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Rehabilitation of Scapular Muscle Balance

Which Exercises to Prescribe?

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Background: Strengthening exercises for the scapular muscles are used in the treatment of scapulothoracic dysfunction related to shoulder injury. In view of the intermuscular and intramuscular imbalances often established in these patients, exercises promoting lower trapezius (LT), middle trapezius (MT), and serratus anterior (SA) activation with minimal activity in the upper trapezius (UT) are recommended.

Hypothesis: Of 12 commonly used trapezius strengthening exercises, a selection can be performed for muscle balance rehabilitation, based on a low UT/LT, UT/MT, or UT/SA muscle ratio.

Study Design: Controlled laboratory study.

Methods: Electromyographic activity of the 3 trapezius parts and the SA was measured in 45 healthy subjects performing 12 commonly described scapular exercises, using surface electromyography.

Results: For each intramuscular trapezius ratio (UT/LT, UT/MT), 3 exercises were selected for restoration of muscle balance. The exercises side-lying external rotation, side-lying forward flexion, prone horizontal abduction with external rotation, and prone extension were found to be the most appropriate for intramuscular trapezius muscle balance rehabilitation. For the UT/SA ratio, none of the exercises met the criteria for optimal intermuscular balance restoration.

Conclusion: In cases of trapezius muscle imbalance, some exercises are preferable over others because of their low UT/LT and UT/MT ratios.

Clinical Relevance: In the selection of rehabilitation exercises, the clinician should have a preference for exercises with high activation of the LT and MT and low activity of the UT.

Keywords: shoulder rehabilitation; scapula; exercise; muscle balance; electromyography

Shoulder pain and dysfunction are common complaints among individuals seeking care from physical medicine and rehabilitation specialists.[1,46] Recently, clinicians[25-27,36,42] and investigators[11,29,31,33] have focused increased attention on the role of the scapula in the pathogenesis of shoulder pain in general and impingement symptoms in particular. Scapulothoracic dysfunction, defined as alterations in the resting position or dynamic motion of the scapula, and changes in scapular muscle recruitment can affect many aspects of normal shoulder function.[24] An increasing number of studies have correlated abnormalities in scapular position and motion (dyskinesis) with impingement symptoms, rotator cuff dysfunction, and instability.[18,29,31,34,48] Various authors have suggested that shoulder abnormalities and abnormal scapular motions may be linked to global weakness of the scapulothoracic muscles[8,9,15,16,38,43]; others attribute scapular dyskinesis to scapular muscular imbalance rather than absolute strength deficits.[8-10,29,40] In particular, excess activation of the upper trapezius (UT), combined with decreased control of the lower trapezius (LT) and the serratus anterior (SA), has been proposed as contributing to abnormal scapular motion.[8-11,29,31,37,47]

In view of the new insights and research findings on the role of the scapula in shoulder pathologic abnormality,

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current exercise protocols emphasize the importance of scapular muscle training as an essential component of shoulder rehabilitation.[3,5,12,20,22,28,35,42,49] Restoration of muscle control and balanced coactivation in particular is a challenge to the clinician. For patients with an imbalance in the scapular muscles, selective activation of the weaker muscle parts with minimal activity in the hyperactive muscles is an important component in the reduction of the imbalance. Because a lack of activity in the LT, middle trapezius (MT), and SA frequently is combined with excessive use of the UT, the balance ratios UT/LT, UT/MT, and UT/SA are of particular importance.[10,11,29,47] In addition, integration of shoulder girdle exercises into a global functional kinetic chain pattern has become a treatment goal in shoulder rehabilitation, specifically in overhead athletes.[5,14,25]

The selection of appropriate exercises in the rehabilitation of scapular muscle performance depends on the actual strength of the muscles but also on the relative strength of 1 muscle in relation to another. In a study by Ludewig et al,[30] a selection of exercises was introduced with a low UT/SA ratio, meaning high activity in the SA with simultaneous minimal activation of the UT. However, no other exercises have been described to optimize the muscle balance within the trapezius muscle by calculating UT/LT and UT/MT muscle ratios. In addition, UT/SA ratios have not been calculated for exercises other than push-up exercises. Therefore, the purpose of this study was to determine the UT/LT, UT/MT, and UT/SA muscle ratios for a number of commonly used shoulder girdle strengthening exercises to determine which exercises are appropriate to optimize scapular muscle balance.

MATERIALS AND METHODS

Subjects

Forty-five healthy volunteers (20 men, 25 women), recruited from the student population, participated in the study. Their mean age was 20.7 years (±1.7 years), mean height was 1.73 m (±0.09 m), mean weight was 65.15 kg (±10.89 kg), and mean body mass index was 21.75 (±2.39). Exclusion criteria for participation in the study were a history of cervical spine and shoulder injury or surgery, participation in overhead sports at a competitive level, and upper limb strength training for more than 5 hours per week. Inclusion and exclusion criteria were assessed with a questionnaire. Before participation, subjects read and signed the informed consent form. The investigation was approved by the Ethical Committee of Ghent University.

Instrumentation

Before electrode application, the skin was shaved if necessary and prepared with alcohol to reduce skin impedance (typically, <10 kΩ). Bipolar surface electrodes (Blue Sensor, Medicotest, Ballerup, Denmark) were placed with a 2-cm interelectrode distance over the upper, middle, and lower portions of the trapezius muscle and the lower portions of the SA muscle. Electrodes for the UT were placed midway between the spinous process of the seventh cervical vertebra and the posterior tip of the acromion process along the line of the trapezius. The MT electrode was placed midway on a horizontal line between the root of the spine of the scapula and the third thoracic spine. The LT electrode was placed obliquely upward and laterally along a line between the intersection of the spine of the scapula with the vertebral border of the scapula and the seventh thoracic spinous process.[4,8,9,11] The last set of surface electrodes was applied on the SA parallel to the muscle fibers, below the axilla, anterior to the latissimus dorsi, and posterior to the pectoralis major.[12,28-30] A reference electrode was placed over the clavicle. In all of the subjects, the dominant arm was tested. Each set of bipolar recording electrodes from each of 4 muscles was connected to a Noraxon Myosystem 2000 electromyographic (EMG) receiver (Noraxon USA, Scottsdale, Ariz). The sampling rate was 1000 Hz. All raw myoelectric signals were preamplified (overall gain = 1000, common rate rejection ratio 115 dB, signal to noise ratio <1 μV RMS [root mean square] baseline noise, filtered to produce a bandwidth of 10-1000 Hz).

Testing Procedure

We began by recording the resting level of the electrical activity of each muscle. Then, verification of EMG signal quality was completed for each muscle by having the subject perform maximal isometric contractions in manual muscle test positions specific to each muscle of interest.[21,23] For the UT muscle, resistance was applied to abduction of the arm because Schludt and Harms-Ringdahl[41] found this position superior to shoulder girdle elevation in activating the UT muscle. The MT muscle was tested by applying resistance to horizontal abduction in external glenohumeral rotation.[23] For LT testing, the arm was placed diagonally overhead in line with the lower fibers of the trapezius. Resistance was applied against further elevation.[23] Serratus anterior manual muscle testing was performed by resisting humeral elevation at an angle of 135° of forward flexion.[8,23] Subjects performed three 5-second maximum voluntary isometric muscle contractions against manual resistance by the principal investigator (A.C.). A 5-second pause occurred between muscle contractions.[13,19] A metronome was used to control duration of contraction. As a normalization reference, EMG data were collected during maximal voluntary contraction (MVC) for each muscle. After signal filtering with a low-pass filter (single pass, Butterworth, 6-Hz low-pass filter of the sixth order) and visual inspection for artifacts, the peak average EMG value over a window of 1 second was calculated for each trial. Further calculations were performed with the mean of the repeated trials as a normalization value (100%).

Each subject performed a series of 12 exercises, which were randomized to avoid systematic influences of fatigue and learning effects. The exercises were selected based on a literature review.[2,5-7,12,17,20,22,28,32,35,44,45,49] Numerous studies have been conducted examining individual muscle activity during commonly used rehabilitation exercises. In general, exercises are considered to be relevant for a certain muscle

TABLE 1
Exercises Commonly Used for Trapezius Training[a]

Exercise Movement	UT	MT	LT	Reference(s)
Abduction	x	x	x	22,35
Forward flexion		x	x	22,34,35,39
Dynamic hug	x			7,12,39
External rotation			x	2
Extension		x	x	7,22,35
Horizontal abduction (neutral or external rotation)	x	x	x	7,22,35
Military press	x			17,35
Rowing (low or high)	x	x	x	17,20,35
Scaption (neutral or external rotation)	x	x	x	2,12,22,35
Scapular retraction		x	x	7,22
Shoulder shrug	x			12,22

[a]UT, upper trapezius; MT, middle trapezius; LT, lower trapezius.

or muscle group if high EMG amplitudes are provoked. Table 1 summarizes the results of the literature review with respect to muscle activity of the 3 trapezius parts. On the basis of the results of these previous investigations, a group of 12 exercises was selected as relevant for the 3 trapezius parts. The 12 exercises are described in Table 2. All exercises, with the exception of the exercises performed in side-lying position, were completed bilaterally. Before data collection, the exercises were performed without resistance for familiarization purposes. Each exercise was performed in 3 phases—a concentric, isometric, and eccentric phase, each during 3 seconds. A metronome was used to control the duration of the phases. Subjects completed 5 trials of each exercise. Between trials, a resting period of 3 seconds was provided. Subjects were allowed to rest for 2 minutes between exercises. During each exercise, verbal encouragement and, if necessary, performance corrections were given by the same examiner.

The amount of weight used by the subjects, or resistance given by the pulley apparatus, was determined based on gender and body weight (see Appendix A, Tables 1A and 2A, in the online version of this article at http://ajsm.sagepub.com/cgi/content/full/35/10/1744/DC1). Subjects were divided into genders and into 3 subgroups based on their weight for resistance determination.

Signal Processing and Data Analysis

All raw EMG signals were analog/digital converted (12-bit resolution) at 1000 Hz. They were digitally fully wave-rectified and low-pass filtered (single pass, Butterworth, 6-Hz low-pass filter of the sixth order). Results were normalized to the maximum activity measured during the MVC trials. The EMG data for each muscle and each subject were averaged for each phase across the 3 intermediate repetitions of the 5 repetitions completed. Periods were defined by markers based on the 3-second phases of the exercises. One-second markers were automatically placed on the EMG signal, based on the metronome sound. The mean amplitude EMG signal, expressed as a percentage of MVC, was used to assess the activity of the 3 parts of the trapezius muscle and the SA muscle in each of the 12 exercises.

Statistical Analysis

A priori power analysis for this study was set at 80%, based on an α level of .05, resulting in a minimal sample size of 40. Means and standard deviations were calculated across subjects for the normalized UT, MT, LT, and SA EMG values of each of the 3 phases of the 12 exercises. Because the specific topic of interest of this study was to investigate muscle balance ratios among the scapular muscles during the selected exercises, the relative activity of the UT with respect to the MT and LT and to the SA was determined. Intermuscular and intramuscular ratios were calculated by dividing normalized EMG values of the UT by normalized EMG values of the LT, MT, and SA, resulting in the ratios UT/LT, UT/MT, and UT/SA. These values were multiplied by 100 to obtain relative activity of UT (in %) compared with the other scapular muscles. Values <100% reflect muscle activity of the MT, LT, or SA being superior compared with UT, with lower values suggesting lower relative UT activity. Values >100% reflect muscle activity of UT exceeding muscle activity of the other scapular muscles. Means and standard deviations were calculated for the 3 ratios.

Because all data were normally distributed with equal variances, parametric tests were used for statistical analysis. The dependent variables of interest were the UT/LT, UT/MT, and UT/SA ratios. Each of these ratios was analyzed using a general linear model analysis of variance with 2 within-subject factors: phase (3 levels) and exercises (12 levels). In case of significant Mauchly test results for sphericity, Greenhouse-Geisser correction was performed. The α level for the analysis of variance was set at .05.

Before further statistical analysis, exercises were categorized in terms of accuracy by performing 1-sample *t* tests for each ratio and each phase, with 100%, 80%, and 60% as reference values. Ratios not significantly lower than 100% suggest that the UT is more active than the LT, MT, and SA muscle and are considered inadequate for the purpose of our study. Ratios significantly lower than 100% refer to exercises relevant to our research question as we wanted to determine exercises in which the LT, MT, and SA are activated with minimal activation of the UT muscle. In this group, exercises were additionally divided into 3 subgroups based on the ratio: 100% to 80% (moderate), 80% to 60% (good), and <60% (excellent). For each ratio, the 3 best exercises were used for further analysis. Classification was based on the following criteria: exercises in which in each phase, the ratio is smaller than 60% (category 1); exercises in which in each phase, the ratio is smaller than 80%, with at least 1 phase having a ratio between 60% and 80% (category 2); exercises with a ratio significantly smaller than 100%, with at least 1 phase between the 60% to 80% limits (category 3); and exercises with at least 1 of the 3 phases significantly higher than 100% (category 4). Exercises from category 4 were excluded for further analysis and discussion.

TABLE 2
Description of the 12 Exercises Performed by the Study Subjects

Exercise	Material	Description
Prone shoulder abduction	Dumbbell	Subject prone with the shoulder in neutral position; subject performs shoulder abduction to 90° with external rotation in a horizontal plane
Forward flexion	Dumbbells	Subject standing with shoulder in neutral position; subject performs maximal forward flexion in a sagittal plane
Forward flexion in side-lying position	Dumbbell	Subject in side-lying position, shoulder in neutral position; subject performs forward flexion in a horizontal plane to 135°
High row	Vertical pulley apparatus and V-bar	Subject standing in front of vertical pulley apparatus with the shoulders in 135° forward flexion; subject performs an extension with the shoulders until neutral position
Horizontal abduction	Dumbbells	Subject prone with the shoulders resting in 90° forward flexion; subject performs horizontal abduction to horizontal position
Horizontal abduction with external rotation	Dumbbells	Subject prone with the shoulders resting in 90° forward flexion; subject performs horizontal abduction to horizontal position, with an additional external rotation of the shoulder at the end of the movement
Low row (1)	Pulley apparatus with 2 handles	Subject standing in front of pulley apparatus, shoulders in 45° forward flexion and neutral rotation; subject performs extension with the elbows extended
Low row (2)	Pulley apparatus with 2 handles	Subject standing in front of pulley apparatus, shoulders in 45° forward flexion and neutral rotation; subject performs extension with the elbows flexed
Prone extension	Dumbbells	Subject prone with the shoulders resting in 90° forward flexion; subject performs extension to neutral position with the shoulder in neutral rotational position
Rowing in sitting position	Pulley apparatus with 2 handles	Subject sitting in front of pulley apparatus with the shoulders in 90° forward flexion; subject performs an extension movement with the elbows flexed and in the horizontal plane
Scaption with external rotation	Dumbbells	Subject sitting with the arms at the side; subject performs maximal elevation of the arms in the plane of the scapula (30° anterior of the frontal plane)
Side-lying external rotation	Dumbbell	Subject side-lying with the shoulder in neutral position and the elbow flexed 90°; subject performs external rotation of the shoulder (with towel between trunk and elbow to avoid compensatory movements)

Across the 3 selected exercises from categories 1 to 3, multiple pair-wise comparisons were performed for each phase using paired-sample *t* tests with Bonferroni correction. All statistical analyses were performed with SPSS version 12.0 for Windows (SPSS Science, Chicago, Ill).

RESULTS

The results of the descriptive analysis of the normalized EMG data for the 12 exercises over the 3 phases are summarized in the online version of this article (see Appendix A, Table 3A, at http://ajsm.sagepub.com/cgi/content/full/35/10/1744/DC1). As the major topic of interest of this study was intermuscular and intramuscular ratios during shoulder exercises, the mean normalized EMG activity of each individual muscle across phases was not taken into account for further statistical analysis and is only stated for descriptive purposes.

Results of the calculations of the ratios UT/LT, UT/MT, and UT/SA are summarized in the online version of this article (see Appendix A, Table 4A, at http://ajsm.sagepub.com/cgi/content/full/35/10/1744/DC1). The generalized linear model analysis of variance for repeated measures showed significant main effects for exercise: $F(2.32,102.15) = 28.42$, $P < .001$; $F(1.52,67.07) = 30.86$, $P < .001$; and $F(2.79, 122.56) = 37.53$, $P < .001$ for the UT/LT, UT/MT, and UT/SA ratios, respectively. A significant main effect of phase was also obtained for all ratios: $F(1.59,69.87) = 6.86$, $P = .004$; $F(2.88, 138.25) = 16.18$, $P = .001$; and $F(1.44,63.24) = 24.54$, $P = .001$ for the UT/LT, UT/MT, and UT/SA ratios, respectively. Importantly, the data revealed an additional exercise × phase interaction effect for each ratio: $F(2.29,100.76) = 4.71$, $P = .008$ for UT/LT; $F(3.85,169.32) = 10.24$, $P = .001$ for UT/MT; and $F(4.17,183.67) = 15.48$, $P = .001$ for UT/SA.

Before post hoc statistical analysis, 1-sample *t* tests were performed with 100%, 80%, and 60% as reference values for all ratios across phases and exercises to classify the exercises based on their relevance (see Appendix A, Table 5A, at http://ajsm.sagepub.com/cgi/content/full/35/10/1744/DC1). Based on these criteria, the exercises side-lying forward flexion (Figure 1A), side-lying external rotation (Figure 1B), and horizontal abduction with external rotation (Figure 1C) were selected as relevant exercises with low UT/LT ratios. For the UT/MT ratio, side-lying forward flexion and side-lying external rotation were again selected as relevant for this ratio, in addition to the prone extension exercise (Figure 1D). For the UT/SA ratio, no exercise met the criteria of category 1. Only 1 exercise, high

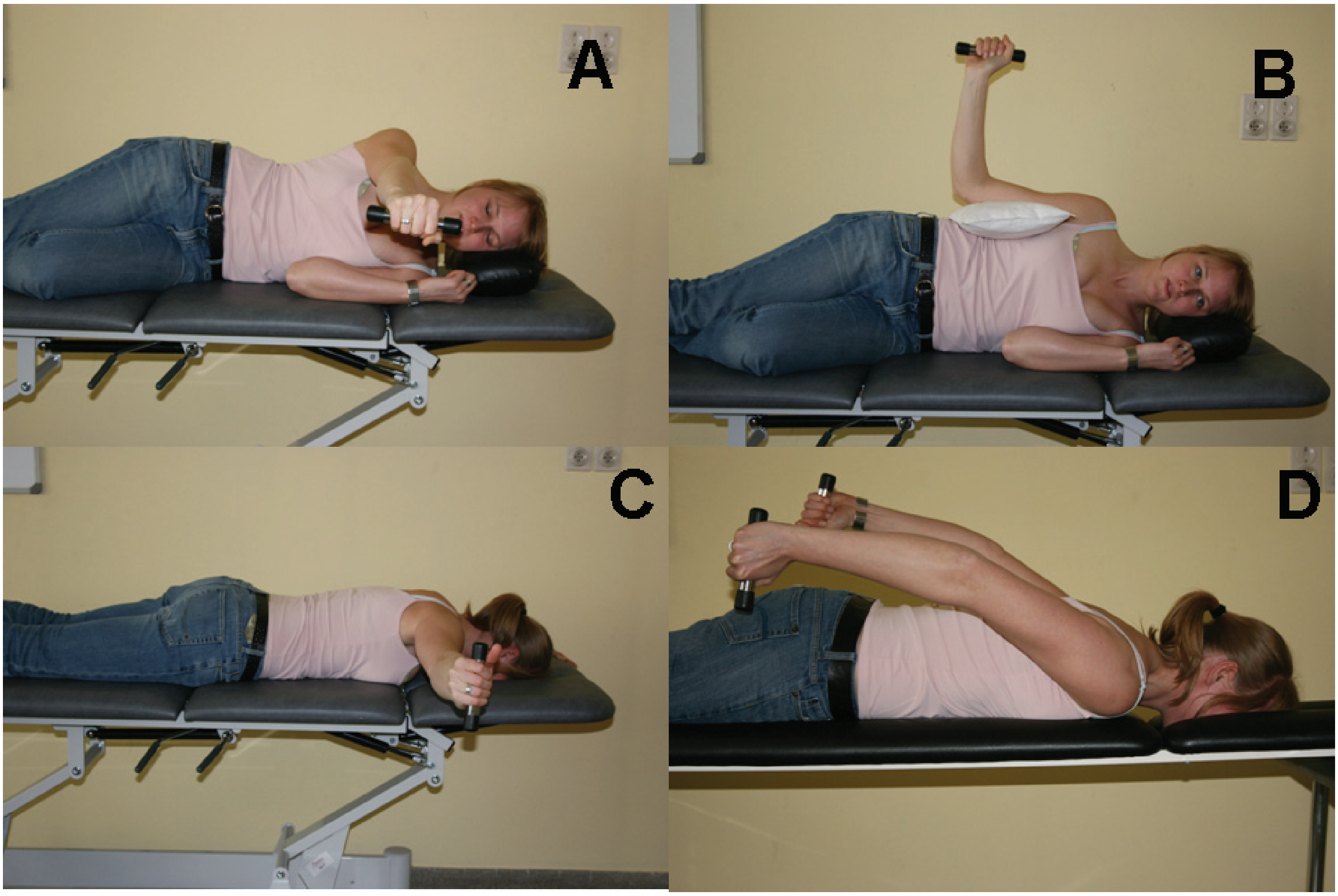

Figure 1. Exercises to restore intramuscular trapezius muscle balance. A, forward flexion in side-lying position; B, side-lying external rotation; C, horizontal abduction with external rotation; and D, prone extension. The results of this study suggest that the exercises A, B, and C are optimal for restoration of UT/LT muscle imbalances, and A, B, and D are optimal for restoration of UT/MT muscle imbalances. UT, upper trapezius; LT, lower trapezius; MT, middle trapezius.

Figure 2. High row exercise.

Figure 3. Forward flexion in standing position.

row (Figure 2), reached the criterion of category 2. The exercises forward flexion (Figure 3) and scaption with external rotation (Figure 4) were further selected within the 3 best exercises—however, with moderate accuracy (category 3).

For the 3 best exercises, post hoc t tests with Bonferroni correction were performed across the phases to see whether some phases were more accurate than others in terms of adequate muscle ratios.

Figure 4. Scaption with external rotation.

DISCUSSION

The purpose of this investigation was to identify scapular muscle strengthening exercises in which the LT, MT, and SA muscles are optimally activated with minimal participation of the UT. Our results support the hypothesis that, out of a number of commonly used rehabilitation exercises, exercises with optimal muscle balance ratios may be selected based on EMG analysis.

Three exercises were selected as exercises with a low UT/LT ratio: side-lying external rotation, side-lying forward flexion, and prone horizontal abduction with external rotation. Previous investigations have shown that the side-lying external rotation exercise enhances activity in the supraspinatus, infraspinatus, teres minor, and posterior deltoid.[44] Ballantyne et al[2] also demonstrated high levels of EMG activity in the LT muscle when the shoulder was externally rotated with the patient in a prone position. Performing the exercise in a side-lying position possibly minimizes UT activity by eliminating gravity and thus minimizing the postural role of that muscle. Probably for the same reason, side-lying forward flexion gives minimal UT activity. In both these exercises, the isometric phase revealed the lowest UT/LT ratio. This emphasizes the importance of controlled contraction throughout the required range of motion, with a "hold" phase at maximal external rotation or 135° of forward flexion. Moreover, our results suggest that patients with UT/LT imbalances should not perform forward flexion movements in the standing position because of excessive activity in the UT.

The horizontal abduction with external rotation exercise frequently is promoted for optimal shoulder rehabilitation.[35,44] Townsend et al[44] as well as Moseley et al[35] included this exercise in their selection for glenohumeral and scapulothoracic muscle strengthening programs. Our results confirm the clinical relevance of this exercise and emphasize the additional advantage of optimal muscle balance restoration capacity. In addition, our results show that the additional external rotation performed during the isometric phase is essential for selection into the top 3 of all exercises. Overall across phases, the horizontal abduction with external rotation exercise reveals lower UT/LT ratios than the horizontal abduction exercise.

Surprisingly, no rowing exercise was selected based on low UT/LT ratio. However, clinical papers often suggest this exercise for LT strength training.[5,6,26,35,38,39] Our results show not only that throughout these exercises, mean EMG activity of the LT is rather low, but also that the ratios are not in favor of the LT. Further investigation on different exercise modalities, for example, prone versus standing position and integration of other parts of the kinetic chain into the exercise, are needed to evaluate the therapeutic value of this exercise in the restoration of scapular muscle balance.

Our analysis of exercises with optimal UT/MT ratios resulted in 3 exercises, of which 2 were already selected based on low UT/LT ratio. Indeed, it seems that both exercises, side-lying external rotation and side-lying forward flexion, optimally recruit the MT with minimal activity in the UT. As a previous study showed that overhead athletes with impingement symptoms show decreased activity in the LT as well as in the MT with excessive activation of the upper part,[10] these exercises may be used for restoration of both muscle imbalances.

A third exercise, selected on the basis of low UT/MT ratio, was prone extension. Moseley et al[35] found the MT to be highly activated during the prone extension movement. Our results confirm the accuracy of this movement for training this muscle part, with minimal UT activation. Notable is the finding that performing an extension movement in standing position, such as during the high and low row exercises, does not result in optimal UT/MT ratios. As in the UT/LT exercises, body position apparently influences individual muscle activity and hence intramuscular activity ratios.

No exercise met the criteria for selection in optimizing UT/SA ratio. This means that of the exercises performed in this investigation, none can be qualified for SA training with inhibition of the UT. This finding is probably the result of the criteria we used to select our exercises. Indeed, during our literature research, the main topic of interest was finding commonly prescribed exercises for trapezius training, rather than SA. None of the exercises selected in our investigation were previously promoted specifically to enhance SA strength. Intermuscular balance ratios between SA and UT were already examined by Ludewig et al.[30] Our exercises have overall higher ratios than the exercises selected in the Ludewig[30] study. Indeed, the push-up exercise, examined in that study with a variety of modalities, is considered to be an optimal exercise in SA training. Ludewig et al[30] reported generally low UT/SA ratios (<30%) for all phases throughout all push-up modalities, with the exception of the eccentric nonplus phase. Our UT/SA ratios vary from 50.51% in the isometric phase of the high row exercise to 467.60% during the isometric phase of the horizontal abduction with external rotation exercise. Based on our results, optimal UT/SA exercises cannot be identified.

In general, the EMG values of the active muscles are lower in our investigation, compared with those in the Moseley[35] study examining EMG activity during a variety of commonly used shoulder rehabilitation exercises.

Differences in methods and determination of testing weight may account for these differences. Therefore, as the purpose of our study was to evaluate balance ratios rather than individual normalized muscle activity, our EMG data for each individual muscle were not taken into account for further statistical analysis and should be compared with other studies with caution.

Some limitations of our investigation should be noted. The use of surface electromyography during dynamic movements has been a topic of discussion in literature regarding skin displacement, movement artifacts, influences of contraction modalities on the EMG signals, and normalization methods.[13,19] In general, systematic control of all interfering factors during the test is recommended to obtain reliable EMG data in a noninvasive manner. On the basis of these recommendations, our investigation was executed with maximal standardization and accuracy. In addition, we did not obtain synchronized kinematic data during the exercises to standardize the procedure, like in some other studies.[2,20,28,30] Although numerous investigations have been performed without simultaneous kinematic movement analysis,[12,35,44] we have to acknowledge this limitation. For further discussion on the technical issues of the use of surface electromyography during dynamic movements, see Appendix B in the online version of this article at http://ajsm.sagepub.com/cgi/content/full/35/10/1744/DC1).

From a clinical point of view, the major limitation of this study can be found in the outcome itself. Indeed, all the exercises selected for a low UT/LT or UT/MT ratio are performed in a lying position, prone or side-lying. However, recent literature emphasizes the importance of functional exercises, resembling daily or sport-specific arm function, and integration of the shoulder rehabilitation exercise into a functional kinetic chain.[5,14,25] These treatment goals are very difficult to accomplish with the patient lying prone or on his or her side. Diagonal patterns, combined with trunk and lower limb stabilization, as promoted by a number of authors,[14,25] are not possible in our exercise modalities. Therefore, we propose our exercises to be performed in the early stages of rehabilitation and before more functional kinetic chain exercises, in which functional muscle recruitment patterns can be trained with normalized intermuscular and intramuscular balance ratios.

Our data were obtained from a group of young, healthy subjects with no history of shoulder impairment. It should be noted that extrapolation of our results to patients with shoulder injury or other age categories should be performed with caution. On the basis of our results, we cannot conclude that patients suffering from shoulder pain or local muscle imbalances will show similar muscle balance ratios performing the exercises we propose. Our study may be considered as a first step in the investigation of rehabilitation exercises for the restoration of trapezius muscle balance, where the use of noninjured subjects must be recognized as a clinical limitation.

On the basis of our research question and our results, we believe further examinations should be performed. Bilateral versus unilateral movements should be compared, as well as the influence on unilateral versus bilateral stance during the exercises in standing positions, and the influence of lumbar and thoracic spine position. In addition, it may be interesting to obtain data from other muscles beyond the SA and the trapezius that can contribute to scapular movement and control, which were not considered in this study.

CONCLUSION

We investigated the activation of the 3 trapezius muscle parts and the SA muscle during 12 commonly used shoulder girdle rehabilitation exercises and calculated intermuscular and intramuscular balance ratios. This is the first study calculating balance ratios of trapezius activity during these exercises. Based on our results, we suggest the use of side-lying external rotation, side-lying forward flexion, prone horizontal abduction with external rotation, and prone extension exercises to promote LT and MT activity with minimal activation of the UT part. These results may help the clinician in the treatment of scapular muscle imbalances.

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