Recruitment of Shoulder Complex and Torso Stabilizer Muscles With Rowing Exercises Using a Suspension Strap Training System

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Background: Suspension training systems, which use body weight resistance under unstable conditions, may be effective for muscle strengthening in persons with scapular dyskinesis or subacromial impingement syndrome.

Hypothesis: Greater arm, scapular, and trunk muscle recruitment will occur during horizontal abduction row exercises.

Study Design: Descriptive laboratory study.

Level of Evidence: Level 5.

Methods: Surface electromyography data were collected from 28 participants (14 men, 14 women). A total of 13 right-sided muscles were studied at a sampling frequency of 1000 Hz. Maximal voluntary isometric contractions (MVICs) were established. Participants completed 3 repetitions per exercise in random order. We compared muscle recruitment during 3 rowing exercises: low row, high row, and horizontal abduction row. Data were compared with repeated-measures analyses of variance and post hoc Bonferroni corrections.

Results: For high row and horizontal abduction row conditions, the upper, middle, and lower trapezius and posterior deltoid demonstrated >60% MVIC magnitudes of recruitment, and the upper erector spinae demonstrated 40% to 60% MVIC magnitudes of recruitment, respectively. In contrast, in the low row exercise, 40% to 60% MVIC magnitudes of recruitment were observed only in the middle trapezius, latissimus dorsi, and posterior deltoid.

Conclusion: With the suspension system, high row and horizontal abduction row exercises promote muscle strengthening (>50% MVIC) in the upper, middle, and lower fibers of the trapezius, posterior deltoid, and upper erector spinae.

Clinical Relevance: Rowing exercises performed with suspension straps may be recommended for muscle strengthening in patients with scapular dyskinesis and subacromial impingement syndrome as well as for healthy persons in need of enhanced scapular muscle performance.

Keywords: electromyography; exercise therapy; scapular dyskinesis

Scapular dyskinesis may be caused, in part, by muscle imbalances about the shoulder.¹⁷ These muscle imbalances can be assessed by analyzing muscle recruitment through electromyography (EMG). Ludewig et al,¹⁷ for example, examined upper trapezius-to-serratus anterior

EMG recruitment ratios during push-up exercises because a reduced ratio (ie, lower upper trapezius recruitment coupled with higher serratus anterior recruitment) optimizes dynamic force coupling to improve posterior scapular tipping and maximize subacromial space. Other investigators have observed

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The authors report no potential conflicts of interest in the development and publication of this article.

DOI: 10.1177/1941738120945986

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higher upper trapezius-to-middle trapezius and upper trapezius-to-lower trapezius recruitment ratios during shoulder exercises in patients with subacromial impingement syndrome.^{3,4} As a consequence, one recommendation is that rehabilitation providers should refrain from prescribing shoulder strengthening exercises with the arm elevated more than 90° because the likelihood for compressing the rotator cuff against the undersurface of the acromion increases in that position.¹³ Instead, during early periods of rehabilitation, scapular retraction exercises are recommended to avoid positions that may contribute to impingement while promoting strengthening in the scapular stabilizing muscles.^{13-15,23}

Scapular retraction exercises promote “pulling” movements that are common in a person’s daily activities, such as opening doors, picking up objects from the floor, or starting a lawnmower. Rehabilitation providers educate patients on exercise programs designed to improve pulling performance in athletics or the work environment.^{6-8,16,19,24} Trapezius muscle recruitment during “pulling” exercises (eg, rows) does not differ between healthy individuals and patients with subacromial impingement syndrome and therefore the exercises are considered to be safe.¹¹ Variations in the exercise, however, induce different upper trapezius-to-middle trapezius and upper trapezius-to-lower trapezius recruitment ratios.¹¹ Rowing exercises at 0° of shoulder abduction are recommended earlier in rehabilitation programs, whereas rowing exercises at elevated abduction angles are recommended later in rehabilitation programs. As patients progress in strength, one way to alter the demand of various pulling exercises is through use of a suspension strap system. When using a suspension strap system, the performer simultaneously recruits abdominal and back musculature to stabilize the spine so that primary mover muscles are able to execute vigorous arm motion when performing a rowing movement.^{18,19,24}

We compared recruitment in multiple muscles across 3 rowing exercises—low rows, high rows, and horizontal abduction rows—and evaluated differences in relative recruitment ratios for several scapular stabilizing muscles. Our primary aim was to compare muscle recruitment across low, high, and horizontal abduction rows for (1) primary movers of the scapula and arm, (2) secondary movers of the scapula and arm, (3) primary movers of the elbow, and (4) torso stabilizers. The secondary aim was to examine recruitment ratios for the primary movers to help rehabilitation professionals understand potential benefits or disadvantages when prescribing low, high, or horizontal abduction rows for patients.

METHODS

Participants

Based on an a priori power analysis, 28 healthy participants were recruited. The study was approved by the Mayo Clinic Institutional Review Board, and all participants provided informed consent.

Instrumentation

EMG signals were acquired with bipolar Bagnoli DE-2.1 surface electrodes and a Bagnoli-16 main amplifier unit (Delsys Inc) and processed with EMGWorks 4.2.0 software (Delsys Inc). For further information on EMG instrumentation, electrode placement, and processing procedures, please see the Appendix (available in the online version of this article).

Procedures

Electrodes were adhered over the bellies of 13 right-sided muscles, parallel to each muscle’s respective line of action. For organizational clarity, the 13 muscles were classified into 4 sets of muscle groups: (1) primary movers of the scapula and arm (upper trapezius, middle trapezius, lower trapezius, latissimus dorsi, posterior deltoid), (2) secondary movers of the scapula and arm (serratus anterior and anterior deltoid), (3) brachii muscles (triceps brachii, biceps brachii), and (4) torso stabilizers (upper thoracic erector spinae, lower lumbar erector spinae, rectus abdominis, external oblique).

Suspension straps (TRX Suspension Trainers; Fitness Anywhere LLC) were secured to a fixed point above the participant, which permitted the user to move against his or her body weight from a suspended position.^{22,24} Participants performed 3 repetitions of each rowing exercise: low row (Figure 1, a and b), high row (Figure 1, a and c), and horizontal abduction row (Figure 1, a and d). For each repetition, both shortening and lengthening phases of the movement were performed over 2-second durations. Participants were permitted a 2-minute break between rowing exercises to minimize fatigue. Testing order was randomized for each participant.

EMG data obtained during the tests were normalized to the muscles’ respective maximal voluntary isometric contraction (MVIC) (see Appendix, available online). EMG amplitudes were calculated for each of the 3 repetitions per trial. Mean amplitudes in a 500-ms window surrounding each repetition’s peak value observed during the concentric recruitment periods were calculated. For analysis purposes, mean values across the 3 repetitions were analyzed.

Statistical Analysis

EMG recruitment amplitudes were compared between testing conditions with repeated-measures analyses of variance at $\alpha = 0.05$. Post hoc comparisons were conducted with Bonferroni-corrected α to compensate for multiple comparisons. In the analysis of recruitment ratios, ratio data within each muscle pair (ie, upper trapezius-to-middle trapezius, upper trapezius-to-lower trapezius, upper trapezius-to-latissimus dorsi, and upper trapezius-to-posterior deltoid) across the 3 testing conditions were analyzed with Friedman analysis of variance by ranks tests ($\alpha = 0.05$) and Wilcoxon signed rank tests with Bonferroni corrections. All data were analyzed with SPSS Statistics Version 22 software (IBM Corp). Additional information relevant to the statistical analysis is provided in the Appendix (available online).

Figure 1. Rowing exercises. (a) Starting position for low row (LR), high row (HR), and horizontal abduction row (HAR) with the body at a 45° angle relative to the floor using the reference frame in the background. The arms are flexed to 90°, elbows extended, and scapulae protracted. (b) End point of the concentric phase of LR with arms extended, elbows flexed, and scapulae retracted and depressed. Participants returned to the starting position using an eccentric contraction of the primary movers and then performed 2 more repetitions. (c) End point of the concentric phase of the HR with arms horizontally abducted to 90°, elbows flexed to 90°, and scapulae retracted. Participants returned to the starting position using an eccentric contraction of the primary movers and performed 2 more repetitions. (d) End point of the concentric phase of HAR with arms horizontally abducted to 90°, elbows extended to 0°, and scapulae retracted. Participants returned to the starting position and completed 2 more repetitions.

Table 1. Characteristics of study participants^a

Characteristic	Men (n = 14)	Women (n = 14)
Age, y	23.3 (0.7)	23.3 (1.3)
Height, m	1.8 (0.1)	1.7 (0.1)
Mass, kg	80.8 (9.4)	64.3 (5.9)
Body mass index, kg/m ²	24.9 (3.0)	23.2 (2.2)

^aValues are provided as mean (SD).

RESULTS

Among 28 volunteers (14 men and 14 women), none were excluded and all were participants (Table 1). Muscle recruitment in the (1) primary movers of the scapula and arm, (2) secondary movers of the scapula and arm, (3) brachii muscles, and (4)

torso stabilizers varied across the 3 rowing exercise conditions, though highest magnitudes of recruitment in the primary movers were observed in the high row and horizontal abduction row conditions (Table 2). Median recruitment ratios for primary movers of the scapula and arm during the 3 rowing conditions ranged from 0.4 to 6.1 (Table 3). With the exception of the upper trapezius-to-latissimus dorsi pair, median ratios for the upper trapezius-to-middle trapezius, upper trapezius-to-lower trapezius, and upper trapezius-to-posterior deltoid pairings ranged from 0.4 to 1.3.

DISCUSSION

Low Row: Muscle Recruitment (Aim 1)

A benefit of the low row exercise was the movement of the scapula into retraction, depression, and downward rotation coupled with arm extension and adduction. The humeral head was not likely to be compressed against the undersurface of the acromion process, thereby reducing one's susceptibility to subacromial impingement.⁹ The low row exercise, however, was disadvantaged in that it may have had minimal capacity to

Table 2. Muscle recruitment across exercise conditions as a percentage of maximal voluntary isometric contraction (MVIC)^a

Muscle	Exercise ^b		
	Low Row	High Row	Horizontal Abduction Row
Primary movers of scapula and arm			
Upper trapezius	16.4 (20.2) L	75.0 (34.0) VH	84.8 (55.5) VH
Middle trapezius	43.3 (19.3) H	74.8 (34.6) VH	94.0 (31.3) VH
Lower trapezius	23.8 (20.5) M	73.8 (28.0) VH	69.7 (39.5) VH
Latissimus dorsi	48 (23.3) H	11.5 (10.2) L	31.2 (17.4) M
Posterior deltoid	45.3 (20.1) H	62.9 (17.4) VH	88.1 (16.6) VH
Secondary movers of scapula and arm			
Serratus anterior	19.5 (22.6) L	12.7 (16.0) L	15.0 (17.4) L
Anterior deltoid	4.2 (5.1) L	9.6 (9.0) L	18.3 (14.4) L
Brachii			
Triceps brachii	13.1 (11.2) L	13.4 (11.3) L	33.4 (19.5) M
Biceps brachii	20.5 (15.2) M	38.3 (20.4) M	22.2 (34.2) M
Torso stabilizers			
Upper (thoracic) erector spinae	20.7 (22.4) M	53.7 (43.6) H	53.4 (50.8) H
Lumbar erector spinae	19.3 (23.7) L	27.0 (23.6) M	29.5 (43.0) M
Rectus abdominis	8.1 (12.8) L	4.3 (14.5) L	7.2 (21.0) L
External oblique	8.6 (10.2) L	7.1 (11.1) L	10.8 (15.8) L

H, high; L, low; M, moderate; VH, very high.

^aValues are provided as mean (SD) % MVIC.

^bThe % MVICs are categorized as follows: VH, >60% MVIC; H, 41% to 60% MVIC; M, 21% to 40% MVIC; L, 0% to 20% MVIC.

promote strengthening effects. Per our findings (Table 2), recruitment levels were below the 50% MVIC threshold beyond which strengthening effects were promoted in all 13 muscles we examined.^{1,2}

High and Horizontal Abduction Row: Muscle Recruitment (Aim 1)

The benefit of high and horizontal abduction rows was the high (>50% MVIC) recruitment in 4 of the 5 primary movers (Table 2). During high and horizontal abduction rows, the arm moved from a position of 90° of flexion at the start position to a horizontally abducted position at the end point. Upper trapezius recruitment was very high to help stabilize the scapula and to resist downward rotation in response to increased recruitment of the posterior deltoid as it produced horizontal abduction.^{10,20} Upper trapezius recruitment with high and horizontal abduction rows can be

sufficient to promote muscle strengthening,^{1,2} but may potentially compromise the subacromial space if recruited excessively and out of balance with other scapular stabilizing muscles.¹⁷ During high and horizontal abduction rows, the middle trapezius stabilized and retracted the scapula on the chest wall, in part responding to tension created by the posterior deltoid. Without proper stabilization, the posterior deltoid would pull the scapula into protraction and downward rotation, negating horizontal abduction. The trapezius and posterior deltoid were recruited at levels sufficient for muscle strengthening.^{1,2}

A second benefit of high and horizontal abduction rows was high recruitment in the upper (thoracic) erector spinae at levels sufficient to produce a strengthening effect.^{1,2} Middle trapezius muscle force produced scapular retraction; nevertheless, the same forces simultaneously caused spinous processes of lower cervical and upper thoracic vertebrae to rotate toward the

Table 3. Recruitment ratios for primary movers of the scapula and arm

Muscle Pair	Exercise ^a			Test Statistics
	Low Row	High Row	Horizontal Abduction Row	
UT:MT	0.4 (0.2-0.8)	0.9 (0.7-1.4)	0.9 (0.6-1.4)	HAR > LR ($P < 0.001$) HR > LR ($P < 0.001$)
UT:LT	0.5 (0.2-0.8)	1.0 (0.7-1.2)	0.8 (0.6-1.3)	HAR > LR ($P = 0.006$) HR > LR ($P = 0.006$)
UT:LD	0.4 (0.13-0.8)	6.1 (3.5-10.4)	2.8 (1.8-4.2)	HR > LR ($P < 0.001$) HAR > LR ($P < 0.001$) HR > HAR ($P < 0.001$)
UT:PD	0.4 (0.2-0.7)	1.3 (0.8-1.6)	1.0 (0.6-1.4)	HR > LR ($P < 0.001$) HAR > LR ($P < 0.001$) HR > HAR ($P = 0.02$)

HAR, horizontal abduction row; HR, high row; LD, latissimus dorsi; LR, low row; LT, lower trapezius; MT, middle trapezius; PD, posterior deltoid; UT, upper trapezius.

^aValues are provided as median (interquartile range) of recruitment ratios during the concentric phase of the 3 rowing exercises.

ipsilateral scapula and decreased forceful scapular retraction bilaterally. When upper thoracic erector spinae were recruited concurrently with the middle trapezius, the proximal end of the middle trapezius was relatively fixed and the vertebrae stabilized so the primary force created in the middle trapezius could be focused at its scapular end to produce scapular retraction.²⁰

A disadvantage of all 3 rowing exercises was the absence of a strengthening effect in the lumbar erector spinae and abdominal muscles. Participants maintained a neutral lumbar spine posture during each rowing movement in response to a thoracolumbar flexion moment created by the pulling force generated by the upper extremities through the suspension straps. Working bilaterally, the lumbar erector spinae and rectus abdominis provided vertical stability to the lumbar spine in the sagittal plane whereas the external oblique muscles maintained vertical stability in the frontal plane.^{18,20} Based on our findings, while these muscles were recruited at low to moderate levels, strengthening effects were unlikely to occur during rowing exercises.

Recruitment Ratios (Aim 2)

Recruitment ratios exceeding 1.0 indicate the upper trapezius is recruited to a greater extent than is the other coupled muscle, which may potentially make an individual more susceptible to subacromial impingement.^{3,4,17} Kibler et al^{12,13,15} suggest patients with subacromial impingement, when performing exercises that recruit the scapular retractors, position the arm below shoulder level (ie, 90° of flexion or abduction) to avoid placing the arm in a position that may reduce subacromial space. Rowing exercises using a suspension strap system satisfy that recommendation because rows emphasize scapular retraction, depression, and downward rotation with arm extension, and the arm is never elevated beyond 90°.¹⁰

Recruitment ratios for the primary movers of the scapula and arm were calculated for 3 rowing exercises. Upper trapezius-to-middle trapezius and upper trapezius-to-lower trapezius were equal to or less than 1.0 for all 3 conditions. This supported findings from previous studies.^{3,4,24} The upper trapezius-to-lower trapezius ratios below 1.0 observed in our study differ from ratios ranging from 1.14 to 2.65 reported by Kara et al¹¹ during elastic band-resisted rowing exercises. Differences in methodologies may account for those contrasting findings because while we examined EMG magnitudes during the concentric “pulling” phase of the exercises, Kara et al¹¹ examined EMG only in the isometric “holding” phase of the exercises. Collectively, the low row condition produced the lowest relative upper trapezius recruitment ratios across all the primary movers.

Previous investigators measured comparable scapular muscle recruitment ratios in exercises with participants in prone or side-lying positions using pulley systems or dumbbells.^{4,15} Findings from our study provide an option for upright exercise using the suspension strap training system. Balanced scapular muscle recruitment ratios were developed in rowing exercises that did not require the performer to elevate the arm more than 90°. The rowing exercises investigated in this study may be an option when prescribing exercises for patients or athletes to strengthen posterior shoulder and back musculature without placing the arm into a position that may increase the risk of subacromial impingement. Specifically—and supporting the recommendations of Kara et al¹¹—the low row exercise, which had the lowest upper trapezius-to-middle trapezius and upper trapezius-to-lower trapezius recruitment ratios, may be a more appropriate exercise when initially working with patients experiencing shoulder problems. Horizontal abduction rows, on the other hand, elicited the greatest muscle recruitment values

across all 13 muscles tested while maintaining median scapular recruitment ratios of 0.9 and 0.8, respectively, for upper trapezius-to-middle trapezius and upper trapezius-to-lower trapezius pairings. Horizontal abduction rows may be more effective when prescribing exercise to well-trained athletes or patients who have already mastered the low row and are in need of a more challenging exercise to promote muscle strengthening.

Limitations

This was a foundational study, and extrapolation to patients cannot be made. Future studies examining rowing exercises with suspension straps in patient populations are recommended. Additionally, we were unable to capture EMG recruitment of the rhomboid muscles because of their deep relationship to the middle trapezius.⁵ Cross-talk from the rhomboids may have contributed to the high to very high recruitment obtained from the middle trapezius. Future research would benefit from recording EMG activity from the rhomboids with fine-wire electrodes.²¹ Similarly, we were unable to capture EMG recruitment of the rotator cuff muscles because of their deep relationship to more superior muscles, including the trapezius and deltoid. Future research would benefit from examining EMG activity in the rotator cuff muscles during comparable rowing exercises.

CONCLUSION

Rowing exercises with suspension straps elicited upper trapezius-to-middle trapezius and upper trapezius-to-lower trapezius recruitment ratios near or less than 1.0, indicating training stimuli that did not promote overrecruitment of the upper trapezius may potentially compromise subacromial space dimensions. While low row exercises minimized the upper trapezius recruitment ratios, high row and horizontal abduction rows elicited higher recruitment in most primary movers of the scapula and arm (upper trapezius, middle trapezius, lower trapezius, and posterior deltoid). Additionally, high rows and horizontal abduction rows elicited high levels of recruitment in trunk stabilizing muscles (eg, upper erector spinae) not observed in low rows. High rows and horizontal abduction rows therefore may better promote strengthening effects than low rows do in advanced stages of rehabilitation.

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