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Lower trapezius and serratus anterior activation: which exercise to use for scapular neuromuscular reeducation?

Ativação do trapézio inferior e serrátil anterior: qual o exercício para reeducação neuromuscular da escápula?

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Abstract

Introduction: Low levels of activation of the serratus anterior (SA) and lower trapezius (LT) muscles are associated with kinematics dysfunctions of the scapular belt, for which the focus of functional recovery is neuromuscular reeducation. Hence, the proposed exercises should keep muscular activation at levels between 20% and 40% of the maximal voluntary contraction. **Objectives**: To compare the activation of SA and LT muscles in different exercises by using surface electromyography. **Methods**: Five exercises (modified crucifix, scaption, modified military press, pull over and low row) were executed by ten healthy subjects. **Results**: The highest SA activation was found during scaption, and the adequate activation occurred in the modified military press. The highest LT activation was found during scaption and low row exercises. **Conclusions**: The exercises that kept the recommended range of activation for neuromuscular reeducation were the military press, for the SA muscle, and the low row and scaption, for the LT muscle.

Key words: Electromyography; Exercise; Physical Therapy Modalities; Scapula; Shoulder.

Resumo

Introdução: Baixos níveis de ativação do serrátil anterior (SA) e do trapézio inferior (TI) estão associados a disfunções cinemáticas da cintura escapular cujo foco da reabilitação funcional é a reeducação neuromuscular. Para tanto, os exercícios propostos devem manter a ativação muscular entre 20% e 40% da contração voluntária máxima. **Objetivos:** Comparar a ativação do SA e TI em diferentes exercícios por eletromiografia de superfície. **Métodos:** Cinco exercícios (*modified crucifix*, *scaption*, *modified military press*, *pull over* e *low row*) foram executados por dez sujeitos saudáveis. **Resultados:** A maior ativação para o SA foi encontrada durante o *scaption* e sua ativação adequada ocorreu durante o *modified military press*. Para o TI, a maior ativação ocorreu durante os exercícios *scaption* e *low row*. **Conclusões:** A ativação muscular dentro da faixa recomendada para a reeducação neuromuscular ocorreu no *modified military press* para o AS; e no *low row* e *scaption*, para o TI.

Descritores: Eletromiografia, Escápula; Exercício; Modalidades de Fisioterapia; Ombro.

Introduction

Scapular biomechanics is the key element of shoulder stability as a whole. When the scapulohumeral rhythm is in balance, there is a decrease in the recruitment of muscle fibers during any movement of the upper limb, reducing energy expenditure. In addition, the scapulohumeral balance reduces shear forces, improves adhesion of the humeral head in the glenoid cavity and favors articular congruence. The result of this integration is a harmonious movement between scapula and humerus, impairment of this relationship leads to a secondary subacromial impingement[1-3].

Other mechanisms often associated with secondary subacromial impingement are low levels of serratus anterior and lower trapezius muscle activation, which cause prominence of the medial border and inferior angle of the scapula combined with its excessive internal rotation[4-6].

Changes in the movements of the scapula or in its positioning are a set of dysfunctions that can be described as scapular dyskinesia. The dyskinesia is a result of alterations in muscle activation and involves mainly the serratus anterior and lower trapezius muscles. Excessive anterior tilt of the scapula, internal rotation, or excessive elevation of the acromion are factors that decrease the rotator cuff activation and cause an inadequate distribution of tension along the tendons. Such situations impair the optimum length-to-tension ratio of these muscles, leading to a loss of stabilization and increasing the chance of muscular disruption or degeneration[7, 8].

Scapular stability demands correct positioning of the scapula, precise timing of muscle activation, and an adequate level of recruitment for each muscle involved in any task. The scapula is extremely important in this role, since small changes of activation in the muscles around the scapula can affect its alignment as well as the forces involved in upper limb movement[9].

The focus of scapular dyskinesia rehabilitation is in improving motor control rather than strengthening muscle. In the intermediate phase, exercises in open kinetic chain are commonly used. These exercises require low external resistance, usually in a range between 20% and 40% of maximal voluntary contraction (MVC), since this range of activation acts as neuromuscular training toward the goal of motor reeducation. In this type of training it is better to avoid the muscle fatigue and muscular strengthening of traditional exercises[10].

From this perspective, knowledge of the appropriate exercises for functional recovery of the scapulohumeral rhythm can make the rehabilitation process more effective, faster, and cheaper. Despite this, there is a gap in the literature on the topic of exercises that act as neuromuscular training toward the goal of motor reeducation of scapulohumeral rhythm instead of muscle strengthening. Therefore, the aim of this study was to compare the percentage of activation of the serratus anterior (SA) and lower trapezius muscles (LT) in five exercises in healthy individuals using surface electromyography and seeking activation levels between 20% and 40% of MVC.

Material and methods

This is a cross sectional study with a convenience sample. A call for volunteers was forwarded to physiotherapy students of the proponent institution. After having received information about the research and signed the consent form, the subjects were driven to the laboratory and instructed on how to perform the exercises.

To comply with the inclusion criteria, subjects had to be between 20 and 40 years old and to consider themselves able to perform any upper-limb activity. Exclusion criteria included history of rotator cuff tear, symptoms of subacromial impingement syndrome, injury of the muscles directly involved in the exercises proposed in this research, and having performed any kind of strength training or regular physical activities that use the muscles being assessed.

The principles of the Declaration of Helsinki and Resolution 196/96 of the National Health Council[11, 12] were applied, and all patients provided written informed consent to participate. The study was approved by the Ethics Committee of the Centro Universitário Metodista do IPA, Rio Grande do Sul, Brazil, in decision 256/2010.

Data acquisition

The acquisition of Electromyographic (EMG) signals was performed using an electromyography device (Miotec®, model Miottol 400) with four channels, 14-bit resolution, electrical isolation of 5000 volts, 2000 Hz per channel, common mode rejection ratio of 110db, and connection to a computer by USB port. Data were collected and analyzed using Miograph 2.0 software. A notebook was used to collect and process data. To capture EMG signals, Ag/AgCl (silver/silver chloride) surface electrodes (Meditrace®, Canada) with diameter of 2.2 cm were used in bipolar configuration on the skin overlying the belly of the serratus anterior and the lower trapezius, according to guidelines of the International Society of Electrophysiology and Kinesiology (ISEK)[13].

Procedures for data collection

The skin impedance was reduced by asepsis with alcohol (70%) and gentle skin abrasion. The placement of electrodes followed the recommendations of ISEK[13]. For the lower trapezius muscle, the subject was placed in humeral flexion of 90°, and the electrodes were positioned at an oblique and vertical angle 5 cm apart from the base of the spine of the scapula, parallel to the muscle fibers. For the serratus anterior muscle, the shoulder was abducted 90°, and the electrodes positioned horizontally in line with the lower angle of the scapula, just anterior to the latissimus dorsi muscle. The reference electrode was positioned on the anterior tibial tuberosity of the right leg.

After having the electrodes placed on them, the subjects performed some upper-limb movements: elevation, shoulder flexion, external rotation, and internal rotation of the scapula only to confirm the position of the electrodes and the reception of myoeletric signals. Immediately after these procedures, the subjects were instructed on accomplishing maximum voluntary contraction (MVC) of the serratus anterior and lower trapezius muscles, following Kendall´s[14] protocol. The MVC was followed by a self-determined rest period, and the subjects began the exercises when they considered themselves able to do so.

Data analysis

Miograph 2.0 software was used for analysis, and the following procedures were adopted: EMG signals were filtered by a third-order band-pass Butterworth filter with cut-off frequencies between 20 and 500Hz; EMG signals were clipping (considering the beginning and end of each contraction) and the average RMS (root mean square) was calculated for the two muscles of interest. For data analysis, we used all RMS values normalized for MVC.

Physical exercises

The exercise protocol was started with a verbal communication and was composed of one series of five repetitions for each of the five different exercises, with an interval of at least one minute of rest between every new exercise or until the subjects had considered themselves able to continue. Initially, each exercise was demonstrated by the same researcher for each participant, and, immediately after, the subject was instructed to perform the exercise until the completion of the protocol.

The rhythm of each exercise was controlled by a digital metronome; thus, all participants had the same execution rhythm. A load of 2 kg was used for the purpose of neuromuscular training, since this load can induce appropriate levels of activation. Moreover, this load can serve as a direct reference to other professionals in clinical practice[10].

Modified crucifix (CM): in supine position, headboard elevated 45°, horizontal flexion of the shoulder with the forearm in pronation and the elbow in full extension, bilateral execution with a starting position in a 90° abduction, and a final position in a 115° abduction (Figure 1a).

Scaption (SP): in a standing position, a unilateral execution of 130° elevation in the scapular plane with the forearm in neutral position (Figure 1b).

Modified military press (MMP): in a sitting position with headboard elevated 45°, initial position of both upper limbs with abduction (90°) in the plane of the scapula, elbow flexion (90°), and forearm supination. Final position with elbow extension and shoulder forearm pronation (120°) (Figure 1c).

Pull-over (PO): in a supine position, shoulder flexion, holding a dumbbell with both hands, an initial position of 90° shoulder flexion and elbow in full extension, and a final position on the edge of the active range of shoulder flexion with 15° of maximum tolerance of elbow flexion (Figure 1d).

Low-row (LR): in a standing position with the arm alongside the body and the forearm in pronation, internal rotation of the humerus; the subject performs combined motion of shoulder extension and scapular retraction (Figure 1e).

Statiscal analysis

Normality of data distribution was verified with the Shapiro-Wilk test, and data exploration was conducted using descriptive statistics (mean and standard deviation or median, minimum, and maximum). The normalized signals of the muscles studied were compared among the exercises with the Wilcoxon test. We adopted the significance level of 5%. Data were analyzed by SPSS for Windows (version 17.0) statistical software.

Figure 1: Exercises performed by the subjects
A: Modified crucifix; B: Scaption; C: Pull Over; D: Modified Military Press; E: Low row.

Results

A total of 16 subjects agreed to participate in the study, but six were excluded because they were undergoing strength training. Thus, ten subjects, all female, with a mean age of 24.5 years (3.1), remained in the sample.

The EMG signals normalized for MCV with median, minimum and maximum values, arranged by type of exercise, are reported in Table 1.

The five exercises elicited significant differences in muscular activation of the SA and LT muscles.

The highest SA muscle percentage of MVC was found during the scaption, and adequate percentage of MVC occurred during the modified military press. Regarding LT muscle activation, the highest percentage of MVC was found in the scaption and low row exercises.

Table 1: Muscular activation normalized for MVC

Exercise	Lower trapezius (%MVC)	Serratus anterior (%MVC)	*p*
Modified crucifix	7 (2-12)	15 (9-31)	0.005
Scaption	27 (8-47)	53.5 (24-76)	0.032
Modified military press	6 (3-12)	29 (10-55)	0.005
Pull over	4.5 (3-11)	13 (6-18)	0.011
Low row	26.5 (17-56)	10.5 (5-17)	0.005

Values of median with minimum and maximum. MVC: maximal voluntary contraction, significance when p<0,05.

Discussion

Our study investigated some exercises appropriate for the intermediate phase of functional recovery in patients who need greater activation of the serratus anterior and lower trapezius muscles, following the activation range proposed for neuromuscular reeducation. These exercises were chosen because almost all of them are conducted in open kinetic chain, requiring minimum scapular control and avoiding compensation with the scapula or trunk.

We found high levels of activation of the SA in SP – 53% (24-76) – and adequate levels of activation in MMP – 29% (10-55). These two exercises were those that exhibited the highest percentages of MVC (Table 1).

Regarding the activation of the lower trapezius muscle, we found higher percentages of MVC in SP – 27% (8-47) and LR – 26.5% (17-56) (Table 1).

The MC and PO exercises exhibited medians that can be considered close to adequate for neuromuscular reeducation, but only in the serratus anterior muscle.

There is considerable evidence in the scientific literature that in scapular dyskinesia there is a lack of muscle coordination that is related to poor muscular activation of the lower trapezius and serratus anterior muscles. It is suggested that this incoordination contributes to secondary impingement syndrome. Therefore, the basis of this disorder is mainly neuromuscular. This could not be linked to muscular weakness, given that it is related to motor control. Thus, as previously mentioned in our work, the exercises for functional recovery of patients with this imbalance must be performed with reduced activation, around 20% to 40%[15].

Exercises that exceed this activation threshold are producing the effect of muscle strengthening. Moreover, exercises that come close to 100% activation cause the recruitment of other muscle fibers, not only those of the target muscle, thereby causing adaptive movements which do not contribute to neuromuscular reeducation.

In this context, there are other studies with similar purposes investigating exercises that could be proposed for functional recovery, because they are executed in open kinetic chain requiring a minimum of motor control. However, most of these studies do not contribute to the complete elucidation of the exercises that are suitable for a functional recovery having the goal of improving motor control.

In the Ekstrom et al.[16] study, it is possible to note that only three of the ten investigated exercises are in the activation range of interest. The first was an isometric exercise in which the upper limb was positioned with humeral elevation above the head and aligned with the fibers of the lower trapezius muscle in a prone decubitus showing 43%±17% MVC for serratus anterior and 97%±16% MVC for the lower trapezius muscle. It should be noted that this exercise elicited almost 100% MVC of the lower trapezius. Since it was conducted in the prone decubitus and in almost maximal activation with the limb fully extended above the head, especially in this position it could lead to the coactivation of the upper trapezius muscles because of the need of neck extension. So this exercise can only be performed if the subject has moderate or good motor control. The second exercise was the unilateral row, which showed 45%±17% MVC for the lower trapezius muscle and 14%±6% MVC for the serratus anterior muscle; and the third was a combined exercise in a position of 90° shoulder flexion, adduction, and external rotation, which caused 100%±24% MVC for the serratus anterior muscle and 39%±15% MVC for the lower trapezius.

In another study, Cools et al.[17], had an excellent proposal comparing 12 exercises and measuring the activation ratio of the serratus anterior, middle, and lower trapezius muscles, all in relation to the upper trapezius muscle. This study presented some important methodological issues worth highlighting. The participants performed three repetitions of MVC with five-second rest intervals, which would provide fatigue influence on EMG signals, decreasing their reliability. Finally, the authors did not explain clearly how the analysis of electromyographic signals was performed.

Arlotta et al.[18] measured the lower trapezius activity during five exercises. Only three of them showed activation in the recommended range for neuromuscular reeducation. In the modified prone cobra, 44.67%±14.60% activation was observed; in the prone row, 36.44%±14.35%; and in the latissimus pull down, 35.31%±20% MVC. So all these exercises would be suitable in regard to the activation threshold. Although the author has used only isometric exercises, these exercises are interesting because they match the findings of our study. The factor that could be an interfering variable in this study is that the external resistance was imposed by the researcher's hand and always by the same person; but even so, it is impossible to be sure whether resistance and duration was the same in all subjects. Thus, the isometric load would only apply if other instruments were inserted into the methodology, such as a load cell.

A very interesting study conducted by Decker et al.[19] measured the activity of the serratus anterior muscle in eight exercises. There is little information about the imposed load for each individual; moreover, it is noted that MVC was repeated five times with a small rest interval of three to five seconds, which could influence myoelectric signals by muscle fatigue. Three exercises proposed by Decker were conducted in open kinetic chain (the serratus anterior punch, the scaption and the dynamic hug). It is noted that all muscle activations reached were very much above 40% MVC. Therefore, those exercises should be contemplated when the aim is muscle strengthening, as concluded by the authors.

Another interesting study that aimed at helping in the choice of exercises for motor control recovery of the serratus anterior and lower trapezius muscles and that involved healthy individuals only was the study of Witt et al.[20]. Twenty-one subjects performed exercises with an elastic resistance band and dumbbells, all in diagonal patterns; however, for statistical analysis, the authors did not perform any test to verify the normality of data distribution, and in the results analysis the absence of symmetrical distribution was evident. The standard deviation exceeds the mean, and even doubles it, for several variables; but the authors used a robust test for parametric outcomes, which greatly increases the chance of a type I error, leading to a non-reliable conclusion.

In this study, like other studies using surface electromyography to measure muscular electrical activity in dynamic contractions, there is the possibility of classic EMG bias, which is based on the fact that the electrodes move over the skin of the individual during the muscle contractions and that this can change the reading of the muscle fibers, capturing signals from different ones. Moreover, we stress the fact that the fibers show differences in length and contraction velocity during the dynamic exercises. However, the same linear relationship presented in isometric exercises may be reproduced in the dynamic exercise if the speed of exercise is constant, which happened in our study, as described in the methodology[21-23].

Another factor for consideration is that the sample used in this study was composed of women only. Some authors suggest that there would be differences in activation between genders, but there is still controversy about this, especially in relation to the muscles of the shoulder complex. The most specific study that used EMG and tried to prove the differences in activation has some methodological questions related to signal analysis and to the utilized tasks. Specifically, all tasks were isometric, and the analysis was performed using relative muscle activation, differing from our study[24].

This research was conducted with a reduced sample and healthy individuals; hence, without scapular dyskinesia. It would be interesting to include a group with the dysfunction of interest. For these reasons we suggest caution in extrapolating the results of our study to different populations. Nevertheless, our results contribute to the choice of suitable exercises in clinical practice during functional recovery from neuromuscular balance and provide insights for future studies that evaluate more muscles, such as the upper trapezius and its relationship with the serratus anterior, or that include a group with scapular dyskinesia to measure the effects of an intervention, measuring the degree of activation induced by other exercises.

Conclusions

The exercises that stayed within the recommended range of activation for neuromuscular reeducation among the five proposed exercises were the modified military press, for the SA muscle, and the low row and scaption, for the LT muscle.

In view of the methodological questions of some studies that used exercises in open kinetic chain or exercises that require a minimum scapular control, we conducted a study that provides more information regarding muscle activation of the lower trapezius and serratus anterior muscles, filling the gap in this area of scientific study.

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