral elevation were determined through continuous collection of sensor data at a rate of 120 Hz during the 3 repetitions. The scapular and clavicular rotation data were then averaged and reported in 5° increments of humerothoracic elevation.

Data Analysis

Although 66 people were tested, some had obvious dyskinesis only with flexion and others had obvious dyskinesis only with abduction. The pooled kinematic data for flexion from all of the shoulders rated as having obvious dyskinesis (n = 31) were compared with data from shoulders rated as having normal motion (n = 31) for flexion. For data analysis, the data from all participants rated as normal or obvious dyskinesis unilaterally were used. For those rated as normal or obvious dyskinesis bilaterally, the athletes were listed numerically based on testing date, and data from alternate sides (left, then right) were selected. Therefore, data from only 1 side were used for any single person in order to maintain independent samples.[32] For abduction, the pooled kinematic data from all 11 shoulders with obvious dyskinesis were compared with the data from 36 shoulders rated as having normal motion during abduction, using the same data selection method. Means for each of the 5 kinematic descriptors of scapular motion were compared for weighted flexion and weighted abduction at 30° increments of motion between rest and 120° of humeral elevation. Kinematic data above 120° of elevation were not used because of the greater error with the scapular tracking device in this range.[26]

We performed a mixed-model analysis of variance to assess group-by-angle interactions. However, the data were not normally distributed, as determined by the Wilk-Shapiro test for normality. Therefore, we conducted a nonparametric analysis of variance on ranks for statistical analysis. The factor group included those with normal scapular motion or obvious dyskinesis, as identified by the SDT. The repeated factor was humerothoracic elevation angle, which began with the arms at rest by the side (termed *min*) and then at 30° increments to 120°. An α level of .05 was used for all tests. Post hoc testing with the least significant difference procedure was used for data exploration because of the lack of a priori hypotheses about the comparisons performed.[33] All statistical tests were performed with SAS (version 9.1; SAS Institute, Cary, NC). An odds ratio was calculated to determine the association between the presence of obvious dyskinesis as determined by the SDT and symptoms identified by the pain subscale of the Penn Shoulder Score.[34] The pain subscale involves the participant's rating the intensity of pain from 0 (*no pain*) to 10 (*worst pain*) under 3 conditions: (1) at rest with the arm by the side, (2) with normal activities such as dressing, and (3) with strenuous activities such as reaching and throwing, for a possible total of 30 points. Although the pain ratings of these athletes were relatively low, we wanted to develop a rating system that could be used as a screening tool in athletes. Of the 142 athletes screened for this study, 69.7% (n = 99) indicated that they experienced pain during strenuous activities such as sports. Two separate threshold criteria were assessed for the presence of symptoms: greater than or equal to 3/30 or greater than or equal to 6/30 on the Penn Shoulder Scale. We used 2 thresholds to see if the intensity of reported symptoms would change the odds ratio.

RESULTS

Group mean plots of scapular motion for each of the kinematic variables versus humeral elevation for weighted flexion and weighted abduction are shown in Figures 2 and 3, respectively.

For flexion, a main effect was found for humeral angle ($P < .001$) for all 5 of the kinematic descriptors during both raising and lowering of the arm, simply indicating that the scapula and clavicle move in a characteristic pattern as the arm is raised and lowered. A group-by-angle interaction was noted for scapular upward rotation ($P < .001$), clavicular elevation ($P < .001$), and clavicular protraction ($P = .04$), indicating differences between those judged as normal on the SDT and those judged to have obvious dyskinesis. The dyskinesis group had less upward rotation at rest and remained less upwardly rotated during arm elevation, with an approximate 9° difference between the groups at rest ($P < .001$) and at 30° ($P = .001$) and 60° ($P = .01$) of humerothoracic elevation. For clavicular elevation, the dyskinesis group began with less clavicular elevation ($P = .05$) and remained less elevated during raising and lowering, with post hoc differences at 30° ($P = .03$) and 60° ($P = .03$) of elevation. The differences between groups at these angles were about 4°. The dyskinesis group also began in a more protracted position and remained more protracted than the normal group during arm elevation, with differences at rest ($P = .02$), 30° ($P = .03$), 60° ($P = .008$), 90° ($P = .002$), and 120° ($P = .03$), with a maximum difference between groups of 4.5° at 90° of humerothoracic elevation. The dyskinesis group began more internally rotated and then moved into relatively more external rotation during the higher angles of elevation. However, the between-groups differences were not significant. Similarly, no differences were found

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scapular downward rotation. C, Scapular external rotation, with decreasing values representing scapular internal rotation. D, Clavicular elevation, with decreasing values representing clavicular depression. E, Clavicular protraction, with decreasing values representing retraction. The clavicle remains retracted with respect to the coronal plane of the thorax and, therefore, exhibits negative values. Error bars indicate standard error. [a] Indicates $P < .05$.

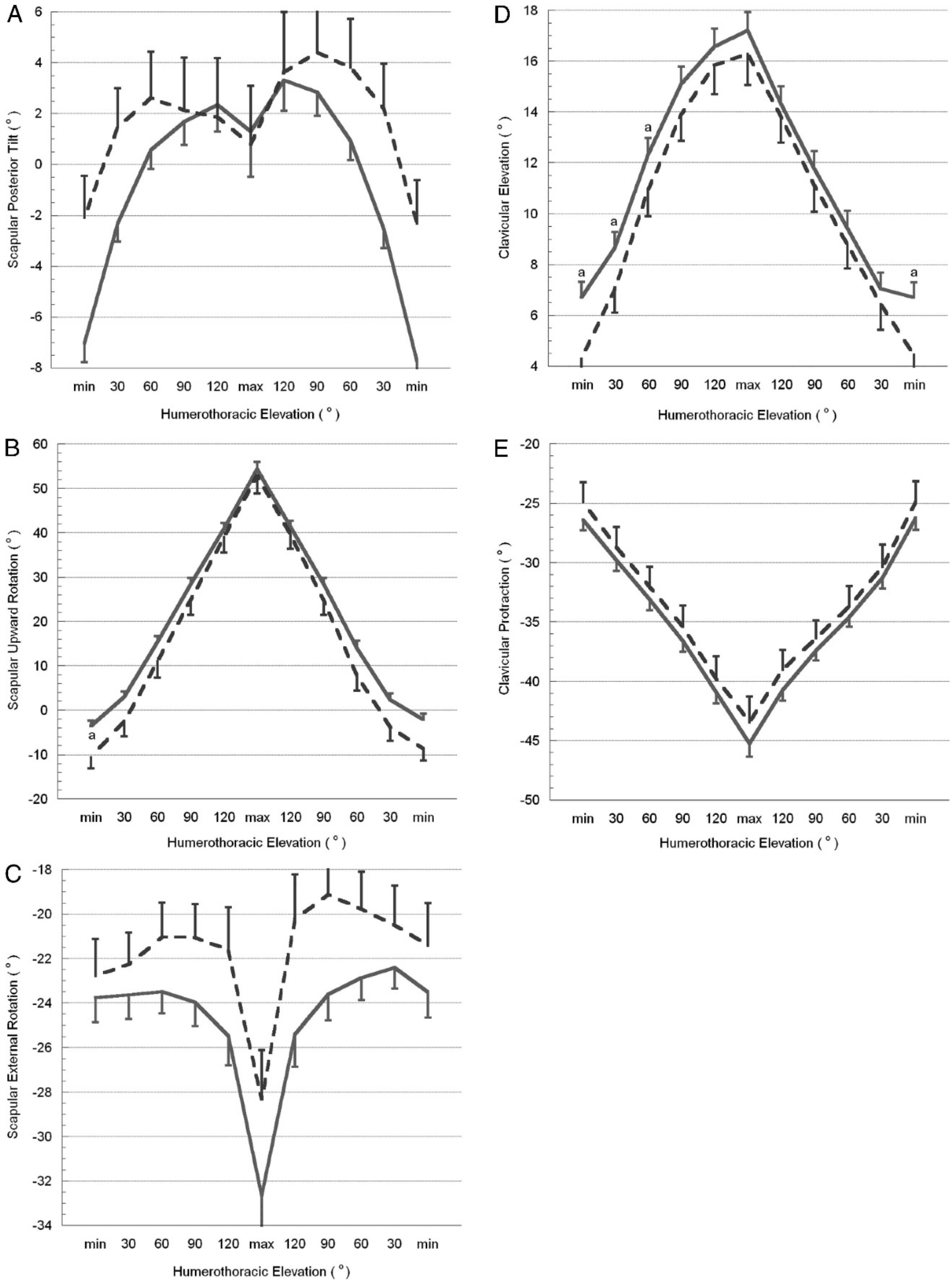

Figure 3. Mean scapular and clavicular rotations during humerothoracic coronal-plane abduction during arm elevation (minimum [min] to maximum [max]) and lowering (max to min). The solid line represents the mean values of the participants judged to have normal motion; the dashed line represents the mean values of the participants judged to have obvious dyskinesis during weighted test movements. The minimum values for humerothoracic abduction for the normal and abnormal groups were 6.2 and 3.7, respectively; the maximum values were 149.2 and 149.3, respectively. A, Scapular posterior tilting, with negative or decreasing values representing anterior tilting. B,

Table 2. The Relationship Between Scapular Dyskinesis Ratings Using the Visual Classification System (SDT) and Self-Reported Pain (n = 104)

Scapular Dyskinesis	Pain > 3/30		Pain > 6/30	
	Yes	No	Yes	No
Yes	12	16	4	24
No	37	39	15	61

Abbreviation: SDT, scapular dyskinesis test.

between the groups for posterior tilting or during the descending phase (arm lowering) with the flexion task.

For abduction, group-by-angle interactions were noted for upward rotation, clavicular elevation, and posterior tilting, with the dyskinesis group having less scapular upward rotation ($P = .001$), less clavicular elevation ($P = .03$), and greater posterior tilting ($P < .001$) than the group judged visually as normal. As with the weighted flexion test movement, the dyskinesis group demonstrated less upward rotation and less clavicular elevation than the normal group during weighted abduction, although the post hoc tests were significant only at rest ($P = .03$) for upward rotation and at rest ($P = .005$) and at the 30° ($P = .04$) and 60° ($P = .05$) positions for clavicular elevation. The actual between-groups differences at these positions were 5° to 7° for upward rotation and less than 3° for clavicular elevation. The dyskinesis group began with greater posterior tilting at rest (a 5° difference), but no between-groups differences were seen at rest or at other angles with post hoc testing. As with flexion, a difference between the groups was present during arm lowering with post hoc testing ($P = .01$), but this difference was only significant with the arm at the side, with the clavicle being less elevated in the dyskinesis group ($P = .01$).

The frequency of shoulder symptoms among participants visually judged to have obvious dyskinesis by both raters according to the SDT is shown in Table 2. We calculated odds ratios using the presence or absence of dyskinesis and shoulder symptoms based on a value of either greater than or equal to 3/30 or 6/30 on the Penn Shoulder Scale. The resultant odds ratios were 0.79 (95% confidence interval = 0.33, 1.89) and 0.68 (95% confidence interval = 0.2, 2.25), respectively, indicating no relationship between the presence of pain and scapular dyskinesis in these athletes.

DISCUSSION

The pattern of scapular upward rotation, posterior tilting, and external rotation, as well as clavicular retraction and elevation during humeral elevation, that we found is consistent with the results of others who have defined scapular motion of unimpaired shoulders using electromechanical digitization[3,35,36] and electromagnetic sensors.[4,9,28,37] The finding of differences between the groups (normal and obvious dyskinesis) in several kinematic descriptors demonstrates that shoulders judged as having obvious dyskinesis actually possess different kinematics, providing evidence for validity of the SDT. We purposely chose to exclude participants visually judged as having subtle dyskinesis from 3-D testing because we believe this rating reflects an ambiguous clinical situation. In people with subtle dyskinesis, the decision to intervene in some way (eg, scapular exercise, taping, bracing) would likely be based more on factors other than motion assessment, whereas a rating of obvious dyskinesis would form a stronger basis for intervention.

The greatest difference between the normal athletes and those with dyskinesis was in upward rotation, with the dyskinesis group being roughly 9° more downwardly rotated at rest through 60° of humeral elevation in the sagittal plane. Interestingly, the dyskinesis group eventually "caught up" and achieved the same maximal amount of upward rotation as the normal group, but the large differences throughout this arc of motion are clearly visible and may have functional significance, especially at 60°. Impingement symptoms are commonly present during a 60° to 120° arc of arm elevation, where the cuff most closely approximates the acromion.[38] The suprahumeral structures, namely the rotator cuff, subacromial bursa, and long head of the biceps tendon, are likely to incur greater compression with a reduction in upward rotation. Kamkar et al[39] suggested that upward rotation of the scapula due to serratus anterior muscle activity is vital to prevent the humeral head from impinging on the acromion and that excessive winging or anterior tilting leads to a relative decrease in the subacromial space. In volunteers with impingement syndrome, Ludewig and Cook[4] found a decrease in upward rotation at 60° of humeral elevation, as we noted, although McClure et al[9] saw increased upward rotation in those with impingement, which the authors felt might be a compensatory mechanism. Our athletes were not currently seeking treatment and had lower pain levels than those referred for physical therapy intervention in the McClure et al[9] study. Similarly, the participants in the Ludewig and Cook[4] study were overhead workers with symptoms of impingement, not patients referred for treatment. Those with higher pain levels seeking medical attention may develop compensatory strategies, but this has not been determined in a longitudinal study. In addition, compared with individuals not participating in overhead athletics, throwing athletes demonstrate kinematic adaptations including increased scapular upward rotation, which is thought to enhance their performance.[37] Given these findings, it appears that the decreased upward rotation found in the group with abnormal motion may put these athletes at risk for subacromial impingement.

The dyskinesis group had less clavicular elevation at 30° and 60° during arm elevation. This result is consistent with the SICK scapula syndrome, which Burkhart et al[40] described as scapular malposition, inferior medial border prominence, coracoid pain and malposition, and dyskinesis of scapular movement. The scapular malposition in the

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Scapular upward rotation, with decreasing values representing downward rotation. C, Scapular external rotation, with decreasing values representing scapular internal rotation. D, Clavicular elevation, with decreasing values representing clavicular depression. E, Clavicular protraction, with decreasing values representing retraction. The clavicle remains retracted with respect to the coronal plane of the thorax and, therefore, exhibits negative values. Error bars indicate standard error. [a] Indicates $P < .05$.

SICK scapula appears clinically as a "dropped" or lower scapula on the involved side in symptomatic throwing athletes[40] and may be described kinematically as a depressed clavicle (ie, reduced clavicular elevation), which was seen in those with obvious dyskinesis in this study. The inferior medial border prominence of the SICK scapula syndrome was defined visually in our study as winging, which presents kinematically as anterior tilting. Although the raters often appreciated the winging visually, we did not note increased anterior tilting in the kinematic analysis. One explanation for this result may be that the excursion during movement (which was not tested statistically) may be more relevant than absolute position. Normal participants tilted during arm elevation in either plane about 10°, whereas those with dyskinesis tilted posteriorly only about 4°, even though they started in a more posteriorly tilted position. This lack of posterior excursion during arm elevation may have been visually detected as winging. Measurement error may have also contributed, as the large muscle bulk of the supraspinatus and infraspinatus in these athletes could have reduced the ability of the scapular tracking jig to "grasp" the scapular spine and detect anterior-posterior tilting motion. The dyskinesis of scapular movement in the SICK scapula assumes that the abnormalities present at rest persist during arm movement. Our finding of differences between the groups in clavicular elevation, clavicular protraction, and upward rotation at multiple points in the range of motion, particularly in the lower ranges, supports this assertion.

The dyskinesis group began in a more protracted position and remained more protracted than the normal group during both arm elevation and lowering. Solem-Bertoft et al[41] found a reduction in the opening of the subacromial space with the scapula in a protracted position, compared with a retracted position on magnetic resonance imaging. The greater protraction in those with dyskinesis may be relevant to the compression of structures within the subacromial space.

Kinematic differences between the normal and dyskinesis groups were not seen for scapular internal-external rotation. Winging, as defined in our study, may result from increased scapular internal rotation or increased anterior tilting. The latter would be visually apparent as inferior angle winging. An increase in internal rotation would present visually as medial border winging, which our raters did observe, and this was included in our definition of winging. In a kinematic study of asymptomatic adults with a mean age of 25.9 years, the pattern of progressive upward rotation and posterior tipping (tilting) was exhibited by 100% of the participants during humeral elevation in the scapular plane.[35] However, external rotation demonstrated greater variability, with 84% having a pattern of progressive external rotation and 16% maintaining about the same scapular-plane orientation at multiple levels of arm elevation. It may be that the differences in internal rotation in those with visually apparent medial border winging were not great enough to achieve significance in a scapular rotation variable that exhibits large amounts of variability among persons in this general age group. Alternatively, the large muscle bulk of these athletes may have produced measurement error.

Considering the evidence linking scapular dyskinesis with potentially adverse biomechanics of the shoulder, we expected an association between symptoms and scapular dyskinesis. However, our findings do not support this association. Although the data presented here fail to support a relationship between dyskinesis and pain, the results are based on a subclinical sample with minimal pain and, therefore, should not be generalized to patients seeking care in a clinical setting. Further research is needed in the clinical setting to elucidate the relationship between scapular motion patterns and patient symptoms.

One limitation of this study is that the participants were competitive collegiate athletes, and despite the acknowledgement of shoulder pain by some, none felt their pain to be significant enough to require current treatment or limit athletic participation. Therefore, care should be taken in generalizing the study's findings to a clinical population. Further studies of patients with shoulder injuries appear warranted.

CONCLUSIONS

The SDT is a visual classification system for scapular motion patterns that has been used to differentiate those with normal motion from those with dyskinesis. Validity of this test has been demonstrated by differences in scapular kinematics found between participants with and without dyskinesis. Furthermore, those identified as having dyskinesis possess alterations in scapular kinematics similar to those with shoulder impingement syndrome and to throwing athletes described as having the SICK scapula syndrome. Further studies should determine the relationship among pathology, symptoms, and scapular dyskinesis and determine the prognostic value of identifying abnormal scapular kinematics in a patient population.

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