Stretching and Strengthening Exercises: Their Effect on Three-Dimensional Scapular Kinematics

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ABSTRACT. Wang C-H, McClure P, Pratt NE, Nobilini R. Stretching and strengthening exercises: their effect on three-dimensional scapular kinematics. Arch Phys Med Rehabil 1999;80:923-9.

Objective: To quantitatively evaluate the effects of commonly used shoulder exercises on shoulder kinematics and resting posture.

Study Design: A repeated-measures design was used with measurements performed before and after a 6-week exercise program.

Method: Twenty asymptomatic subjects with forward shoulder posture were recruited. Stretching exercises for the pectoral muscles and resisted strengthening exercises for the scapular retractors and elevators and the glenohumeral abductors and external rotators were performed three times per week for 6 weeks. A three-dimensional electromechanical digitizer was used to measure thoracic inclination and scapular orientation and position. These measurements were taken with the arm (1) at the side, (2) abducted to 90°, and (3) at maximal abduction. The isometric force of glenohumeral external and internal rotation and horizontal abduction and adduction were measured with a hand-held dynamometer. All subjects were tested before and after the 6-week exercise program. Hotelling's T^2 and paired t tests were used for data analysis.

Results: The strength of horizontal abduction and internal and external rotation increased after exercise ($p < .01$). The anterior inclination of the thoracic spine decreased, and the glenohumeral contribution to arm elevation increased ($p < .01$). Resting scapular posture did not change. As the arm was abducted to 90°, the scapula showed less upward rotation and less superior translation after the exercise program ($p < .01$).

Conclusion: The exercise program improved muscle strength, produced a more erect upper trunk posture, increased scapular stability, and altered scapulohumeral rhythm.

THE EXTENSIVE MOTION of the shoulder is accomplished by coordinated movement of all four joints of the shoulder girdle.[1,2] The maintenance of smooth and coordinated motion requires intact joints and coordinated action among the muscles that move them.[2] If there is a deficiency in any of these structures, shoulder dysfunction may occur because of changes in scapular position, scapulohumeral rhythm, and improper muscular balance. Such disturbances of normal motion may lead to shoulder instability or impingement.[3,4]

Poor shoulder posture and muscle imbalance are believed to be important factors that contribute to shoulder dysfunction and insidious pain syndromes.[4,5] Some authors state that postural deviation and muscle imbalance around the shoulder area are frequently concurrent.[4,5] For instance, Kendall and McCreary[5] believed that when subjects remained in a slouch posture, ie, with the head and shoulders forward, for prolonged periods, the elongated muscles (posterior scapular stabilizers) may become weaker and the shortened muscles (pectorals) may become stronger. As a result, force imbalance develops between those two muscle groups, which, in time, may result in changes in resting scapular position and in forward shoulder posture. In addition, such changes are thought to cause excessive scapular anterior tilting and deficient upward rotation of the scapula during shoulder elevation as well as pain in the shoulder region.[4,5] The theories of shoulder muscle imbalance have been challenged in recent years.[6,7] DiVeta and colleagues[6] found low correlation between the position of scapula and the muscular force produced by the middle trapezius and pectoralis minor muscles. Greenfield and coworkers[7] also reported that scapular protraction, rotation, and symmetry, and midthoracic curvature were not significantly different between patients with shoulder overuse injuries and matched healthy subjects.

Based on the theories of muscle imbalance, clinicians postulate that strengthening of the posterior scapular stabilizers combined with stretching of the pectoral muscles can correct posture and muscular imbalance and can alter scapulohumeral rhythm.[4,8-10] To treat impingement, Allegrucci and associates[8] recommended restoring normal strength and endurance of rotator cuff and other muscles around the scapular region to correct imbalances that exist between the anterior and posterior shoulder musculature. They also suggested stretching of the pectoral muscles. Exercise protocols of rotator cuff and scapular retractor strengthening and pectoral stretching are believed to restore the normal kinematics of glenohumeral and scapulothoracic motion and thus establish proper scapulohumeral rhythm. There is little quantitative data documenting the effect of such exercise programs on shoulder kinematics.

In preliminary work, we examined the effects of a 6-week active-exercise program for the scapular retractors on scapular resting position and scapular retraction and protraction muscle strength.[11] Scapular position was measured via a three-dimensional digitizer, and isometric muscle strength was measured by the Kincom. We found no significant change after exercise in either isometric muscle force or resting scapular position. Because the intensity of the active exercise program was insufficient to produce a strengthening effect and only scapular resting position was measured, we decided to assess the effects of a more aggressive strengthening program on both resting posture and scapular position during arm elevation.

The purpose of this study was to determine the effects of a moderately aggressive exercise program, including passive stretching and resistive exercise, on a group of asymptomatic

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subjects with forward shoulder posture. We used a repeated-measurement design with measurements taken before and after a 6-week exercise program. The exercise program included stretching of the pectoral muscles and strengthening of the rotator cuff and posterior scapular stabilizers. The measured variables were three-dimensional scapular position at rest and during abduction in the plane of the scapula and the strength of the muscles producing shoulder internal and external rotation and horizontal adduction and abduction.

METHOD

Subjects

Twenty asymptomatic subjects with forward shoulders participated. A subject was considered to have forward shoulder posture if, from a side view in the standing position, the glenohumeral joint was clearly anterior to a plumb line aligned with the lobe of the ear.[6] Interestingly, most healthy volunteers initially screened for inclusion met this criterion. There were nine men and 11 women; 19 of 20 were right-hand dominant. The mean age was 30.1 years (SD = 6.1), the mean height was 168.1cm (SD = 10.4), and the mean weight was 66.2kg (SD = 15.7). No subject had been treated for shoulder dysfunction or had engaged in shoulder exercises in the previous 3 months. Subjects were excluded if they had had overt shoulder trauma or shoulder surgery, had symptoms resulting from cervical or other neural problems, had acute pain around the shoulder area, or were younger than 18 years. Before beginning the study, all subjects were informed about the nature of the study and signed a consent form. The study was approved by the committee for the Protection of Human Subjects, Allegheny University of the Health Sciences.

Measurements

The Metrecom,[a] a computerized, electromechanical, three-dimensional digitizer designed for posture analysis, was used. It employs a linkage arm instrumented with six precision potentiometers and a small probe. The cartesian coordinates of the probe tip are captured, and these coordinates are subsequently processed to determine position and orientation. Five palpable landmarks on the spine and scapula and two points on a 10-cm plastic bar strapped on the subject's arm were digitized in the following sequence: the seventh cervical spinous process (C7), the seventh thoracic spinous process (T7), the root of the spine of the scapula on the medial border of the scapula, the acromion at the acromioclavicular joint, the inferior angle of the scapula, and the proximal and distal points on the plastic arm bar.

Orientation and position of the scapula was calculated based on the model shown in figure 1. Subjects were seated in a standard fashion in a stabilization chair (fig 2), and the global reference frame was based in the chair. The X axis was a pure horizontal line (positive to the subject's left), the Y axis was a pure vertical line (positive superiorly), and the Z axis was the cross product of the X and Y axes, which was a pure horizontal line positive anteriorly. The center of the scapula was defined as the centroid of the three digitized scapular points. Medial-lateral translation represented the horizontal distance from the center of the scapula to a vertical line passing through C7 (fig 1A). Superior-inferior translation represented the vertical distance from the center of the scapula to a horizontal line passing through C7 (fig 1B). Upward rotation represented the angle between the vertical and a line passing through the root of the spine of the scapula and the inferior angle of the scapula (fig 1C). Scapular internal rotation represented the angle between the coronal plane and a line passing through the root of the spine of the scapula and the acromioclavicular joint (fig 1D). Scapular tilt was described in reference to the upper thoracic spine. Scapular tilt represented the angle between a line passing through C7 and T7 and a line passing through the inferior angle and the root of the spine of the scapula (fig 1E). To measure humeral position, a plastic splint with two small holes 10cm apart was strapped to the lateral aspect of the arm in alignment with the humeral shaft. The two holes were digitized to represent the humerus. All measurements were taken on the right side with the arm at rest, with the humerus abducted to a horizontal position in the scapular plane (as determined with an inclinometer), and with maximal abduction of the humerus. Thoracic inclination angle (fig 1E) was the angle formed between a line passing through C7 and T7 and the vertical.

The Nicolas hand-held dynamometer[b] was used to measure the isometric strength. A custom steel frame was constructed to stabilize the dynamometer, and measurements of shoulder external and internal rotation and horizontal abduction and adduction force were taken with the right shoulder in 90° of humeral abduction with the subject sitting.

Procedure

All measurements were taken by the primary investigator. Only right upper limbs were measured, irrespective of dominance. To prevent trunk movement during the measurement of isometric strength, each subject was seated and stabilized with pads on the chest and interscapular area and a strap on the pelvis (fig 2). To evaluate the isometric force of shoulder rotation, the shoulder was positioned in 90° coronal plane abduction and 90° external rotation with the elbow flexed and the forearm oriented vertically. It was necessary to position the arm in the coronal plane, rather than the scapular plane, for strength testing, because of constraints of the steel frame holding the dynamometer. The resistance pad was placed on the forearm, just proximal to the two styloid processes of the wrist. To evaluate the isometric force of shoulder horizontal adduction and abduction, the shoulder was positioned the same way but the resistance pad was placed on the humerus, just proximal to the two humeral epicondyles. The exact position of the stabilizing frame and chair were recorded so that positioning could be reproduced for the postexercise measurement. The subject then exerted maximum force against the stationary pad of the dynamometer unit, which was secured in the steel frame apparatus. Before the measured trials, one submaximum and one maximum warm-up session were performed. For data collection, the subject was required to produce three maximal isometric contractions for 5 seconds each.

For measurements with the Metrecom digitizer, subjects were seated in the same stabilization chair as described above with the back exposed. The height, length, and tilting angle of each pad were measured and recorded by the investigator for the reference of the second measurement. A 10-cm plastic bar was strapped on the midline of the subject's arm laterally, with the distal part of the bar just proximal to the two humeral epicondyles.

A plywood frame was positioned 45° anterior to the frontal plane to act as a guide for the arm during abduction, to maintain the arm in the scapular plane. With the frame as a guide, the arm was abducted with the forearm extended and the thumb directed superiorly. The 90° abduction position was documented by means of an inclinometer and the height of the arm in this position was marked on the plywood frame as a reference. After two practice trials of maximal elevation, the seven points described above were digitized at each position of abduction (rest, 90°, and maximal). A 1-minute rest was provided between

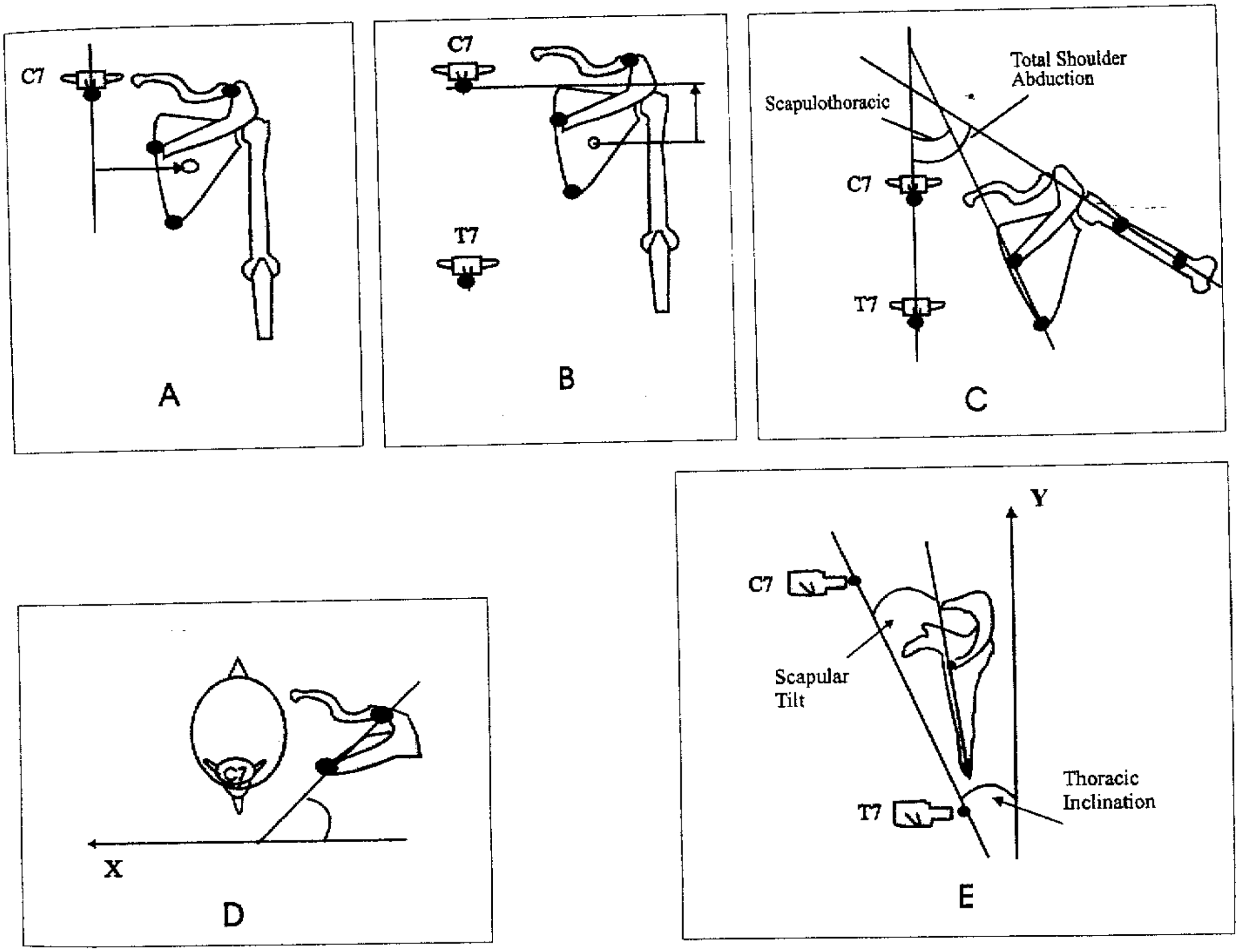

Fig 1. (A) Medial-lateral translation calculated as the horizontal distance between C7 and the centroid of the scapula. (B) Superior-inferior translation calculated as the vertical distance between C7 and the centroid of the scapula. (C) Upward rotation: scapulothoracic rotation was the angle between the spine and the medial border of the scapula; total shoulder abduction is the angle between the spine and the humerus. (D) Scapular internal rotation: the angle between the coronal plane and a line passing through the root of the spine of the scapula and the acromioclavicular joint. (E) Scapular tilt: the angle between a line passing through C7 and T7 and a line passing through the inferior angle and the root of the spine of the scapula. Thoracic inclination was the angle formed between the coronal plane and a line passing through C7 and T7.

positions. The measurements for each position were then repeated and the data from the two trials were averaged.

Reliability

A pilot study was conducted to ascertain the intrarater reliability of the NHHD unit and the Metrecom for evaluating the isometric muscle strength and the resting positions of the arm and scapula, respectively. All of the procedures of measurement with the dynamometer unit and Metrecom were conducted on 14 asymptomatic subjects twice by the same investigator with at least a 7-day interval between measurements. The results of the two measurements were compared to calculate the intraclass correlation coefficients; the values for isometric strength of shoulder internal and external rotation and horizontal abduction and adduction were all above .99, which indicated excellent reliability. The intraclass correlation coefficients values of resting positions of the arm and scapula were all above .85 (table 1) except for that of scapula internal rotation (0.6), which also represented acceptable reliability of angular measurement by Metrecom.

Exercise Program

At the first contact, the investigator chose one of three different resistance levels of theraband (green, blue, and black) for each individual, based on the results of the muscle force measures taken with the dynamometer. Based on the reliability study, the force range of glenohumeral internal rotation fell between 2.6 and 15kg. As an approximation, we divided the range of forces into three levels to determine the type of theraband a subject would use. A subject used green theraband (least resistance) first if the subject's internal rotation force was less than 4kg, blue if the subject's force fell between 4 and 8kg, and black if the subject's force was more than 8kg. The investigator then demonstrated and described the nature of each exercise. Subjects were asked to do five repetitions of each of the exercises to see if they were too hard or too easy, based on

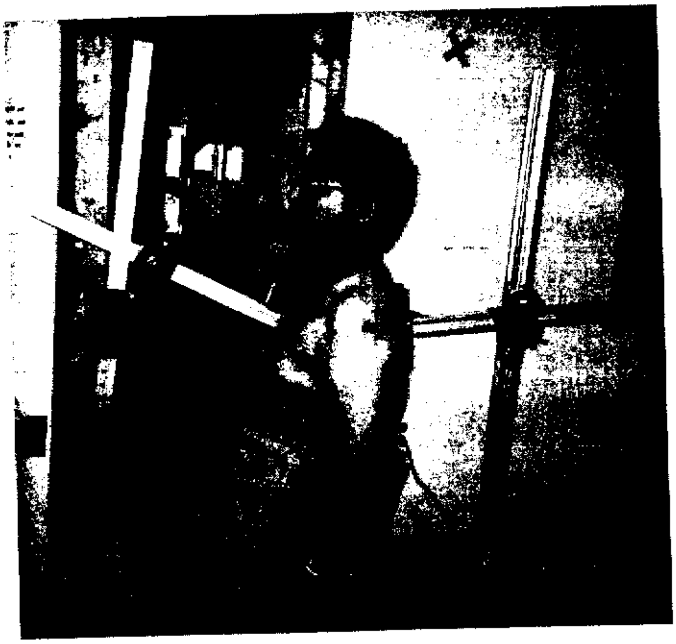

Fig 2. Subject seated in custom stabilization chair positioned for isometric testing of humeral internal rotation. The hand-held dynamometer was adjusted appropriately for muscle tests of humeral external rotation, horizontal adduction, and horizontal abduction. The posterior stabilization pad was removed for measurement of thoracic and scapular position with the Metrecom.

feedback from the subject and on observation by the investigator. When necessary, the performance of each exercise was corrected by the investigator based on observation and palpation of the target muscle groups. Six subjects used green theraband, six used blue, and eight used black. A log was given to subjects to document the frequency of their performance, and the investigator contacted subjects once a week by telephone to encourage compliance. The exercises are shown in figure 3, which represents the drawings given to subjects. The program included resisted strengthening exercises for scapular elevation, shoulder abduction in the scapular plane, shoulder horizontal abduction with scapular retraction, and shoulder external rotation. All subjects were required to perform a standard home exercise program three times per week. One set of 10 repetitions for one session was required in the initial 2 weeks and five more repetitions were added every 2 weeks. In addition, a "corner stretching" exercise for the pectoralis muscles was given (illustrated in fig 3). Subjects were instructed to place their hands above their head on the adjacent corner walls, lean forward into the corner, and hold the stretch for 10 seconds for each of 10 repetitions. Five more repetitions were added every 2 weeks.

Table 1: Reliability of Measurements Between Repeated Sessions ($n = 14$)

Variable	Mean (SD)	ICC	SEM
Isometric force (kg)			
External rotation	4.9 (1.5)	.99	0.02
Internal rotation	7.9 (2.5)	.99	0.16
Horizontal abduction	11.1 (3.9)	.99	0.13
Horizontal adduction	9.7 (3.4)	.99	0.05
Scapular position (degrees)			
Posterior tilt	10.4 (5.1)	.95	1.2
Upward rotation	14.5 (5.9)	.89	2.0
Internal rotation	37.7 (6.0)	.59	3.8
Superior/inferior (cm)	10.0 (0.5)	.91	0.1
Medial/lateral (cm)	10.1 (0.9)	.89	0.1
Upper thoracic inclination (degrees)	22.2 (6.1)	.89	2.0

Abbreviations: ICC, intraclass correlation coefficient; SEM, standard error of measurement.

Data Analysis

All dependent variables were compared before and after exercise with multivariate repeated-measures analysis of variance (MANOVA). We performed MANOVA (Hotelling's T^2) analyses by combining all strength variables, and by combining the rest, horizontal, and maximal elevation values for each scapular kinematic variable. The alpha level was set at .05 and univariate follow-up procedures were performed where there were significant findings with the MANOVA procedure.

RESULTS

Muscle Strength

Descriptive data relating to muscle strength before and after exercise are summarized in table 2. Results of the MANOVA for muscle strength before and after exercise indicate that all four isometric strength variables were significantly increased after the exercise program ($p < .05$) except that of the horizontal adduction. However, there was no significant difference found in the ratio of shoulder external rotation to internal rotation strength and that of horizontal abduction to horizontal adduction strength.

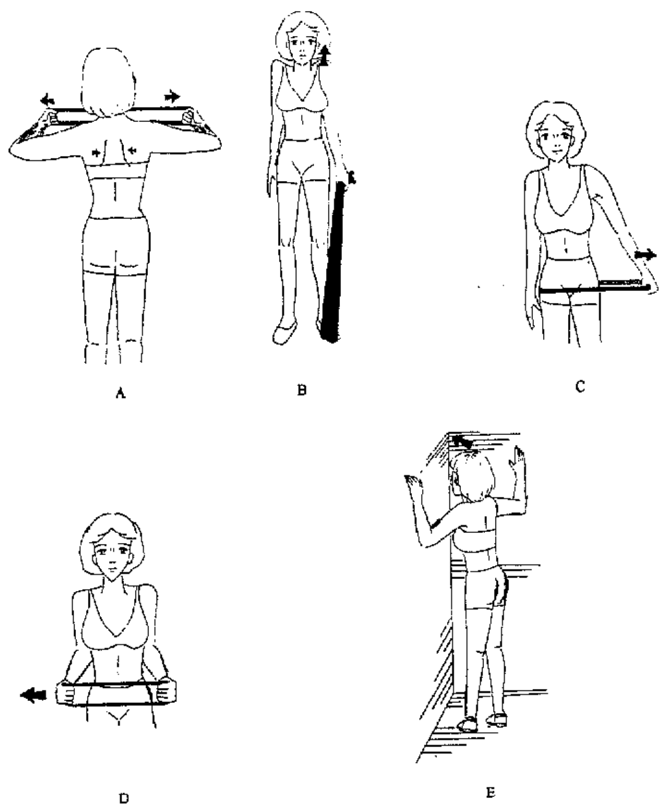

Fig 3. The exercise program: (A) scapular retraction; (B) shoulder shrugging; (C) shoulder abduction; (D) shoulder external rotation; (E) corner stretching.

Table 2: Isometric Muscle Strength Before and After Exercise

Variable	Before Exercise	After Exercise
External rotation* (kg)	6.0 (2.2)	8.0 (2.7)
Internal rotation* (kg)	8.4 (3.4)	11.3 (4.0)
Ratio of external to internal ratio	0.75 (0.2)	0.74 (0.2)
Horizontal abduction* (kg)	12.5 (4.8)	15.8 (6.0)
Horizontal adduction (kg)	10.3 (4.4)	11.4 (4.2)
Ratio of abduction/adduction	1.28 (0.3)	1.44 (0.5)

Values reported as mean (SD).
* $p < .001$ (all other p values $> .05$).

Kinematic Variables

Descriptive data relating to the scapular kinematic variables and upper thoracic inclination are summarized in table 3. During elevation of the arm there was a pattern of scapular upward rotation, posterior tilting, and superior translation with relatively little protraction and medial translation.

No significant difference was found for the scapular tilting angle before and after exercise in any of the three levels of shoulder abduction in the scapular plane. A significant difference existed before and after exercise at 90° of shoulder abduction in the scapular plane, which indicated less scapular upward rotation after performing exercises. The scapula represented a continuous internal rotation as the shoulder abducted from resting to maximum range before exercise; however, after exercise, it internally rotated as the shoulder abducted from resting to 90° and then externally rotated when the shoulder abducted from 90° to maximum range. A significant difference in protraction was found only at 90° of shoulder abduction before and after exercise. The scapular translated laterally and superiorly as the shoulder abducted from resting to 90°, then translated medially and further superiorly when the shoulder abducted from 90° to maximum range of motion. The scapula showed significantly less superior translation at 90° of shoulder abduction after exercise. The upper thoracic spine (C7 to T7) became less flexed by about 3° after the exercise program, which was statistically significant ($p < .05$).

Table 4 shows the values for total shoulder abduction and the values of the resultant ratio of glenohumeral to scapulothoracic upward rotation motion. The mean maximal shoulder abduction increased significantly after exercise. There was also a significant increase in the glenohumeral contribution to movement at both 90° and maximum shoulder elevation after exercise.

Table 3: Scapular Kinematic Variables and Upper Thoracic Inclination Before and After Exercise

Variable/Arm Position	Before Exercise	After Exercise
Posterior tilting (degrees)		
Rest	18.7 (10.7)	18.2 (5.6)
Horizontal	30.0 (11.9)	30.7 (7.5)
Max	46.9 (9.1)	49.1 (7.2)
Upward rotation (degrees)		
Rest	13.5 (6.9)	12.6 (4.6)
Horizontal*	29.3 (5.9)	23.2 (5.3)
Max	44.8 (6.3)	42.4 (6.8)
Internal rotation (degrees)		
Rest	38.2 (7.5)	39.5 (4.6)
Horizontal*	40.4 (8.8)	47.9 (6.9)
Max	41.2 (9.2)	40.6 (10.5)
Superior/inferior translation (cm)		
Rest	10.8 (1.3)	11.3 (1.2)
Horizontal*	9.2 (1.4)	10.1 (1.7)
Max	7.8 (1.4)	8.5 (1.3)
Medial/lateral translation (cm)		
Rest	10.7 (1.0)	10.7 (1.1)
Horizontal	11.1 (1.1)	11.5 (1.4)
Max	9.8 (1.3)	10.1 (1.5)
Upper thoracic inclination (degrees)		
Rest*	24.6 (6.3)	21.3 (6.4)
Horizontal*	25.1 (6.3)	22.6 (6.6)
Max*	21.4 (6.1)	19.0 (6.1)

Values reported as mean (SD). Posterior tilting and internal rotation represented by *increasing* values; superior translation and medial translation represented by *decreasing* values.
* $p < .01$ (all other p values $> .05$).

DISCUSSION

Muscle Strength

The exercise program was designed to strengthen the posterior scapular muscles as well as the glenohumeral external rotators. Our subjects showed significant gains in isometric force for both external and internal rotation as well as horizontal abduction, but not horizontal adduction. We did not expect and cannot explain the gain in internal rotation strength. We selected the four strengthening exercises based on previous reported electromyographic (EMG) data. Moseley and coworkers[12] and McCann and associates[13] analyzed EMG activities of scapular muscles for several commonly prescribed rehabilitation exercises, including glenohumeral external rotation, horizontal abduction (or scapular retraction), shoulder abduction, and shoulder shrugging, which were performed in our study. Based on these two previous EMG studies, our exercise program should not have produced significant muscle activity in the glenohumeral internal rotators (pectoralis, teres major, and subscapularis) and the horizontal adductors (mainly the pectoralis). One possible explanation is that the corner stretching exercise may have produced eccentric muscle activity in the pectoralis muscles if the subjects did not relax these muscles as they leaned their body toward the wall.

There was virtually no change in the ratio of external/internal rotation force after the exercise period. Despite a relative increase in horizontal abduction strength, the mean ratio between horizontal abduction/adduction did not change significantly ($p = .21$). Perhaps a different and more specific set of exercises would produce a change in these ratios.

The exercise regimen of three times per week for 6 weeks was chosen. The effects of the commonly used resistive exercise protocol, three times per week for 6 weeks, have been studied by other authors. For example, Rozier and coworkers[14] compared the maximum isometric and isotonic muscle torques before and after a 6-week exercise program in two groups of subjects (three times per week and daily for five times per week). Strength gains were significant in both groups but no significant difference in strength gains were found between the two groups. Zmierski and colleagues[15] also found significant

Table 4: Maximal Shoulder Abduction and Glenohumeral/Scapulothoracic Upward Rotation Ratio Before and After Exercise

Variable	Before Exercise	After Exercise
Maximal shoulder abduction (degrees)	160.7 (8.2)	167.3 (9.3)*
GH/ST (rest to 90°)	2.1 (0.7)	3.3 (1.1)*
GH/ST (rest to maximal)	2.6 (0.5)	3.0 (0.7)*

Values reported as mean (SD).
Abbreviation: GH/ST, Glenohumeral elevation/scapulothoracic upward rotation.
*$p < .01$.

strength gains after a 6-week, three-times-per-week program of scapular muscle strengthening. Because the target muscle strength increased significantly in this study after exercise (33% and 26% for external rotation and horizontal abduction, respectively), we believe the exercise regimen chosen for this study was appropriate. In earlier work, where only active retraction exercise was used without resistance (other than gravity), we failed to obtain a strengthening effect with the same frequency of exercise.[11]

Kinematic Variables

The three-dimensional scapular position and orientation at rest was not changed after exercise. This finding is consistent with the work of DiVeta,[6] who found no correlation between scapular resting posture and scapular muscle strength. In other work, we also failed to show a change in scapular resting posture after a 6-week active-exercise program.[11] These earlier findings are what prompted us to assess scapular position with the arm actively elevated. After exercise, we did find changes in scapular position with the arm actively elevated to 90°. The scapula was less upwardly rotated, less superiorly translated, and more internally rotated. Associated with these changes was an increase in the ratio of glenohumeral to scapulothoracic upward rotation, or so-called "scapulohumeral rhythm."

Some authors believe that decreased scapular upward rotation may result in shoulder impingement syndrome.[1,4,16] This belief is based on the notion that when the shoulder is abducted overhead with insufficient scapular upward rotation, the greater tuberosity and the acromion become too close, and therefore, the soft tissues in the subacromial space may be pinched by the bony structures. Based on this idea, clinicians often prescribe exercises focusing on scapular upward rotators, such as serratus anterior muscle, to achieve "sufficient" scapular rotation during shoulder abduction.[4,8] This idea has been challenged by two studies.[7,17] Greenfield and associates[7] compared resting scapular position between healthy subjects and subjects with overuse injuries of the shoulder and found no difference in scapular upward rotation between the two groups. Cole and coworkers[17] examined the three-dimensional position of the scapula in an asymptomatic group and a group with shoulder impingement with the arm at rest, abducted to 90°, and maximally abducted. No significant difference for scapular upward rotation was found between those two groups. However, the impingement group was significantly less posteriorly tilted during arm elevation.

Based on our data, the scapula actually showed less upward rotation to accomplish a significantly higher range of total shoulder elevation after the 6-week exercise program. It is possible that after the exercises the scapular muscles were stronger to stabilize the scapula on the thorax. This may have allowed greater glenohumeral motion to occur. Rotator cuff strengthening and improved gliding of the cuff tendons relative to the surrounding subacromial tissues and humeral head may have also facilitated glenohumeral motion.

The increased scapular internal rotation found at the 90° position is difficult to explain. We took considerable care to position the subject the same way for each test session relative to the plywood frame used to guide the arm in the scapular plane. The upper portion of the serratus anterior may have been more active after the exercise program because increased activity of the lower portion would be expected to cause upward rotation and posterior tilting. At maximal elevation, there was no difference after exercise.

The decrease in superior translation of the scapula reflects greater stabilization of the scapula and enhanced motion at the glenohumeral joint, presumably because of improved function of the rotator cuff. Babyar[18] found that superior translation of the scapula was reduced after a single training and exercise session in subjects with a history of limited shoulder motion. Cole[17] found that subjects with impingement had greater scapular superior translation compared to controls during shoulder elevation to 90°. Warner and associates[19] also reported that four of seven subjects with shoulder dysfunction showed a more elevated scapula during shoulder abduction.

We found that the mean upper thoracic inclination angle decreased (extended) about 3°, which was statistically significant, after the exercise program. The clinical significance of this amount of change is unclear. We found in other work that, compared with an upright posture, a slumped (flexed) thoracic posture resulted in decreased elevation muscle force and altered scapular movement patterns.[20] According to our reliability study, the standard error of measurement (SEM) was 2°; this suggests that only changes greater than 4° (2 SEM or 95% confidence interval) can be considered true changes and not change attributable to measurement error. Seven subjects had changes greater than 4° (range 4.1 to 10.4), eight had changes between 2° and 4°, and the remaining five had changes less than 2°. Many subjects informally reported feeling "straighter" or "taller" after the exercises. The perception of a more erect posture may result from improvement of the subjects' self-awareness of their posture.

Limitations

Our subjects were essentially young and healthy, and the significance of the forward shoulder posture by plumbline analysis is questionable because most volunteers demonstrated this phenomenon. Subjects with current shoulder pathology may respond differently to a strengthening program, and we are currently pursuing a study involving patients.

Another limitation of this study is that measurements were taken under static conditions rather than continuously during motion. We have recently developed a new method for tracking the scapula during elevation, and preliminary data suggest static measures are very similar to dynamic measures at corresponding levels of humeral elevation. Also, many functional activities are performed with the shoulder in a static position.

We prescribed theraband to our subjects based on the objective measurements as well as on observations of the investigator and on responses from the subjects. Theraband is convenient and inexpensive. However, because theraband is elastic, the resistance offered by the band is dependent on its length, which was not strictly controlled. Therefore, the exact amount of resistance provided in this study is not known.

CONCLUSIONS

Isometric shoulder external rotation, internal rotation, and horizontal abduction force were increased after a resistive exercise program performed three times a week for 6 weeks. The ratio of external rotation force to internal rotation force and the ratio of horizontal abduction to adduction force did not change. The use of exercise to alter shoulder posture is not supported by our results. The exercises used seem to promote scapular stability and produce a relative increase in glenohumeral motion during humeral elevation. These exercises may also produce a more upright posture of the upper thoracic spine. Further work is necessary to clarify the effects of exercise in patient populations.

References

1. Culham E, Peat M. Functional anatomy of the shoulder complex. J Orthop Sports Phys Ther 1993;18:342-50.

2. Inman VT, Saunders M, Abbott LC. Observations on the function of the shoulder joint. J Bone Joint Surg Am 1944;26:1-30.
3. Paine RM, Voight M. The role of the scapula. J Orthop Sports Phys Ther 1993;18:386-91.
4. Kelley MJ, Clark WA. Orthopedic therapy of the shoulder. Philadelphia (PA): J. B. Lippincott; 1995.
5. Kendall FP, McCreary EK. Muscle testing and function. 3rd ed. Baltimore (MD): Williams & Wilkins; 1983.
6. DiVeta J, Walker ML, Skibinski B. Relationship between performance of selected scapular muscles and scapular abduction in standing subjects. Phys Ther 1990;70:476-9.
7. Greenfield B, Catlin PA, Coats PW, Green E, McDonald JJ, North C. Posture in patients with shoulder overuse injuries and healthy individuals. J Orthop Sports Phys Ther 1995;21:287-95.
8. Allegrucci M, Whitney SL, Irrgang JJ. Clinical implications of secondary impingement of the shoulder in freestyle swimmers. J Orthop Sports Phys Ther 1994;20:307-18.
9. Jobe FW, Moynes DR. Delineation of diagnostic criteria and a rehabilitation program for rotator cuff injuries. Am J Sports Med 1982;10:336-9.
10. Kvitne RS, Jobe FW. The diagnosis and treatment of anterior instability in the throwing athlete. Clin Orthop 1993:291:107-23.
11. Baker-Sawyer K, McClure P, Fitzgerald K. The effect of a scapular retraction exercise program on scapular position and scapular muscle force [abstract]. J Orthop Sports Phys Ther 1996;23: 75-6.
12. Moseley JB, Jobe FW, Pink M, Perry J, Tibone J. EMG analysis of the scapular muscles during a shoulder rehabilitation program. Am J Sports Med 1992;20:128-34.
13. McCann PD, Wootten ME, Kadaba MP, Bigliani LU. A kinematic and electromyographic study of shoulder rehabilitation exercises. Clin Orthop 1993;288:179-88.
14. Rozier CK, Schafer DS. Isokinetic strength training: comparison of daily and three times weekly patterns. Int J Rehabil Res 1981;4:345-51.
15. Zmierski T, Kegerreis S, Scarpaci J. Scapular muscle strengthening. J Sports Rehabil 1995:244-52.
16. Freedman L, Munro RR. Abduction of the arm in the scapular plane: scapular and glenohumeral movements. A roentgenographic study. J Bone Joint Surg 1966;48:1503-10.
17. Cole A, McClure P, Pratt N. Scapular kinematics during arm elevation in healthy subjects and patients with shoulder impingement syndrome [abstract]. J Orthop Sports Phys Ther 1996;23:68.
18. Babyar S. Excessive scapular motion in individuals recovering from painful and stiff shoulders: causes and treatment strategies. Phys Ther 1996;76:226-38.
19. Waner JP, Micheli L, Arstania L, Kennedy J, Kennedy R. Scapulothoracic motion in normal shoulders and shoulders with glenohumeral instability and impingement syndrome. Clin Orthop 1992;285:191-9.
20. Kaebaetse M, McClure PW, Pratt N. The effect of thoracic posture on scapular position, shoulder elevation muscle force and shoulder elevation range of motion [abstract]. J Orthop Sport Phys Ther 1997;25:68.

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