

# Shoulder Retractor Strengthening Exercise to Minimize Rhomboid Muscle Activity and Subacromial Impingement

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## ABSTRACT

**Purpose:** We investigated the best position for shoulder retractor strengthening exercise to maximize middle trapezius activity and minimize rhomboid major activity. Although both trapezius and rhomboids are scapular retractors, rhomboids also act as downward rotators of the scapula, which can worsen subacromial impingement. **Methods:** Twelve healthy participants (age 30 [SD 6] y) with no history of shoulder pain were recruited for this study, which used fine-wire electromyography to examine maximal muscle activation of the middle trapezius and rhomboid major muscle fibres in four different positions: with the shoulder in 90° abduction with elbow completely extended and (1) shoulder internal rotation, (2) shoulder neutral rotation, (3) shoulder external rotation, and (4) rowing (shoulder neutral rotation and elbow flexed 90°). The ratio of trapezius to rhomboid muscles was compared with Wilcoxon signed-rank tests. **Results:** Muscle activation ratio during shoulder retraction exercise was significantly lower by 22% (i.e., rhomboid was more active than middle trapezius) when performed with the shoulder in rowing position (elbow flexed) than with the shoulder in external rotation (elbow extended) position ( $p = 0.031$ ). All four positions produced coactivation of trapezius and rhomboids. **Discussion:** Rowing position may not be the best position for shoulder retractor strengthening in patients with impingement syndrome. The preferable position for maximizing middle trapezius activity and minimizing rhomboid activity may be shoulder external rotation with elbow extended.

**Key Words:** electromyography; resistance training; shoulder; superficial back muscles.

## RÉSUMÉ

**Objet:** Chercher la meilleure position pour un exercice de renforcement du rétracteur de l'épaule afin de maximiser l'activité du trapèze moyen et de réduire celle du grand rhomboïde au minimum. Même si les deux sont des rétracteurs de l'omoplate, les rhomboïdes font aussi pivoter l'omoplate vers le bas, ce qui peut aggraver la compression subacromiale. **Méthodes:** On a recruté 12 participants en bonne santé (âgés de 30 [ET 6] ans) sans antécédent de douleur à l'épaule pour cette étude dans le cadre de laquelle on a utilisé l'électromyographie à fil fin pour étudier l'activité maximale des fibres musculaires du trapèze moyen et du grand rhomboïde dans différentes positions: épaule en abduction à 90° avec coude en extension complète et a) rotation de l'épaule vers l'intérieur, b) rotation neutre de l'épaule, c) rotation de l'épaule vers l'extérieur d) mouvement d'aviron (rotation neutre de l'épaule et coude en flexion à 90°). On a comparé le ratio des trapèzes par rapport aux rhomboïdes au moyen du test de Wilcoxon pour observations appariées. **Résultats:** Le ratio d'activation musculaire au cours de l'exercice de rétraction de l'épaule était beaucoup moins élevé de 22% (c.-à-d. que le rhomboïde était plus actif que le trapèze moyen) l'épaule en position d'aviron (coude en flexion) qu'en position de rotation vers l'extérieur (coude en extension) ( $p = 0,031$ ). Les quatre positions ont produit une coactivation du trapèze et des rhomboïdes. **Discussion:** La position d'aviron n'est peut-être pas la meilleure position pour renforcer le rétracteur de l'épaule chez les patients qui ont un syndrome de pincement. La position préférée pour maximiser l'activité du trapèze moyen et réduire celle des rhomboïdes au minimum peut être la rotation vers l'extérieur, le coude en extension.

Shoulder pain is very common, with a lifetime prevalence of one in three people,<sup>1</sup> and it is the third leading musculoskeletal cause for seeking medical attention (after neck and back pain).<sup>2</sup> Subacromial impingement syndrome is the most common etiology<sup>3</sup> and accounts for approximately 40% of all shoulder pain disorders.<sup>4</sup> Subacromial impingement is defined as painful contact

between the rotator cuff or subacromial bursa and the acromial arch or coracoacromial ligament.<sup>5</sup> Probably because of this syndrome's high prevalence and the frequency with which it is encountered in clinical practice, the scientific literature on it has drastically increased, from 78 publications per year in 1999 to 159 per year in 2009.<sup>6</sup>

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**Competing interests:** None declared.

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In managing impingement syndrome, acromioplasty is often used as the definitive treatment strategy, and the number of these procedures performed over the past decade has dramatically increased: From 1996 to 2006, the number of acromioplasties performed in New York State increased 254% compared with an increase of 78% in all ambulatory orthopaedic surgical procedures.<sup>7</sup> However, a recent Cochrane review concluded that there is “silver”-level evidence that there are no significant differences in outcomes between open or arthroscopic subacromial decompression and active non-operative treatment of impingement,<sup>8</sup> which highlights the importance of conservative management with an emphasis on focused active rehabilitation.

Evidence of the possible implications of posture in the development of functional impingement is mounting. An *in vivo* MRI study with healthy volunteers found that the subacromial space decreases as the shoulder moves into protraction;<sup>9</sup> shoulder force production and range of motion are both adversely affected in a protracted position.<sup>10</sup> Several studies have also investigated the impact of subacromial impingement on shoulder complex muscle activation, and some have demonstrated decreased activation in the middle trapezius in people with impingement syndrome.<sup>11,12</sup> In particular, low or delayed recruitment of the middle and lower trapezius and serratus anterior and increased activity of the upper trapezius and rhomboid muscles can lead to imbalances between scapulothoracic and glenohumeral joints seen in people with impingement.<sup>13,14</sup> Postural re-education and addressing shoulder protractor–retractor imbalance are therefore integral components of the management of impingement.<sup>14</sup>

The two major scapular retractors<sup>15</sup> are the middle trapezius and the rhomboids, but these two muscles vary somewhat in their actions. The middle fibres of the trapezius function as pure scapular retractors, whereas the rhomboids act both to retract the scapula and to rotate it to depress the glenoid fossa. This inferior rotation of the scapula leads to a reduction in the subacromial space and may thus contribute to the development or persistence of impingement symptoms.<sup>11,16</sup> In contrast, middle trapezius exercise does not depress the glenoid fossa and can potentially increase deficient middle trapezius activation.<sup>11,12</sup> Therefore, theoretically, scapular retraction exercises that preferentially recruit the middle trapezius more than the rhomboids should be favoured in treating shoulder impingement syndrome. Exercises that take into account the optimal middle trapezius:rhomboids recruitment ratio may have implications for exercise prescription for patients with subacromial impingement. The purpose of this study was to examine electromyographic activation of the middle trapezius and rhomboids during four types of resisted scapular retraction exercises.

## METHODS

We recruited 12 healthy participants (mean age 30 [SD 6] y; 9 men, 3 women), irrespective of hand dominance, for this study; the only exclusion criteria were current shoulder pain and any history of prior shoulder injury or surgery. All participants signed an informed consent form approved by the ethics boards of West Park Healthcare Centre and the University of Toronto.

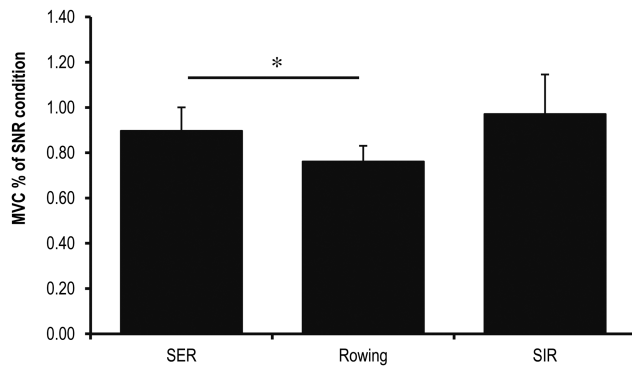
### Fine-wire electromyography

After cleaning the skin overlying the muscle bellies of the shoulder retractor muscles with alcohol, we introduced a pair of custom-made fine-wire electromyography (EMG) sensors into the muscle using a 25-gauge needle (1.5-in. length) under ultrasound guidance. The intra-scapular region on the dominant side medial to the scapular spine was examined sonographically to identify the thickest portion of each applicable muscle. The needle electrode was then advanced, targeting this area of each muscle. We placed one pair of fine-wire electrodes in the middle trapezius muscle and the other pair in the ipsilateral rhomboid major muscle (hereafter *rhomboid*), then carefully pulled out the needle, leaving the fine-wire sensors hooked to the muscle fibres.

Participants performed scapular retraction exercises in four different positions on their dominant side, which for all participants was the right side. Order of testing was decided using a random order scheme.<sup>17</sup> The different testing positions were as follows: 90° shoulder abduction with 180° elbow extension and (1) shoulder neutral rotation (SNR); (2) shoulder internal rotation (SIR), used to isolate the rhomboids;<sup>18</sup> (3) shoulder external rotation (SER), used to isolate the middle trapezius;<sup>18</sup> and (4) rowing position (SNR with 90° elbow flexion), reported to activate the middle trapezius.<sup>19</sup> Lying prone with the shoulder on the edge of the bed, participants were asked to retract their shoulder and resist as hard as possible for 3 seconds as the examiner provided maximal downward force in the direction of horizontal adduction just proximal to the elbow joint. The examiner provided standardized verbal encouragement in all trials to assist in maximal force output. Participants performed three trials of maximal voluntary contraction in each position.

### Data analysis

EMG data were sampled at 10 KHz, band-pass filtered (10–450 Hz) and full-wave rectified using EMGworks 4.0 (Delsys Inc., Boston, MA). We calculated the root-mean-square (RMS) for the middle 1 second of the MVC EMG data for both muscles. The RMS of the middle trapezius was divided by the RMS of the rhomboids to calculate the muscle activation ratio. The muscle activation ratio from condition 1 (SNR) was considered a control condition because the shoulder was in neutral rotation, and the other conditions (2–4) were normalized to MVC in neutral rotation. We chose to use non-



**Figure 1** Differences in muscle activation ratio (middle trapezius:rhomboids)

\*Statistically significant difference ( $p < 0.05$ ); vertical bars represent standard error of the mean.

MVC = maximal voluntary contraction; SNR = shoulder neutral rotation; SER = shoulder external rotation; SIR = shoulder internal rotation.

parametric statistics because of the small sample size. To assess which of four scapular retraction exercises preferentially activated the middle trapezius as opposed to the rhomboids, we performed Wilcoxon signed-rank tests using SPSS Statistics version 16.0 (IBM Corp., Armonk, NY), with the threshold for significance set at 0.05. Figure 1 was prepared using the Microsoft Excel add-on XL Toolbox (Daniel Kraus, Würzburg, Germany).

## RESULTS

We were not able to collect complete data for three participants, and EMG data for a fourth participant were not of good quality; therefore, we report average data from eight healthy participants (see Table 1 for raw values). We found that the middle trapezius:rhomboid ratio was significantly lower (22% lower) in rowing position than in SER ( $p = 0.031$ ; see Figure 1). The rhomboid was more active than the middle trapezius in the rowing position (elbow flexed) than in the SER (elbow extended) position. All four exercise positions produced coactivation of trapezius and rhomboids. We found no significant difference between SNR and SER ( $p = 0.46$ ) or between SNR and rowing conditions ( $p = 0.31$ ).

## DISCUSSION

Strengthening exercises are an important component of rehabilitation for people with impingement syndrome and can reduce pain, improve function, and prevent surgery.<sup>20–23</sup> Knowledge of the types of exercise that address muscle weakness without deteriorating the subacromial space or exacerbating the condition is important. Strengthening of scapular retractors is an important aspect of a shoulder strengthening exercise regimen for impingement syndrome. Our results suggest that shoulder retraction with the shoulder in either internal or external rotation does not preferentially activate the middle trapezius or rhomboids. In the rowing condition, however, rhomboid activity increased by 10% and middle trapezius

**Table 1** Raw MVC Values (Root-Mean-Square)

Muscle	Participant data*			
	SIR	SNR	SER	Rowing
Rhomboids	1.30	1.48	1.66	2.12
	0.82	0.37	0.93	1.61
	1.02	0.71	0.78	0.74
	4.64	3.03	4.72	4.40
	1.11	1.79	1.67	0.84
	1.38	1.09	1.34	1.26
	1.21	0.95	1.52	0.50
	1.41	2.17	1.29	2.64
	1.20	NA	NA	NA
	2.19	NA	NA	NA
	Mean	1.63	1.45	1.74
SD	1.12	0.86	1.25	1.29
Middle trapezius	6.23	4.25	4.28	5.40
	0.69	0.73	1.14	1.39
	0.83	1.27	1.03	0.97
	0.91	0.89	0.94	0.89
	1.28	NA	1.35	1.97
	1.39	1.78	1.73	1.31
	1.26	0.72	1.83	0.44
	2.75	2.62	1.54	2.60
	2.00	NA	NA	NA
	0.97	1.11	NA	NA
	Mean	1.83	1.67	1.73
SD	1.66	1.22	1.08	1.57

\*Except where otherwise indicated, each table row represents data from one participant.

MVC = maximal voluntary contraction; SIR = shoulder internal rotation; SNR = shoulder neutral rotation; SER = shoulder external rotation; NA = not available.

activity decreased by 15%, thus significantly decreasing the middle trapezius:rhomboid ratio in the rowing condition relative to the SER condition. The decrease in middle trapezius in rowing relative to SER can be attributed to the known hyperactivity of the middle trapezius during the SER movement relative to the rowing activity.<sup>24</sup> Our results reflect the differences in muscle activation patterns between the two chief scapular retractors during different types of shoulder exercise.

We found no difference in muscle activation ratio (middle trapezius:rhomboids) between SIR and SER, which supports previous findings.<sup>18</sup> Although muscle testing principles described in standard textbooks<sup>25</sup> have suggested preferential activation of the middle trapezius in SER, our data do not support this finding. Similarly, previous studies have shown no statistically significant difference between muscle activation patterns in a variety of testing positions recommended for isolating other scapular muscles.<sup>18</sup> Because differences in muscle activation patterns are difficult to perceive clinically (manually or visually),<sup>18</sup> clinicians must rely on EMG findings to help them make objective assessments of muscle strength and plan muscle-strengthening regimens. Scapular retractor muscle activation increases with increasing angle of retraction, but muscle activation also varies even when

scapular retraction angle remains unchanged while the shoulder is placed in different positions.<sup>26</sup> Our data, obtained using fine-wire EMG on deep scapular muscles (inaccessible by surface EMG), provide clinical insights into the best positions to strengthen scapular retractors in impingement syndrome, but these results need to be replicated in people with impingement syndrome.

No objective information or scientifically tested clinical guidelines are available to guide clinicians in understanding the impact of various forms of shoulder retraction exercises on muscle activation patterns. A recent study reported that two types of shoulder retraction exercise performed with scapular upward and downward rotation were not effective in strengthening retractors or improving scapular kinematics,<sup>27</sup> but we lack evidence on potentially beneficial exercises. Our study examined the differences in muscle activation patterns between two major scapular retractors, and our findings suggest that exercise performed in rowing position (90° shoulder abduction and 90° elbow flexion position) increases rhomboid activation and decreases middle trapezius activation. The testing position used for strengthening the posterior deltoid muscle (shoulder abduction 90°, slight extension, and internal rotation with resistance in antero-medial direction) is also reported to result in the highest rhomboid muscle activation.<sup>18</sup> For people with impingement syndrome, therefore, it may be best to avoid the rowing position and the posterior deltoid testing position for shoulder retractor strengthening exercise because these positions are likely to increase rhomboid activity and cause further impingement on the subacromial space.

Our study has several limitations. First, rhomboids are deep muscles and are thus inaccessible to surface EMG techniques; however, fine-wire sensors are small and do not capture EMG signals from the entire muscle. Second, we tested a small sample of healthy control participants, which may have biased the results because of the lower power of the study. Third, we did not record scapular retraction kinematics such as position and degree of retraction, which may not have been consistent across conditions. Finally, we did not measure muscle activation in other shoulder muscles; it is important to study muscle activity in the rest of the shoulder muscles because compensatory muscle activation can occur after shoulder impingement.

## CONCLUSIONS

Our data suggest that the optimal exercise for shoulder retractors is in shoulder abduction and external rotation position (with elbow extended), providing maximal trapezius and minimal rhomboid activation. These findings need to be confirmed in people with shoulder impingement. We recommend that future studies test this hypothesis as well as the impact of a rehabilitation programme incorporating shoulder retractor exercise in the optimal

position of shoulder abduction and external rotation (with elbow extension).

## KEY MESSAGES

### What is already known on this topic

The middle trapezius and rhomboid muscles are responsible for retraction of the scapula, but the middle fibres of the trapezius function as pure scapular retractors, whereas the rhomboids act both to retract the scapula and to rotate it to depress the glenoid fossa. This inferior rotation of the scapula leads to a decrease in the subacromial space that may contribute to the development or persistence of impingement symptoms. Middle trapezius muscle activation is decreased and rhomboid muscle activation is increased in participants with shoulder impingement syndrome.

### What this study adds

Our fine-wire EMG data suggest that scapular retractor isometric contraction exercise performed in 90° shoulder abduction with external rotation and elbow extended position can produce higher middle trapezius and lower rhomboid muscle activation. Rowing position (90° shoulder abduction, neutral shoulder rotation, and elbow flexed 90°) may not be the best position for scapular retractor strengthening in patients with impingement syndrome because it preferentially activates the rhomboid more than the middle trapezius.

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