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Scapular Dysfunction in Throwers With Pathologic Internal Impingement

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Study Design: Case control group study.

Objectives: To compare scapular position and orientation between baseball players with and without pathologic internal impingement.

Background: Scapular dysfunction has been implicated as a contributor to throwing-related pathologic internal impingement of the shoulder due to its role in increasing the contact between the greater tuberosity and posterior-superior glenoid, thereby impinging the posterior rotator cuff tendon(s) and labrum. However, to date, no definitive data demonstrate this scapular dysfunction in throwing athletes. The purpose of this study was to assess, in a controlled laboratory environment, whether scapular position and orientation would be different in throwing athletes diagnosed with pathologic internal impingement than in a control group of throwing athletes.

Methods and Measures: Eleven throwing athletes diagnosed with pathologic internal impingement, using both clinical examination and a magnetic resonance arthrogram, were demographically matched with a control group of 11 throwers with no history of upper extremity injury. An electromagnetic tracking device was used to measure scapular internal/external rotation, anterior/posterior tilt, upward/downward rotation, sternoclavicular protraction/retraction, and elevation/depression during humeral elevation within the scapular plane. Comparisons were made between groups with analysis of variance models ($P<.05$).

Results: The individuals in the pathologic internal impingement group demonstrated statistically significant increased sternoclavicular elevation when elevating their humerus from 30° to 120° ($P = .002$) and from 60° to 120° ($P = .003$), compared to the control group. Furthermore, these patients also had increased posterior scapular tilt position ($P = .016$). No statistically significant differences were present in any other scapular variables measured.

Conclusions: Based on the results of this study, throwing athletes diagnosed with pathologic internal impingement present with statistically significant increases in sternoclavicular elevation and scapular posterior tilt position during humeral elevation in the scapular plane. *J Orthop Sports Phys Ther 2006;36(7):485-494.* doi:10.2519/jospt.2006.2146

Key Words: *pathologic internal impingement, scapular kinematics, throwing athletes*

Previous research has demonstrated an association between dysfunctional scapular position and orientation with shoulder pathology.[12,16,20] Ludewig and Cook[16] assessed scapular kinematics using an electromagnetic tracking device in patients with subacromial impingement and demonstrated both decreased upward scapular rotation and decreased posterior tilting during humeral elevation. Similar methods and results were reported by Lukasiewicz et al,[20] who showed that patients with symptomatic subacromial impingement had less posterior tilting as well as increased scapular elevation. In throwing athletes, both Burkart et al[2] and Kibler et al[12] have provided clinically-based descriptions of how 3-dimensional scapular dyskinesis may be associated with subacromial impingement, labral pathology, and rotator cuff tears.

Recently, it has been recognized that throwers can present with posterior shoulder pain during the late cocking phase, specifically at end ranges of humeral external rotation.[9,14,34] It is believed that this pain results from internal impingement of the supraspinatus (and occasionally the infraspinatus) between the greater tuberosity and/or the posterior aspect of the humeral head with the

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posterior-superior glenoid labrum. While it is believed that contact between the humeral head and the posterior-superior glenoid labrum is a normal physiological occurrence, the biomechanics of the throwing motion are believed to intensify this contact and its effect on the involved anatomical structures.[3,5,7,9,15,22,28,34] Thus, pathological internal impingement of the supraspinatus and infraspinatus can result. Using arthroscopy, clinicians have identified undersurface lesions on the posterior aspect of the supraspinatus and anterior portion of the infraspinatus tendons, and fraying of the posterior-superior glenoid labrum in overhead athletes.[3,15,22,34] Some have suggested that scapular dysfunction may play a significant role in pathologic internal impingement.[2,12]

To date, there is no research to identify if scapular dysfunction is present in throwers diagnosed with pathologic internal impingement. The purpose of this study was to report the scapular position and orientation of throwing athletes diagnosed with pathologic internal impingement, as compared to a control group of throwing athletes using a functional humeral elevation task in a controlled laboratory environment.

METHODS

Subjects

Eleven male competitive baseball players diagnosed with pathologic internal impingement in their throwing shoulder were matched, based on arm dominance, age (within 3 years), height (within 0.2 m), mass (within 5 kg), playing position, and throwing experience (within 4 years) to a control group of 11 baseball players with no history of shoulder pain. Six pitchers and 5 position players participated in each group. All subjects were between the ages of 18 and 30 years. The groups included 14 collegiate baseball players and 8 semiprofessional adult-league participants. Subject demographics appear in Table 1.

The diagnosis of pathologic internal impingement in the experimental group was made by an orthopedic surgeon experienced in treating throwing injuries. A complete history and physical exam, coupled with a magnetic resonance imaging arthrogram with gadolinium, was used for diagnosis. Typically, the subjects with pathologic internal impingement presented with primary posterior-superior shoulder pain that was exacerbated by throwing. The pain specifically intensified in the late cocking phase of the throwing motion. Additional complaints included decreased endurance and decreased ball velocity and control during throwing. The magnetic resonance imaging arthrogram was read by a board-certified musculoskeletal radiologist who identified posterior labral pathology (type I or type II SLAP) and/or partial under-surface rotator cuff tear at the supraspinatus/infraspinatus junction. All subjects with shoulder pain underwent a course of conservative treatment after laboratory testing. Those who failed to positively respond to rehabilitation opted for surgical intervention. Eight of the 11 subjects who participated eventually underwent surgical intervention, during which the pathologic internal impingement diagnosis was confirmed. Other concomitant conditions, including a history of neck pain, external impingement, frank glenohumeral laxity, or previous shoulder/elbow injury that required absence from sport participation (greater than 2 weeks), resulted in exclusion from this study. The control subjects had no self-reported history of shoulder/elbow pathology that required absence from participation.

TABLE 1. Subject characteristics.

	Impingement Group		Healthy Group	
	Mean	SD	Mean	SD
Age (y)	22.1	3.5	21.2	1.7
Height (m)	1.8	0.1	1.8	0.1
Mass (kg)	91.0	14.6	89.9	13.0
Throwing experience (y)	16.2	3.5	13.4	2.7

Instrumentation

Scapula and humerus kinematic data were collected using the Flock of Birds electromagnetic tracking device (Ascension Technology Corporation, Burlington, VT) integrated with Motion Monitor software (Innovative Sports Training, Inc, Chicago, IL). The Motion Monitor 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 4 receivers. The instrumentation sampling frequency used for all kinematic assessments in the current study was 100Hz. In a pilot study, we determined the accuracy of our electromagnetic instrumentation and the optimal location within our measurement space for subject positioning and testing. Initially, the root-mean-square error for both position and orientation were calculated for 2.4 × 2.4-m measurement space allocated for our electromagnetic tracking device. The overall position error for the 17.9 m^2 measurement space was 3.3 mm while the orientation error was 0.6°. Given that electromagnetic accuracy is compromised when measurements are taken too close to or too far from the transmitter, we determined the region within that measurement space yielded the lowest amount of error. It was determined that the region of the measurement space that was between 0.9 and 1.2 m directly in front of the transmitter demonstrated the least position

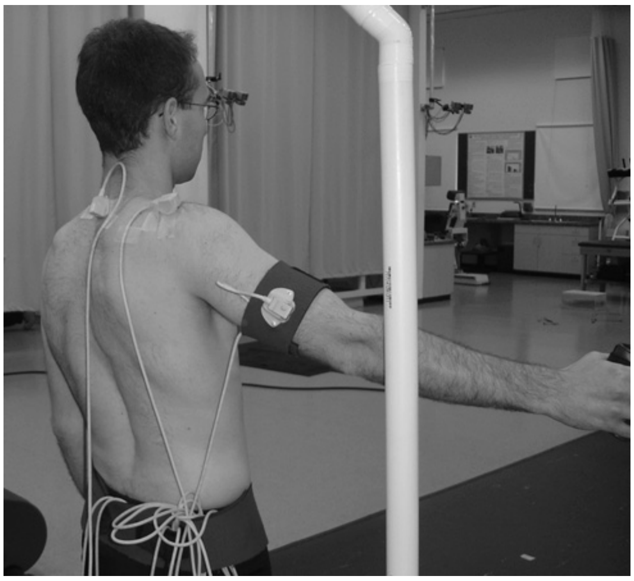

FIGURE 1. A participant performing humeral elevation during data collection.

(0.7 mm) and orientation (0.3°) error. Thus all kinematic assessments in the current study were performed with the subjects standing with their heels 0.9 m away from the transmitter.

A load was used during the kinematic assessment to simulate the load used during rehabilitation of subjects with shoulder pathology.[29] Furthermore, previous studies[16,23] have shown that alterations in scapular kinematics may be increased during a more physically demanding task, such as holding a load during humeral elevation. A Biodex System 3 isokinetic dynamometer (Biodex Medical, Shirley, NY) was used in the current study prior to kinematic assessment to determine the load that each subject would hold during the kinematic trials.[29] The Biodex system utilizes a dynamometer containing strain gauges and potentiometers to measure torque output from most any joint. In the current study, isometric torque for shoulder elevation was quantified.

Procedures

Each subject attended 1 testing session and provided informed consent, as mandated by The University Institutional Review Board prior to participation. The protocol for this study was approved by The University of Pittsburg Institutional Review Board. Next, each subject's maximum elevation torque output was recorded with the Biodex System 3 dynamometer. For testing, the subject was seated in an upright position with his dominant upper extremity positioned in the scapular plane (30° anterior to the frontal plane), 20° of elevation, and the axis of glenohumeral joint rotation aligned with the axis of rotation of the dynamometer. After 3 warm-up trials, testing consisted of three 5-second-maximum isometric elevation contractions. Each repetition was separated by a 10-second rest period. The mean torque of the 3 trials produced during the isometric elevation test was normalized to the length of the subject's arm (acromion to the first web space with the arm fully extended). Twenty-five percent of the normalized force produced was held in the hand of the subject during the humeral elevation trials. This load was chosen to control for the different strengths and lengths of lever arms among subjects and has been reported to simulate the load used during rehabilitation of patients with shoulder pathology.[29] The mean (±SD) load held during scapular assessment for all subjects was 9.1 ± 2.2 N.

Following mass determination, each subject had 3 electromagnetic receivers secured to various anatomical landmarks for kinematic analysis of the scapula and humerus (Figure 1). Electromagnetic receivers were secured with double-sided adhesive disks (3M Health Care, St Paul, MN) and hypoallergenic tape (to further reduce receiver-to-skin movement) superficial to the spinous process of the seventh cervical vertebra and on the flat, broad portion of the acromion on the scapula. A third electromagnetic receiver was secured to the mid portion of the humerus using a neoprene cuff. The receiver positions of the scapula and humerus were previously validated using bone-fixed markers and shown to accurately represent movement of their respective segments.[11,19] However, validity data available for the scapula used smaller receivers than those of this study and therefore provide slightly different results. A fourth receiver was attached to a stylus, which was used for the digitization of landmarks described in the subsequent section.[24,25]

While the subjects stood with their arms at their side, several bony landmarks on the thorax, scapula, and humerus of the dominant limb were palpated and digitized with the stylus. The digitized landmarks appear in Table 2. Digitization of the bony landmarks allowed transformation of the receiver data from a global coordinate system to anatomically based local coordinate systems (Figure 2). Testing consisted of each subject holding the predetermined load (described above) in his hands, with the forearm rotated so the thumb pointed superior, while elevating the humerus in the scapular plane. Humeral elevation/depression began with the arm in the resting position at the subject's side (referred to as approximately 0° of elevation throughout the current paper), progressing toward full elevation (maximum amount of elevation each subject could obtain), then returning to the resting position. Humeral elevation and return to the starting position was maintained in the scapular plane through the use of a guide tube (Figure 1). Furthermore, we used an independent sample *t* test to verify that the average humerus-to-trunk elevation angle (scapular plane) was not statistically different between the 2 groups ($P = .67$). Each subject performed 10 continuous repetitions lasting 4 seconds (2 seconds to reach maximum elevation and 2 seconds to return to the starting position), with assistance from a metronome. The repetitions were then averaged before data analysis. Prior to this study, we determined both the intrasession reliability (intraclass correlation coefficients [ICC]) and precision (standard error of measurement) of the scapular kinematic assessments used in the current study within our laboratory using a pretest-posttest design among 15 subjects. The reliability for this testing yielded intrasession ICC of approximately 0.97, with 0.94° of trial-to-trial variation.

The humeral elevation/depression task used in the current study was chosen because it is a noninvasive, in vivo, validated means of assessing scapular kinematics and mimics how clinicians typically observe scapular dyskinesis during shoulder injury evaluation.[12] Additionally, it replicates a substantial amount of previously published research that has assessed scapular position and orientation, making comparison with previous work feasible.[11] The elevation task is sensitive enough to show changes associated with shoulder pathology.[16,17] Additionally, our laboratory recently described the normal scapular movement patterns present in throwers using identical methodology.[27]

TABLE 2. Description of bony landmarks.

Bony Landmarks	Description of Palpation Point
Thorax	
Eighth thoracic spinous process (T8)	Most dorsal point
Xiphoid process (PX)	Most caudal point of sternum
Seventh cervical spinous process (C7)	Most dorsal point
Jugular notch (IJ)	Most cranial point of the sternum (suprasternal notch)
Scapula	
Acromion (AA)	Most lateral-dorsal point of scapula
Acromioclavicular joint (AC)	Most medial point of acromion
Medial scapular spine (TS)	Midpoint of triangular surface on the medial border of the scapula in line with the scapular spine
Inferior angle of scapula (AI)	Most caudal point of scapula
Humerus	
Medial epicondyle (ME)	Most medial point on the medial epicondyle
Lateral epicondyle (LE)	Most lateral point on the lateral epicondyle
Glenohumeral joint center (GH)*	

* The glenohumeral joint center was not palpated but, rather, estimated with a least-squares algorithm for the point on the humerus that moves the least during several short-arc humeral movements.[8,31]

Data Reduction and Analysis

Raw kinematic data were filtered with a low-pass fourth-order zero-phase-shift filter with a cutoff frequency of 10Hz.[26] Receiver position and orientation data of the thoracic, scapular, and humeral receivers were transformed into a local coordinate system for each of the respective segments. Definitions of the local coordinate systems can be obtained from Table 3 and observed in Figure 2. The coordinate systems used were in accordance with recommendations from the International Shoulder Group of the International Society of Biomechanics.[35] In general, 2 points first described the longitudinal axis of a segment and a third point defined the plane. A second axis is defined perpendicular to the plane and a third axis is defined as perpendicular to both of the first 2 axes. When in a neutral stance, the orthogonal coordinate system for each segment is approximately vertical (y-axis), approximately horizontal to the right (x-axis), and posterior (z-axis). Matrix transformations for each of the segments were used to move from the global to local coordinate systems producing a 4×4 position and orientation matrix.

Euler angle decompositions were used to determine the scapular and humeral orientation with respect to the thorax. Orientation of the scapula was determined as rotation about the y-axis of the thorax (internal/external rotation), rotation about the z-axis of the local axis system (upward/downward rotation), and rotation about the x-axis of the local axis system (anterior/posterior tilting) (Figure 3). Humeral orientation was determined as rotation about the y-axis of the thorax (plane of elevation), rotation about the z-axis of the local axis system (elevation), and rotation about the y-axis of the local axis system (axial rotation). Each of these rotations was chosen based on the recommendations of the International Shoulder Group.[35] The Euler angle sequences were used to most closely represent clinical definitions of movements and to decrease mathematical inconsistencies (ie, gimble lock).[10,35]

Position of the scapula was also described. Scapulothoracic movement does not involve any bone-to-bone contact and the scapula does not attach via a direct contact to 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 sternoclavicular (SC) elevation/depression and protraction/retraction.[11,21] The position of the acromioclavicular joint (AC) and jugular notch (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. The angle of this vector relative to the transverse plane that bisects the IJ point represents SC elevation/

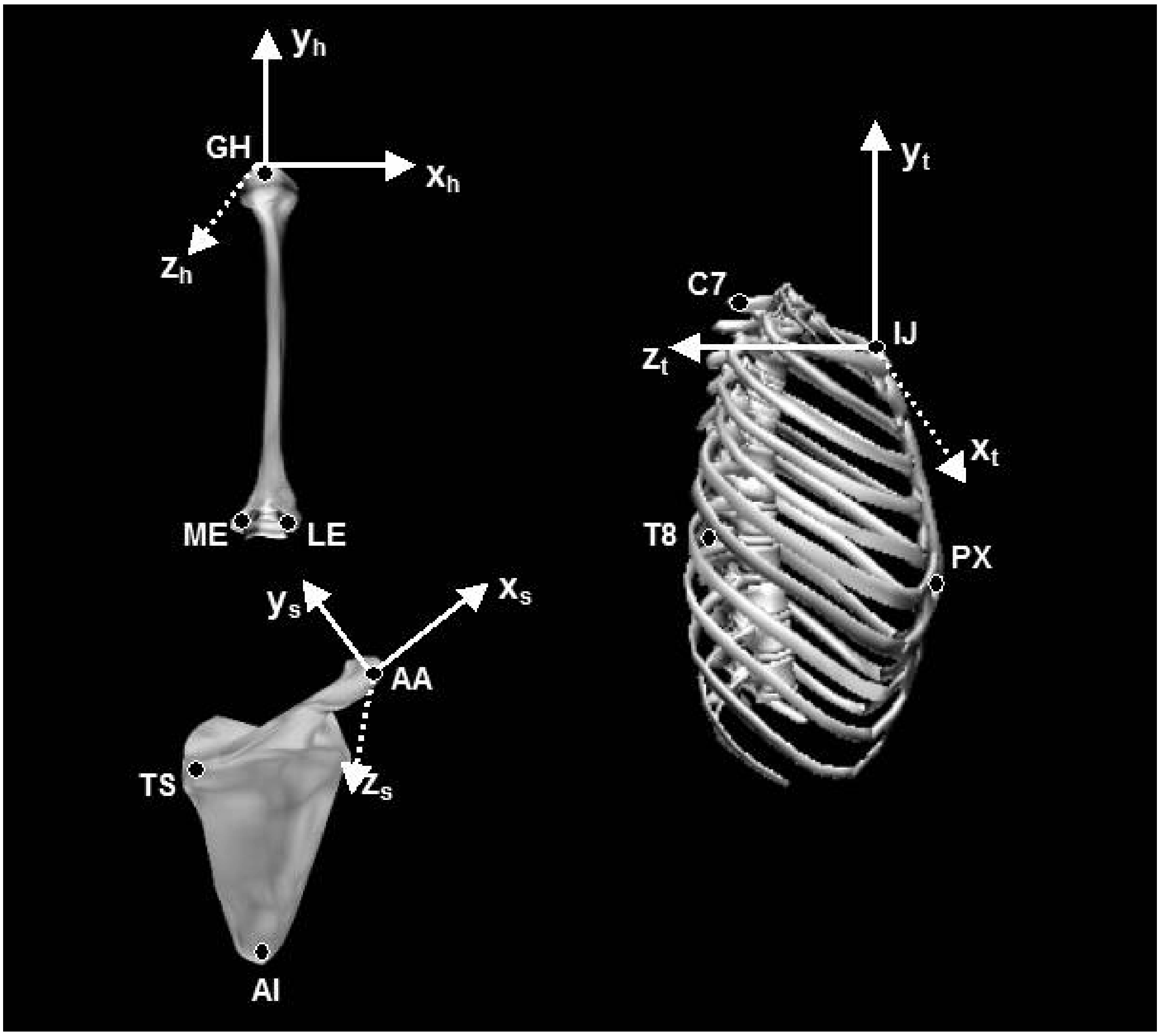

FIGURE 2. Bony landmarks and local coordinates system of the trunk, scapula, and humerus.

depression. For SC protraction/retraction, this vectorwas projected onto the transverse plane bisecting IJ and is calculated as the angle between this projection and the frontal plane that bisects IJ. These descriptions are dependent on an intact acromioclavicular joint.

Both the position and orientation of the scapula were analyzed at the initiation of movement (approximately 0°, 30°, 60°, 90°, and 120° of humeral elevation. No data above 120° of elevation were analyzed due to the lack of accuracy that can occur.[11]

A mixed-model analysis of variance (SPSS version 11.5; SPSS Inc, Chicago IL) was used to determine statistically significant differences for each scapular kinematic variable between groups and within subjects. Each matched pair served as a block in the study design. The interaction of each fixed effect (group and elevation) and the blocks of pairs of subjects served as the respective error term for the analysis. An alpha level of .05 was set prior to all analyses.

RESULTS

Because the assumption of sphericity was not met, the following results and analysis of variance tables (Tables 5-9) used the Huynh-Feldt correction.

A statistically significant interaction (group × elevation) was found for SC elevation/depression (Table 9). Interaction contrasts were done to further examine the differences between the internal impingement and control groups across the different phases of elevation. Because multiple tests were done, a Bonferroni correction (0.05/10, or $P = .005$) was used. Although the means did not show statistically significant group differences at any specific angular position, the interaction contrasts indicated that the internal impingement group had a significantly larger increase in SC elevation than the control group when

TABLE 3. Definitions of local coordinate systems.

Local Coordinate System	Axis	Definition
Thorax	y_t	Vector from the midpoint of PX and T8 to the midpoint between IJ and C7
	x_t	Vector perpendicular to the plane fitted by midpoint of PX and T8, the midpoint of IJ and C7, and IJ
	z_t	Vector perpendicular to x_t and y_t
	Origin	IJ
Scapula	x_s	Vector from TS to AA
	y_s	Vector perpendicular to the plane fitted by TS, AA, and AI (scapular plane)
	z_s	Vector perpendicular to x_s and y_s
	Origin	AA
Humerus	y_h	Vector from midpoint of ME and LE to GH
	x_h	Vector perpendicular to the plane fitted by GH, ME, and LE
	z_h	Perpendicular to y_h and x_h
	Origin	GH

Abbreviations: AA, flat portion of anterior acromion; AI, inferior angle of scapula; C7, spinous process of cervical vertebra 7; GH, glenohumeral joint center; IJ, jugular notch; LE, lateral epicondyle; ME, medial epicondyle; PX, xiphoid process; T8, spinous process of thoracic vertebra 8; TS, Medial Scapular Spine.

elevating the humerus from 30° to 120° (P = .002) and from 60° to 120° (P = .003). No statistically significant interactions were noted for scapular internal/external rotation, upward/downward rotation, anterior/posterior tilt, and SC protraction/retraction (Tables 5-8).

There was a statistically significant main effect of group on scapular posterior tilting. Over the entire humeral elevation motion, the throwers with pathologic internal impingement exhibited more posterior tilting (Table 7), regardless of the level of humeral elevation, than the throwers with no history of shoulder injury. There were no statistically significant main effects of group for internal/external rotation (Table 5), upward/downward rotation (Table 6), SC protraction/retraction (Table 8), and elevation/depression (Table 9). The descriptive scapular positions and orientations during the 5 humeral elevation angles are shown in Table 4.

DISCUSSION

Numerous studies have recognized the prevalence of pathologic internal impingement among throwing athletes.[3,7,9,15,22,28,34] However, very little data are currently available that empirically describe scapular alterations among these athletes. The results of this study indicate that throwers diagnosed with pathological internal impingement demonstrate statistically significant increases in SC elevation and scapular posterior tilt position compared to throwers without internal impingement.

Burkhart et al[2] clinically observed superior scapular prominence among throwers with pathologic internal impingement and subsequent SLAP lesions.[2] During scapular posterior tilting, the superior border tilts dorsally, thus the superior component recognized clinically may be an increase in posterior tilt, which is consistent with the results of this study. However, the 5° difference that the internal impingement subjects in this study presented with may be difficult to detect during visual examination. Furthermore, clinical findings[2] report that throwing athletes with pathological shoulders present with the appearance of a depressed shoulder. These clinicians hypothesize that this depressed shoulder is actually caused by increased scapular protraction, which, due to the shape of the thorax, moves the scapula anteriorly and inferiorly, resulting in a lowered appearance. Yet in the current study, the throwers diagnosed with pathologic internal impingement did not demonstrate a statistically significant increase in SC protraction or depression, but, rather, an increase in SC elevation while elevating the humerus from 30° to 120° and from 60° to 120°, compared to the control subjects. This increase in scapular elevation may be an adaptation by the internal impingement group to avoid a position of contact between the humeral head and the posterior-superior portion of the glenoid. However, further investigations are needed to determine if these adaptations are also present during the throwing motion and if these alterations found between groups are contributory to the development of pathology or compensatory.

With the exception of our previous work,[27] we are unaware of any other published data that examine 3-D scapular position and orientation in throwing athletes. Additionally, scapular position and orientation patterns have not been described in throwers with internal impingement. This makes comparison of our results to other published data very difficult. In the current study, the throwers in the control group demonstrated scapular kinematic patterns consistent (approximately ±5°) with other published research findings in normal shoulders.[1,4,6,18,21,27,33]

In the current study, electromagnetic tracking technology was used to identify scapular position and orientation differences present between throwers with pathologic internal impingement and throwers without shoulder pain. Yet, these differences may be observed clinically as well. Several publications have described reliable means for clinical evaluation of the scapula.[2,13] The increased posterior tilting would most likely manifest as an increased prominence of the superior border of the scapula and the scapular spine, although small deviations in this motion may be difficult to detect visually. Increased scapular

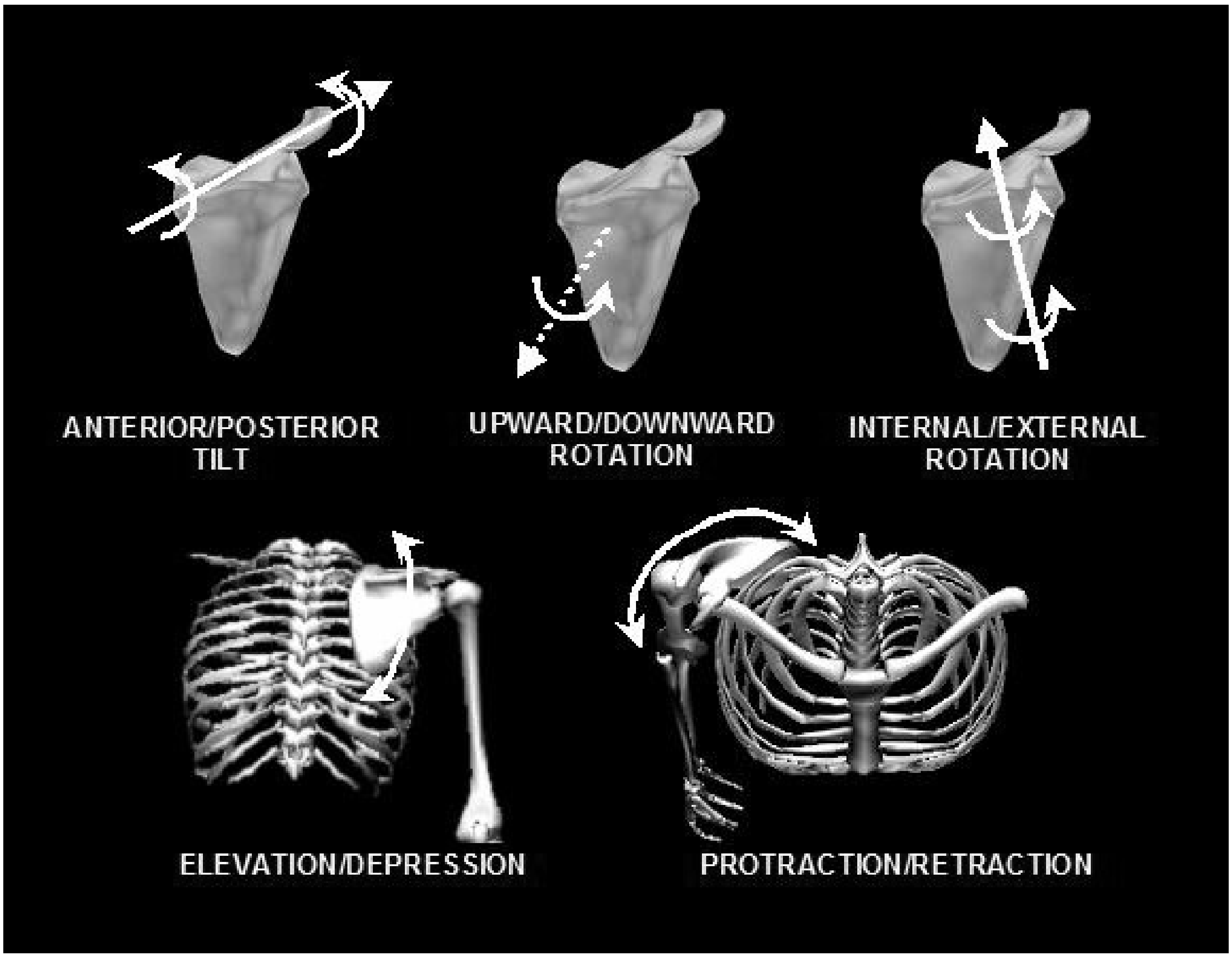

FIGURE 3. Scapular positions and orientations assessed in the current study.

elevation may be observed clinically by measuring the bilateral difference in the vertical height of the superior-medial scapular angles. However, this difference may also be caused by scapular rotations as well as changes in SC elevation. Such tests have not been consistently shown to be reliable and valid. Therefore further research is needed to determine if such clinical measures can be reliably and validly obtained.

When evaluating the results of the current study, the authors note several limitations that warrant acknowledgment. Unfortunately, the current study assesses scapular kinematics in throwing athletes during an elevation task and not during actual throwing. The displacement between the scapula and skin would make assessment of the scapula, using a skin-based marker/sensor system and during a ballistic activity like throwing, extremely difficult.[32] If one were to attempt to measure scapular position during throwing, some invasive means (ie, the use of bone pins with either electromagnetic receivers or reflective markers) would most likely be necessary. A study of that nature would provide valuable information, given that very little is known about the scapula during throwing, despite its recognized importance.[12] The humeral elevation task utilized in the current study was used because it is a noninvasive, in vivo, validated means of assessing scapular kinematics and replicates a substantial amount of previously published research.[11]

A second limitation is that the group of throwers in the current study was composed of both pitchers and position players (ie, infielders and outfielders). There are data to suggest that differences in scapular motion exist between these 2 groups.[30] We employed a matched-control-group design to control for these inherent differences. Thus each subject diagnosed with pathologic internal impingement was matched with a control subject who played the same position. We must also acknowledge that with this nonprospective design, we are unable to state whether the differences observed were present prior to the development of internal impingement, making them a possible contributor, or if they were manifested as a result of the internal impingement. In either case, the results demonstrate that throwers with pathologic internal impingement exhibit scapular position differences, compared to throwers with no history of

TABLE 4. Scapular kinematic data descriptive statistics (mean ± SD degrees).

	Impingement Group	Control Group
Scapular elevation/depression		
(negative values = depression)*		
0° humeral elevation	2.3 ± 10.8	2.2 ± 8.1
30° humeral elevation	3.0 ± 10.9	3.9 ± 8.1
60° humeral elevation	7.5 ± 10.9	7.7 ± 8.2
90° humeral elevation	12.3 ± 10.6	11.1 ± 8.5
120° humeral elevation	16.4 ± 11.3	12.8 ± 8.5
Group means	8.3	7.5
SC protraction/retraction		
(negative values = retraction)		
0° humeral elevation	–19.6 ± 6.0	–24.2 ± 5.7
30° humeral elevation	–20.5 ± 5.4	–24.3 ± 5.7
60° humeral elevation	–21.4 ± 5.0	–23.8 ± 5.3
90° humeral elevation	–23.1 ± 4.9	–24.4 ± 5.7
120° humeral elevation	–27.6 ± 6.2	–27.0 ± 6.6
Group means	–22.4	–24.7
Scapular internal/external rotation		
(negative values = external rotation)		
0° humeral elevation	33.1 ± 7.1	31.4 ± 5.9
30° humeral elevation	35.0 ± 7.3	33.6 ± 6.6
60° humeral elevation	40.0 ± 7.4	39.1 ± 6.8
90° humeral elevation	44.2 ± 8.7	44.0 ± 7.8
120° humeral elevation	47.1 ± 10.2	44.5 ± 8.2
Group means	39.9 ± 8.1	38.5 ± 7.1
Scapular upward/downward rotation		
(negative values = downward)		
0° humeral elevation	–0.1 ± 9.1	2.8 ± 8.2
30° humeral elevation	2.8 ± 10.1	8.0 ± 8.2
60° humeral elevation	12.4 ± 10.8	17.4 ± 7.4
90° humeral elevation	20.5 ± 11.4	25.7 ± 6.8
120° humeral elevation	26.4 ± 11.6	31.1 ± 6.5
Group means	12.4 ± 10.6	17.0 ± 7.4
Scapular anterior/posterior tilt		
(negative values = anterior)		
0° humeral elevation	–7.4 ± 6.2	–12.8 ± 7.8
30° humeral elevation	–5.8 ± 6.1	–10.9 ± 7.9
60° humeral elevation	–4.4 ± 6.5	–9.5 ± 9.4
90° humeral elevation	–2.5 ± 6.4	–8.1 ± 10.0
120° humeral elevation	4.1 ± 6.9	0.8 ± 5.9
Group means[†]	–3.2 ± 6.4	–8.1 ± 8.2

* Statistically significant interaction (group × elevation) from 30° to 120° and 60° to 120° (*P*<.005).

[†] Statistically significant value at *P*<.05. Group means are total mean scapular movement throughout humeral elevation

TABLE 5. Analysis of variance summary table for scapular internal/external rotation.

Source	Sum of Squares	*df*	MS	F	*P*
Group	50.95	1	50.95	0.14	.712
Error	3541.10	10	354.11		
Elevation	3073.96	1.84	1667.59	76.44	.001
Error	402.00	18.43	21.82		
Group × elevation	18.80	1.59	11.84	0.46	.597
Error	410.80	15.88		25.87	

shoulder pathology, at the time they sought medical attention by an orthopedic surgeon. These results suggest that scapular stabilization exercises aimed at restoring normal scapular motion may be a beneficial component to treat throwers with pathologic internal impingement.

CONCLUSIONS

Throwers with pathologic internal impingement demonstrate statistically significant scapular orientation and position differences compared to healthy throwers with no history of injury. Specifically, throwing athletes with pathologic internal impingement present with increased SC elevation and scapular posterior tilt positions during humeral elevation in the scapular plane, as compared to healthy throwing athletes.

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TABLE 6. Analysis of variance summary table for scapular upward/downward rotation.

Source	Sum of Squares	*df*	MS	F	*P*
Group	573.35	1	573.35	2.46	.148
Error	2327.40	10	232.74		
Elevation	11737.36	1.76	6670.29	265.40	.001
Error	442.40	17.60	25.13		
Group × elevation	20.06	2.80	7.15	0.74	.571
Error	272.65	28.04	9.72		

TABLE 7. Analysis of variance summary table for scapular anterior/posterior tilt.

Source	Sum of Squares	*df*	MS	F	*P*
Group	666.18	1	666.18	8.31	.016
Error	802.20	10	80.22		
Elevation	2082.12	1.48	1406.04	31.49	.001
Error	661.19	14.81	44.65		
Group × elevation	18.20	1.69	10.74	0.41	.638
Error	446.34	16.94	26.35		

TABLE 8. Analysis of variance summary table for sternoclavicular protraction/retraction.

Source	Sum of Squares	*df*	MS	F	*P*
Group	146.92	1	146.92	0.97	.349
Error	1520.63	10	152.06		
Elevation	417.62	1.4	301.57	41.75	.001
Error	100.03	13.85	7.22		
Group × elevation	89.31	1.36	65.84	3.85	.061
Error	231.75	13.56	17.09		

TABLE 9. Analysis of variance summary table for sternoclavicular elevation/depression.

Source	Sum of Squares	*df*	MS	F	*P*
Group	15.66	1	15.66	0.03	.857
Error	4567.42	10	456.74		
Elevation	2441.61	1.29	1899.79	217.18	.001
Error	112.42	12.85	8.75		
Group × elevation	68.85	2.04	33.79	8.13	.002
Error	84.67	20.38	4.16		

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