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Scapular Kinematics During Shoulder Elevation Performed With and Without Elastic Resistance in Men Without Shoulder Pathologies

During arm elevation, the scapula generally upwardly rotates, tilts posteriorly, and either moves toward internal or external rotation. Alterations in what are considered normal scapulothoracic motions have been associated with various shoulder pathologies.[19] Accordingly, the assessment and treatment of scapular motion have become key components of shoulder rehabilitation.[3,7,15,16,35]

STUDY DESIGN: Controlled laboratory study using within-group comparisons.

OBJECTIVES: To compare scapular kinematics between active and resisted shoulder elevation performed in the sagittal (flexion), frontal (abduction), and scapular (scapular abduction) planes.

BACKGROUND: Several studies have documented scapular kinematics during arm elevation against an external load; however, there is little information on how scapular kinematics change with loading provided by elastic bands, an exercise approach often used in the clinic.

METHODS: Thirty-two men without shoulder pathology participated in the study. The level of resistance to be used for each individual was determined prior to data collection and standardized by perceived effort on a Borg scale. Three-dimensional scapular kinematics were recorded with an electromagnetic tracking device in all 3 planes of shoulder elevation for both the unloaded (active) and loaded (resisted) conditions. Data for scapular kinematics were analyzed at 30°, 60°, 90°, and 120° of humerothoracic elevation and lowering. Comparisons between loading conditions were made using analysis-of-variance models.

RESULTS: In general, for all 3 planes of movement, the scapula was more downwardly rotated and anteriorly tilted during the elevation phase and more so during the lowering phase of shoulder elevation when performed against elastic resistance. While some of the statistically significant differences might not have been large enough to be considered clinically meaningful, some values were of a magnitude similar to previously reported differences between healthy and symptomatic individuals.

CONCLUSION: The changes in scapular motion during the loaded condition were relatively small in this population with normal scapular motion, but they were in a direction that would be considered to have potential to lead to injuries, suggesting caution when using these exercises in individuals with poor scapular control. *J Orthop Sports Phys Ther 2013;43(10):735-743. Epub 13 September 2013. doi:10.2519/jospt.2013.4466*

KEY WORDS: *biomechanics, motion analysis, scapula, scapulothoracic*

Based on their ease of use, low cost, and portability, elastic bands are frequently used in clinical practice to provide resistance during shoulder elevation exercises for individuals with a variety of shoulder pathologies.[13] It is also common in clinical practice to have patients perform shoulder elevation against resistance as part of the evaluation process to determine the quality of scapular control under loaded conditions. While several studies have documented the influence of external loads provided by handheld weights,[6,10,17,21,23,25,31] there is little information on how scapular kinematics change with loading provided by elastic bands. Determining how shoulder elevation against a standard elastic resistance may affect scapulothoracic motion in individuals without shoulder pathology is important to establishing normal values that may be used to assess the effects of elastic resistance in symptomatic subjects.

Therefore, the aim of this study was to determine the influence of resistance against shoulder elevation with an elastic band on scapulothoracic motion in healthy individuals with normal scapular control. It was hypothesized that the movements of scapular internal/external

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rotation, upward/downward rotation, and anterior/posterior tilt would not change under the loading condition when tested in all 3 planes of shoulder elevation (frontal, sagittal, and scapular) often used in rehabilitation.

METHODS

Subjects

THIRTY-TWO MEN PARTICIPATED IN the study (mean ± SD age, 23.1 ± 1.2 years; height, 1.76 ± 0.05 m; mass, 72.3 ± 9.8 kg; 31 right handed, 1 left handed). The inclusion criteria for participation were no limitation in shoulder range of motion; no prior shoulder surgery or injury; and no signs of impingement based on the Hawkins-Kennedy[12] and Neer[27] tests, instability based on the apprehension[33] and sulcus sign[28] tests, and scapular dyskinesis based on observational evaluation as proposed by Uhl et al.[38] Clinical examination was performed by a physical therapist (G.B.) with 28 years of experience. Subjects were excluded if they had any known systemic or neurological disorders, performed repetitive shoulder movements related to occupational or sports activities on a regular basis, or had a body mass index higher than 30 kg/m^2.

The Hacettepe University Institutional Review Board approved the protocol for this study, and all subjects were informed of the nature of the study and signed a consent form (HEK 10/109).

Exercise Resistance

After taking the participants' history and performing a clinical examination to determine their inclusion in the study, the participants were familiarized with the 3 common shoulder rehabilitation exercises to be performed: shoulder elevation in the frontal plane (abduction) (**FIGURE 1**), elevation in the sagittal plane (flexion) (**FIGURE 2**), and elevation in the scapular plane (scapular abduction) (**FIGURE 3**), defined as a plane 40° anterior to the frontal plane. A wooden structure was used to guide shoulder elevation movement in all 3 planes. Participants were asked to repeatedly perform bilateral shoulder elevation and lowering in a smooth and continuous manner, at a speed matching the beat of a metronome set at 60 beats per minute, using 3 seconds for elevation and 3 seconds for lowering. For all 3 exercises, the participants stood erect and performed shoulder elevation with the thumb pointing upward and the elbows kept in full extension.


FIGURE 1. Shoulder elevation in the frontal plane (abduction) with elastic band.


FIGURE 2. Shoulder elevation in the sagittal plane (flexion) with elastic band.

Subsequently, the appropriate resistance for shoulder elevation for each subject was selected from 7 color-coded resistance levels (yellow, red, green, blue, black, silver, and gold) of elastic bands (Thera-Band; The Hygenic Corporation, Akron, OH). Because of the large difference in resistance and perceived loading between the black and silver bands, an intermediate resistance between these 2 colors was employed by combining the blue and red bands.[1] Prior to their use, all bands were prestretched 20 times to account for the initial rapid loss of tension related to the repetitive stretching.[32,34]

The next step consisted of determining the correct length of elastic bands to be used to ensure that the percentage of elongation was standardized for all participants and across all 3 exercises and remained below 200% for all 3 planes of elevation.[29] To achieve this, the elastic band was fixed under the feet of the participants so as to place the band in the plane of the direction of motion, and the starting length of the band was set to be equal to the length of the upper extremity (acromion to the third metacarpal head).[2]


FIGURE 3. Shoulder elevation in the scapular plane (scapular abduction) with elastic band.

Finally, each participant was asked to perform 3 repetitions of shoulder elevation and lowering with each elastic band, starting with the band of lowest resistance and proceeding with bands of incrementally greater resistance. The participant rated perceived effort after each band, using the Borg CR10 scale,[26]

FIGURE 4. Three-dimensional scapular kinematic recording with electromagnetic tracking system.

until achieving a rating of perceived effort of 5 or 6. The elastic band used for the kinematic study was 2 color levels below that band. The process was repeated for each shoulder elevation plane to account for the potential difference in strength between planes of shoulder elevation, and the appropriate elastic band to be used for testing was selected for each plane.

Instrumentation

Kinematics Bilateral 3-D kinematic data for the scapula and humerus were collected with a Flock of Birds electromagnetic tracking device (Ascension Technology Corporation, Shelburne, VT). This system consists of an electronics unit, standard-range transmitter, 5 sensors (25.4 × 25.4 × 20.3 mm), and 1 digitizer, interfaced with the MotionMonitor software program (Innovative Sports Training, Inc, Chicago, IL). Data collected with this electromagnetic tracking system are reliable, with previously reported trial-to-trial, within-day, without-removal-of-sensors correlation coefficient values ranging between 0.88 and 0.97 and standard error of measurement values ranging from 1.35° to 1.74°.[36] Also, this method of measuring 3-D scapular kinematics has previously been validated by comparing data obtained from skin sensors to those obtained from acromion-fixed sensors, which were similar, especially below 120° of elevation.[14] Data were collected at a rate of 100 Hz per sensor and subsequently filtered using the system's Butterworth filter software, with a 6-Hz low-pass cutoff frequency.

For data collection, 5 sensors were attached directly to the skin of the participants with 2-sided adhesive tape and further secured with nonelastic tape. The thoracic sensor was located over the C7 spinous process, the scapular sensor was applied to each scapula over the flattest aspect of the posterolateral aspect of the acromion in an attempt to reduce artifact produced by skin movement,[18] and the humeral sensor for each arm was applied over the posterior aspect of the humerus distal to the triceps muscle belly (**FIGURE 4**).

The transmitter, mounted on a rigid wooden base, provided a global coordinate system. Participants stood with their arms relaxed while specific bony landmarks on the thorax (C7, T8, T12, jugular notch, xyphoid process), scapula (trigonum spine scapula, inferior angle, posterior acromial angle, coracoid process), and humerus (lateral and medial epicondyle) were digitized to create an anatomically based local coordinate system. The method suggested by Meskers et al[24] was used to define the rotation center of the glenohumeral joint. The International Society of Biomechanics standard protocol was followed to define segmental axes and convert the local coordinate system into angular rotations using the Euler angle sequence.[39] Scapular rotations were represented using the y-x'-z'' sequence, in which the first rotation defined the amount of internal/external rotation, the second upward/downward rotation, and the last anterior/posterior tilt. Humeral rotations were represented using the y-x'-y'' sequence of humerothoracic elevation, in which the first rotation defined the plane of elevation, the second the amount of humerothoracic elevation, and the third the amount of axial rotation.

Experimental Procedure

During a second testing session, the sensors monitoring scapular and humeral motion were securely attached to the participants. Then, 3-D scapular and humeral kinematic data were collected for both the unloaded (against gravity) and loaded (against gravity and elastic resistance) conditions for all 3 planes of shoulder elevation. The testing order for the planes of shoulder elevation and for the loading conditions was randomized using computer-generated random numbers. Participants performed 5 repetitions of full overhead arm elevation and lowering in each plane, using the wooden frame as a guide, at a speed matching the beat of a metronome. Thirty seconds was provided between each set of shoulder elevations. All testing was performed in a single session; therefore, the sensors remained attached to the participants throughout testing.

Statistical Analysis

Data for scapular orientation at 30°, 60°, 90°, and 120° of humerothoracic elevation were obtained for both the elevation and lowering phases of each repetition for each exercise. The scapular orientation values at each humerothoracic elevation angle for each exercise were then averaged across the 5 repetitions.

Statistical analysis of kinematic data was performed using a 2-by-8, 2-way, repeated-measures analysis of variance, with the factors of loading (unloaded versus loaded) and humerothoracic elevation angle (30°, 60°, 90°, 120° of the elevation phase and 120°, 90°, 60°, 30° of the lowering phase). A separate analysis of variance was performed for each plane of elevation. The significance level was set at .05. The Greenhouse-Geisser correction was used to adjust the degrees of freedom when the sphericity assumption was violated. When a significant interaction term was present, predetermined pairwise comparisons between loading conditions at each elevation angle were evaluated. When the interaction term was not significant, the main effect for loading was evaluated. Data for the dominant and nondominant sides were examined separately. Based on visual observation, the data for the nondominant side were very similar to those for the dominant side; therefore, the data for the nondominant side are simply presented

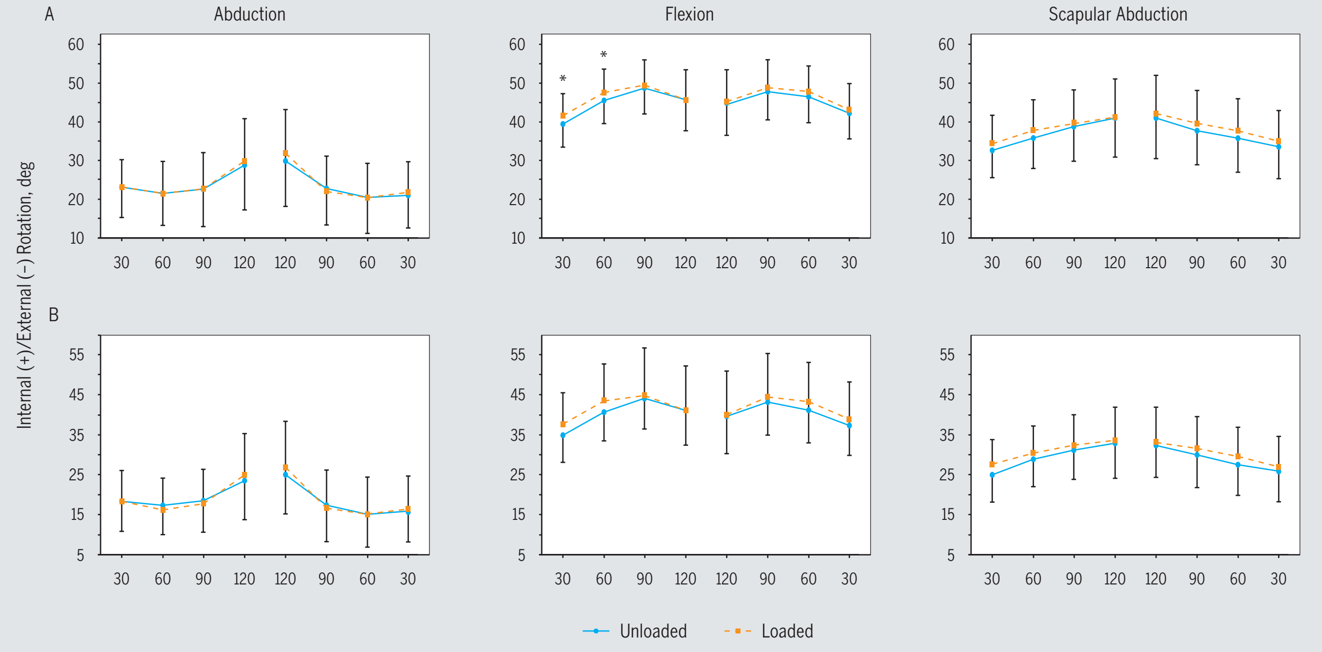

FIGURE 5. Scapular internal/external rotation during shoulder elevation and lowering under loaded and unloaded conditions for the dominant side (A). Data are mean ± SD. *Significant difference between loading conditions at this angle (*P*<.05). For the movement of shoulder abduction, there was no significant interaction or main effect (*P*>.05). For the movement of shoulder scapular abduction, there was no significant interaction, but there was a significant main effect for loading, with the scapula being more internally rotated throughout the movements of elevation and lowering under the loaded condition (*P*<.05). Data for the nondominant side (B) are graphically presented, but statistical analysis was not performed on those data.

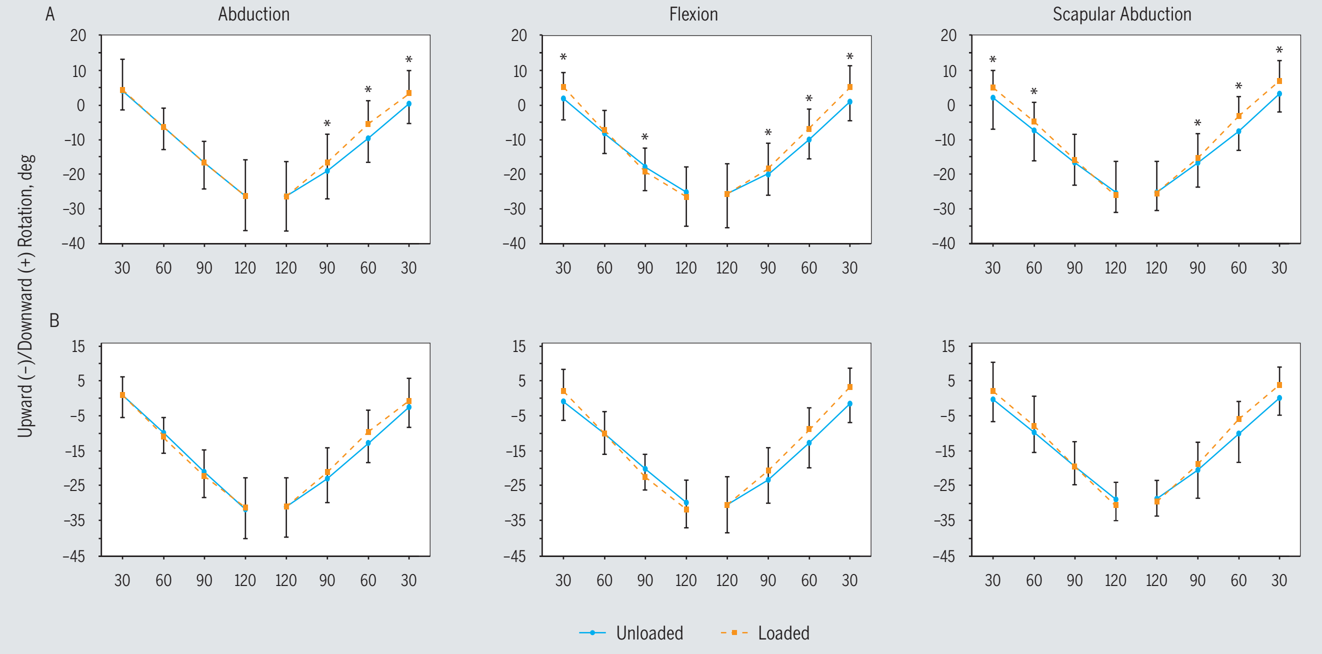

FIGURE 6. Scapular upward/downward rotation during shoulder elevation and lowering under loaded and unloaded conditions for the dominant side (A). Data are mean ± SD. *Significant difference between loading conditions at this angle (*P*<.05). Data for the nondominant side (B) are graphically presented, but statistical analysis was not performed on those data.

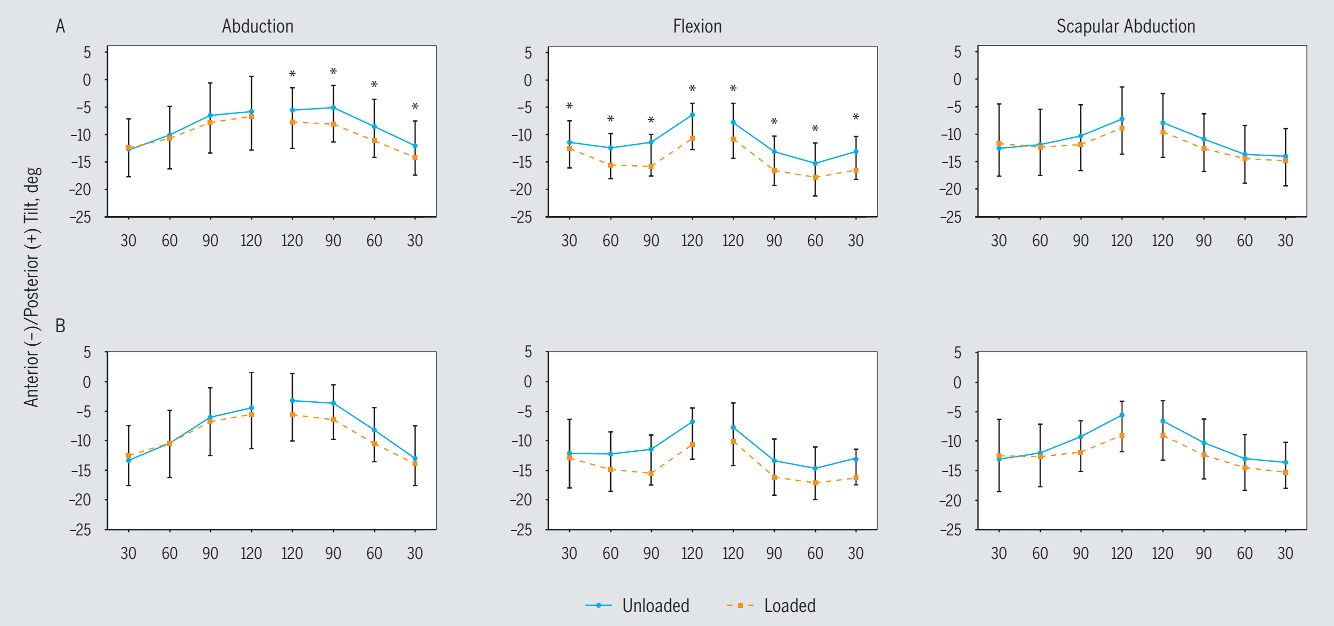

FIGURE 7. Scapular anterior/posterior tilt during shoulder elevation and lowering under loaded and unloaded conditions for the dominant side (A). Data are mean ± SD. *Significant difference between loading conditions at this angle (*P*<.05). There was no statistically significant difference between loading conditions for shoulder scapular abduction (*P*>.05). Data for the nondominant side (B) are graphically presented, but statistical analysis was not performed on those data.

in descriptive graphical format (**FIGURES 5** through **7**).

TABLE 1 NUMBER AND FREQUENCY OF USE FOR EACH COLOR OF ELASTIC BAND FOR EACH EXERCISE*

Thera-Band Color	Abduction	Flexion	Scapular Abduction
Red	1 (3.1)	...	...
Green	1 (3.1)	1 (3.1)	4 (12.5)
Blue	9 (28.1)	5 (15.6)	6 (18.8)
Black	20 (62.5)	20 (62.5)	21 (65.6)
Blue and red	1 (3.1)	6 (18.8)	1 (3.1)

**Values are n (%).*

RESULTS

TABLE 1 PROVIDES A FREQUENCY count of how often various elastic bands were used for each plane of shoulder elevation. For the dominant shoulder, scapular kinematics while performing shoulder elevation with and without elastic-band resistance are illustrated in **FIGURE 5** for internal/external rotation, **FIGURE 6** for upward/downward rotation, and **FIGURE 7** for anterior/posterior tilt for all 3 directions of shoulder elevation. In general, although some variations were observed, the scapula moved toward internal rotation, upward rotation, and posterior tilt during shoulder elevation and toward external rotation, downward rotation, and anterior tilt during lowering for all 3 planes of shoulder elevation (**FIGURES 5** through **7**).

Shoulder Abduction

There was no statistically significant loading-by-angle interaction ($F_{2.7,83.4}$ = 2.5, P = .06) or main effect ($F_{1,31}$ = 0.5, P = .47) of loading for scapular internal/external rotation (**TABLE 2**, **FIGURE 5**). There was a statistically significant loading-by-angle interaction for scapular upward/downward rotation ($F_{3.4,105}$ = 10.5, P<.001). Pairwise comparisons between loaded and unloaded conditions at each angle of shoulder elevation and lowering indicated that the scapula was more downwardly rotated with the loaded condition at 90° ($F_{1,31}$ = 14.7, P = .001; mean difference, 2.5°), 60° ($F_{1,31}$ = 35.4, P<.001; mean difference, 4°), and 30° ($F_{1,31}$ = 42.7, P<.001; mean difference, 3°) of humerothoracic elevation during the lowering phase (**TABLE 2**, **FIGURE 6**).

There was also a statistically significant loading-by-angle interaction for scapular anterior/posterior tilt ($F_{3.2,99.2}$ = 6.1, P = .001). Pairwise comparisons indicated that the scapula was less posteriorly tilted with the loaded condition at 120° ($F_{1,31}$ = 6.6, P = .01; mean difference, 2.1°), 90° ($F_{1,31}$ = 19.8, P<.001; mean difference, 3.1°), 60° ($F_{1,31}$ = 21.2, P<.001; mean difference, 2.6°), and 30° ($F_{1,31}$ = 13.8, P = .001; mean difference, 1.1°) of humerothoracic elevation during the lowering phase (**TABLE 2**, **FIGURE 7**).

TABLE 2 Analysis-of-Variance Results for Shoulder Elevation and Lowering in the Frontal Plane (Abduction) Under Loaded and Unloaded Conditions*

Kinematics	Loading by Angle	Loading	Angle
Scapular internal/external rotation†	.84 (30° elevation)	.47	<.001
	.66 (60° elevation)		
	.84 (90° elevation)		
	.32 (120° elevation)		
	.05 (120° lowering)		
	.43 (90° lowering)		
	.97 (60° lowering)		
	.24 (30° lowering)		
Scapular upward/downward rotation‡	.43 (30° elevation)	.005	<.001
	.92 (60° elevation)		
	.77 (90° elevation)		
	.85 (120° elevation)		
	.59 (120° lowering)		
	.001 (90° lowering)		
	<.001 (60° lowering)		
	<.001 (30° lowering)		
Scapular anterior/posterior tilt§	.53 (30° elevation)	.003	<.001
	.32 (60° elevation)		
	.05 (90° elevation)		
	.25 (120° elevation)		
	.01 (120° lowering)		
	<.001 (90° lowering)		
	<.001 (60° lowering)		
	.001 (30° lowering)		

**The table provides the P values for the pairwise comparisons for each angle of elevation and lowering, followed by the main effects for the loading and angle factors.*
†Loading by angle interaction term, P = .06.
‡Loading by angle interaction term, P<.001.
§Loading by angle interaction term, P = .001.

Shoulder Flexion

There was a statistically significant loading-by-angle interaction for scapular internal/external rotation ($F_{3.6,111.8}$ = 4.8, P = .002). Pairwise comparisons indicated that the scapula was more internally rotated with the loaded condition at 30° ($F_{1,31}$ = 26.7, $P<.001$; mean difference, 2.2°) and 60° ($F_{1,31}$ = 10, P = .003; mean difference, 1.9°) of humerothoracic elevation during the elevation phase (**TABLE 3**, **FIGURE 5**).

There was a statistically significant loading-by-angle interaction for scapular upward/downward rotation ($F_{3,93.3}$ = 21.2, $P<.001$). Pairwise comparisons indicated that the scapula was more downwardly rotated with the loaded condition at 30° ($F_{1,31}$ = 62.3, $P<.001$; mean difference, 3.2°) of humerothoracic elevation during the elevation phase and at 90° ($F_{1,31}$ = 10, P = .003; mean difference, 1.4°), 60° ($F_{1,31}$ = 21.7, $P<.001$; mean difference, 2.8°), and 30° ($F_{1,31}$ = 30.8, $P<.001$; mean difference, 4°) of humerothoracic elevation during the lowering phase. However, the scapula was more upwardly rotated at 90° ($F_{1,31}$ = 7, P = .01; mean difference, 1.5°) of humerothoracic elevation during the elevation phase (**TABLE 3**, **FIGURE 6**).

There was also a statistically significant loading-by-angle interaction for scapular anterior/posterior tilt ($F_{3.3,102.1}$ = 9.2, $P<.001$). Pairwise comparisons indicated that the scapula was less posteriorly tilted with the loaded condition at 30° ($F_{1,31}$ = 5.4, P = .02; mean difference, 1°), 60° ($F_{1,31}$ = 44.3, $P<.001$; mean difference, 3.1°), 90° ($F_{1,31}$ = 56.5, $P<.001$; mean difference, 4.3°), and 120° ($F_{1,31}$ = 54, $P<.001$; mean difference, 4.3°) of humerothoracic elevation during the elevation phase, and at 120° ($F_{1,31}$ = 29.2, $P<.001$; mean difference, 3.1°), 90° ($F_{1,31}$ = 35.4, $P<.001$; mean difference, 3.4°), 60° ($F_{1,31}$ = 22.4, $P<.001$; mean difference, 2.6°), and 30° ($F_{1,31}$ = 20.2, $P<.001$; mean difference, 2.7°) of humerothoracic elevation during the lowering phase (**TABLE 3**, **FIGURE 7**).

Shoulder Scapular Abduction

There was no statistically significant loading-by-angle interaction ($F_{2.5,76}$ = 2.2, P = .10). However, there was a main effect ($F_{1,31}$ = 8.4, P = .007) of loading for scapular internal/external rotation (36.2° for the unloaded versus 37.6° for the loaded condition), indicating that, with loading, the scapula was more internally rotated at all angles of humerothoracic elevation during both the elevation and lowering phases (**TABLE 4**, **FIGURE 5**).

There was a statistically significant loading-by-angle interaction for scapular upward/downward rotation ($F_{4.1,127.3}$ = 19.2, $P<.001$). Pairwise comparisons indicated that the scapula was more downwardly rotated with the loaded condition at 30° ($F_{1,31}$ = 75.8, $P<.001$; mean difference, 2.8°) and 60° ($F_{1,31}$ = 22.9, $P<.001$; mean difference, 2.4°) of humerothoracic elevation during the elevation phase and at 90° ($F_{1,31}$ = 7.3, P = .01; mean difference, 1.4°), 60° ($F_{1,31}$ = 55.4, $P<.001$; mean difference, 4.2°), and 30° ($F_{1,31}$ = 47.6, $P<.001$; mean difference, 3.8°) of humerothoracic elevation during the lowering phase (**TABLE 4**, **FIGURE 6**).

There was also a statistically significant loading-by-angle interaction for scapular anterior/posterior tilt ($F_{2.9,88.5}$ = 5.3, P = .002). Despite this significant interaction, pairwise comparisons for each of the 4 angles of elevation and lowering failed to indicate any significant difference between loaded conditions at any of the angles (**TABLE 4**, **FIGURE 7**).

DISCUSSION

In general, for all 3 planes of shoulder elevation, the scapula was more downwardly rotated and anteriorly tilted during the elevation phase and more so during the lowering phase of the movement when performed against elastic resistance. While the magnitude of the differences was relatively small (less than 5°), it was similar to that of the differences previously measured between healthy and symptomatic individuals.[4] The movement differences were in a direction that would be considered to have potential to lead to injuries, suggesting that clinicians should be cautious when using these exercises in individuals with poor scapular control.

The added resistance to shoulder elevation provided by the elastic band requires an increased effort from the deltoid, which in turn requires additional control of the scapula by the scapulothoracic musculature. Previously, Uhl et al[38] used differences of 8° to 9° as a threshold for symmetrical scapular motion. The differences measured in the current study were lower than those suggested values. But, when considering the normal motion of the scapula during shoulder elevation, the use of resistance resulted in less upward rotation and posterior tilt, and these differences were more apparent in the lowering, eccentric phase of shoulder elevation. Thompson et al[37] previously reported that applying an additional load narrows the acromiohumeral interval and suggested that a lack of appropriate scapular upward rotation and posterior tilt during arm elevation would affect the width of the subacromial space.[11,30]

In previously published work, there is inconsistency in the direction and magnitude of the kinematic changes produced by the addition of external loads to shoulder elevation. This variability across studies may be, in part, due to the different methodologies these studies used for data collection and analysis, which included dynamic[8,23] versus quasi-static[6,10,17,31] assessments, Euler[8] versus Cardan[6,23] angle sequences, and various loading amounts.[6,10,17,23,25,31] Forte et al[10] standardized the load used by the subjects by using free weights equal to 5% of the subject's body mass and showed alterations in scapular kinematics during a quasi-static abduction movement. de Toledo et al[8] recently reported a more upwardly rotated scapula in an unloaded situation when compared to a loaded condition, using resistance provided by a yellow elastic resistance band for all participants. In contrast, previous studies have also reported no difference in scapular internal/external rotation[6,10] and upward/downward rotation[6,23,31] when performing shoulder abduction against resistance. We agree with the suggestion of Forte et al[10] that clinicians should observe the scapula to ensure that the same pattern of movement remains when increasing the applied resistance to shoulder elevation. In addition, based on the current study, applying a predefined amount of resistance, regardless of the plane of shoulder elevation, should result in very small and consistent changes in scapular motions. This observation is based on data collected on asymptomatic young men who were considered to have normal neuromuscular control of the scapula (ie, no scapular dyskinesis) and were tested with the use of moderate resistance as perceived by the subjects. The method of standardization was based on the work of Andersen et al,[1] who reported high trapezius and middle deltoid muscle activation during abduction with selected elastic resistance. The use of higher loads could potentially result in greater changes toward more downward rota-

TABLE 3

Analysis-of-Variance Results for Shoulder Elevation and Lowering in the Sagittal Plane (Flexion) Under Loaded and Unloaded Conditions*

Kinematics	Loading by Angle	Loading	Angle
Scapular internal/external rotation[†]	<.001 (30° elevation)	.06	<.001
	.003 (60° elevation)		
	.33 (90° elevation)		
	.89 (120° elevation)		
	.59 (120° lowering)		
	.70 (90° lowering)		
	.06 (60° lowering)		
	.21 (30° lowering)		
Scapular upward/downward rotation[‡]	<.001 (30° elevation)	.002	<.001
	.20 (60° elevation)		
	.01 (90° elevation)		
	.05 (120° elevation)		
	.92 (120° lowering)		
	.003 (90° lowering)		
	<.001 (60° lowering)		
	<.001 (30° lowering)		
Scapular anterior/posterior tilt[‡]	.02 (30° elevation)	<.001	<.001
	<.001 (60° elevation)		
	<.001 (90° elevation)		
	<.001 (120° elevation)		
	<.001 (120° lowering)		
	<.001 (90° lowering)		
	<.001 (60° lowering)		
	<.001 (30° lowering)		

**The table provides P values for the pairwise comparisons for each angle of elevation and lowering, followed by the main effects for the loading and angle factors.*
[†] Loading by angle interaction term, P = .002.
[‡] Loading by angle interaction term, P<.001.

tion, internal rotation, and anterior tilt of the scapula during shoulder elevation, but this needs to be tested across a spectrum of resistance levels. Similarly, it is possible that the same level of resistance to shoulder elevation used by individuals with scapular dyskinesis, with or without shoulder pain, could impart a greater amount of change in scapular motion.

The findings of this study are limited to asymptomatic young men considered to have normal scapular motion during shoulder elevation performed without resistance. Because age can influence scapular position,[5,9] we recruited men between 21 and 25 years of age so as to increase the homogeneity of the group. Although evidence[20,22] is available that there are no scapular kinematic differences between genders, only men were included in the study, again to provide a more homogeneous sample. While the above reduces the generalizability of our results, we believe that our detailed description of scapular kinematics in this specific group of individuals with asymptomatic shoulders provides important baseline information to guide future research. Future studies should consider investigating the effects of a spectrum of resistance levels on different populations with and without scapular dyskinesis and shoulder symptoms. In addition, because elastic bands, in contrast to handheld weights, provide resistance based on their percent elongation,[32] future studies may want to assess, in addition to their impact on scapular motion, the relative benefits of the different types of resistance.

TABLE 4 ANALYSIS-OF-VARIANCE RESULTS FOR SHOULDER ELEVATION AND LOWERING IN THE SCAPULAR PLANE (SCAPULAR ABDUCTION) UNDER LOADED AND UNLOADED CONDITIONS*

Kinematics	Loading by Angle	Loading	Angle
Scapular internal/external rotation†	.001 (30° elevation)	.007	<.001
	.004 (60° elevation)		
	.11 (90° elevation)		
	.61 (120° elevation)		
	.08 (120° lowering)		
	.008 (90° lowering)		
	.005 (60° lowering)		
	.02 (30° lowering)		
Scapular upward/downward rotation‡	<.001 (30° elevation)	<.001	<.001
	<.001 (60° elevation)		
	.14 (90° elevation)		
	.34 (120° elevation)		
	.60 (120° lowering)		
	.01 (90° lowering)		
	<.001 (60° lowering)		
	<.001 (30° lowering)		
Scapular anterior/posterior tilt§	.30 (30° elevation)	.33	<.001
	.67 (60° elevation)		
	.11 (90° elevation)		
	.11 (120° elevation)		
	.14 (120° lowering)		
	.15 (90° lowering)		
	.43 (60° lowering)		
	.54 (30° lowering)		

**The table provides P values for the pairwise comparisons for each angle of elevation and lowering, followed by the main effects for the loading and angle factors.*
†Loading by angle interaction term, P = .10.
‡Loading by angle interaction term, P<.001.
§Loading by angle interaction term, P = .002.

CONCLUSION

OUR OVERALL RESULTS INDICATE that, for all 3 planes of shoulder elevation, the scapula was more downwardly rotated and anteriorly tilted during the elevation phase and more so during the lowering phase of shoulder movement performed against moderate elastic resistance. While the changes in scapular motion during the loaded condition were relatively small in this asymptomatic male population with normal scapular motion, they were in a direction that may lead to injuries, which suggests that caution should be taken when using these exercises in individuals with poor scapular control. ◉

KEY POINTS

FINDINGS: Overall, the results indicate that for all 3 planes of shoulder elevation, the scapula was more downwardly rotated and anteriorly tilted during the elevation phase and more so during the lowering phase of shoulder movement performed against moderate elastic resistance.

IMPLICATIONS: Although some of the differences were statistically significant, the changes that were noted were of relatively small magnitude (less than 5°). Yet, these changes were in a direction that has the potential to lead to injuries. Clinicians should monitor the effects of resistance on scapular motion when performing shoulder elevation exercises.

CAUTION: The findings of this study are limited to asymptomatic young men using moderate elastic resistance against shoulder elevation.

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