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Original Article

Electromyographic Ratio of Shoulder Stabilizer Muscles During Performance of Exercises with Oscillatory Poles

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ABSTRACT

Shoulder pain and dysfunction processes are very common and demand great attention from the professionals who work with training and rehabilitation of this joint. Excessive activation of the upper trapezius muscle (UT) combined with decreased activation of the lower trapezius (LT) have been proposed as a contributing factor to shoulder injuries. Several equipments are used in training and rehabilitation of these muscles like elastic bands, free weights and recently, oscillatory poles. Despite having been used in clinical and sports context, little is known about their effects on the recruitment of shoulder stabilizers. Thus, the objective of the present study was to determine the activation ratio between UT and LT in different exercises performed with an oscillatory pole. 12 young (20.4 ±2.0 years) and physically fit females participated in this study. EMG signal of UT and LT was collected during 3 different exercises performed with oscillatory pole. The EMG signal analysis was done with Root Mean Square (RMS) values by the calculation of the ratio between the muscles UT and LT for each exercise. Statistical analysis was carried out with ANOVA for repeated measures and post hoc of Bonferroni tests, considering significant $p<0.05$. Exercise III showed lower ratio between UT and LT (0.722), followed by exercises I and II, respectively (0.876 and 0.995). Conclusion: The use of oscillatory pole in exercises performed with single hand grip, sagittal plane and with the pole perpendicularly to floor are recommended for training and rehabilitation of scapular stabilizer muscles since these promote lower activation of UT than LT.

Keywords: shoulder rehabilitation, muscular balance, scapula, eletromyography.

INTRODUCTION

Shoulder pain and dysfunction processes are very common and demand great attention from the training and rehabilitation teams[1-3]. In order to maintain suitable kinematics of this joint, the integrity of the muscle tissues is crucial, since besides generating strength and movement, they also act as stabilizers of the entire articular complex [4].

When the stabilizer structures do not provide suitable support, incorrect performance of the articular biomechanics and complications such as bursitis, tendinitis, injuries in the rotator cuff as well as instability may occur[1,4-7]. The rotator cuff, for example, through co-contraction of the stabilizer muscles straight from the glenohumeral joint, reduces the humerus translationin the glenoid fossa, so much as that 50% of strength reduction of the rotator cuff increases in 46% the anterior instability[4].

The importance of the scapular stabilizer muscles in the shoulder pathologies has been recently stressed[8-10]. Studies report that in 64% of the cases of instability of the glenohumeral joint, scapular instability also exists[4]. Excess of activation of the upper trapezius (UT), concomitantly to decrease of activation of the lower trapezius (LT), are proposed as contributions to abnormal scapular movement[8,11-13]. Cools ***et al.***[11] show that athletes with impingement syndrome present decrease of LT and medium trapezius (MT) activity compared to the UT. Thus, the balance in the UT/LT ratio is particularly important, since the LT activity is frequently combined with excessive activation of the UT[14].

The prevention and rehabilitation programs try to interfere in the etiological factors which lead to the onset of shoulder injuries, improving the biomechanics responsible for the stabilization of this joint [4]. Currently the exercise protocols stress the importance of the scapular muscles training as an essential component in the rehabilitation of the shoulder and hence, the muscle control and balance restoration has become a great challenge [15-18].

Surface electromyography (EMG) is widely used as an instrument to study the shoulder muscle activity[5,6]. The understanding on the muscular functions provides background to guide the interventions which aim to optimize the movement and the function in the rehabilitation and training processes [6]. Recent studies on the many pathologies which happen to the shoulder tried to describe the exercises used in rehabilitation, according to the activation level of the musculature involved [2,5,6,19,20].

Training and rehabilitation of the shoulder muscles has been performed with the use of many types of equipment such as free weights, elastic bands and recently oscillatory poles [21]. The oscillatory poles are intervention tools which provide fast eccentric and concentric muscle contractions, generating co-contraction of the muscle groups through oscillatory movements caused by the movement of the pole with the upper limb (figure 1 illustrates the oscillatory pole at rest and in movement)[1,4]. The co-contraction of the muscle groups increases local instability and protects the joint against compressive and traction forces [4]. Lister ***et al.***[1] identified by surface electromyography that the supraspinal muscles, trapezius upper fibers and trapezius lower fibers present higher activity during exercises performed with the use of oscillatory pole than with elastic band or free weights.

Despite the wide use of the oscillatory pole in training and rehabilitation, there are not studies in the literature which assess the activation ratio of the UT and LT muscles in different muscles performed with this instrument. Thus, the aim of this study was to determine the UT/LT muscular ratio in different exercises performed with oscillatory pole.

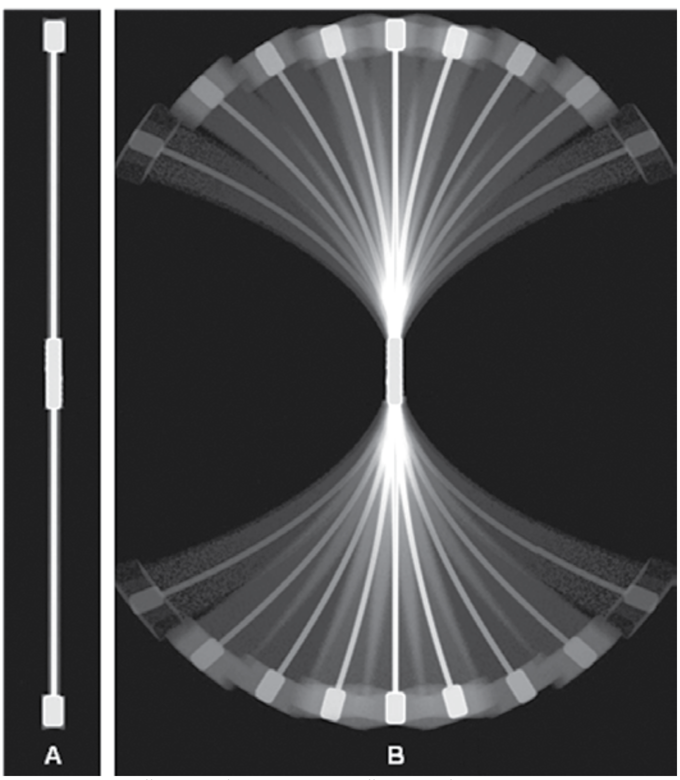

Figure 1. A) Oscillatory pole at rest. B) Oscillatory pole in movement.

According to Cools ***et al.***[14], the body positioning influences on the individual muscular activity as well as the ratio between muscles. Thus, this study has as hypothesis that alteration in the oscillatory pole positioning during exercises commonly used in training and rehabilitation with this equipment promotes different levels of activation of the UT and LT muscles with consequent interference in the UT/LT ratio.

METHOD

Subjects

12 female, physically active, right-handed university students, with mean age of 20.4 years (± 2.0) volunteered to participate in the study. The volunteers who did not present history of injury in the upper limbs in six-month period before the study were included.

All volunteers were informed accordingly about the procedures of the study and signed a Free and Clarified Consent Form approved by the local ethics committee.

Evaluation procedures

The data collection procedures were carried out in two days, with minimum interval of 24 hours and maximum of 72 hours between them. On the first day, familiarization of the volunteers with the data collection environment was performed, with the use of the oscillatory pole (Flexibar®) and with the three proposed exercises (figure 2). On the second day, the three exercises with the oscillatory pole were randomly performed.

Prior to the exercises, the volunteers received visual feedback through a monitor for maintenance of standing neutral position and were instructed to keep this posture during the entire exercise[22]. Movement of the oscillatory pole was performed by elbow flexion and extension movements. The rhythm of the pole movement during the exercises was controlled by a metronome calibrated at 300bpm and for maintenance of the expected shoulder flexion in each exercise, a target was used as visual feedback. All exercises were performed during 15 seconds with a 60-second resting period between each one. Figure 3 shows the monitor and the target used respectively for standing posture adequation and maintenance of the shoulder positioning.

Electromyography

Ag/AgCl bipolar surface electrodes (Meditrance®) with captation area of 1cm and interelectrode distance of 2cm were used for the electromyographic signal. The electrodes were placed on the right hemibody of the volunteers on the muscles: trapezius upper fibers (UT), at 50% of distance between the acromion and the spinal process of C7; and trapezius lower fibers (LT), at 2/3 of distance between the superior edge of the scapula and the spinal process of T8[23].

Previous to the electrodes placement, trichotomy was performed; abrasion with thin sand paper and cleansing with alcohol at the level of the studied muscles, as well as on the right acromion,

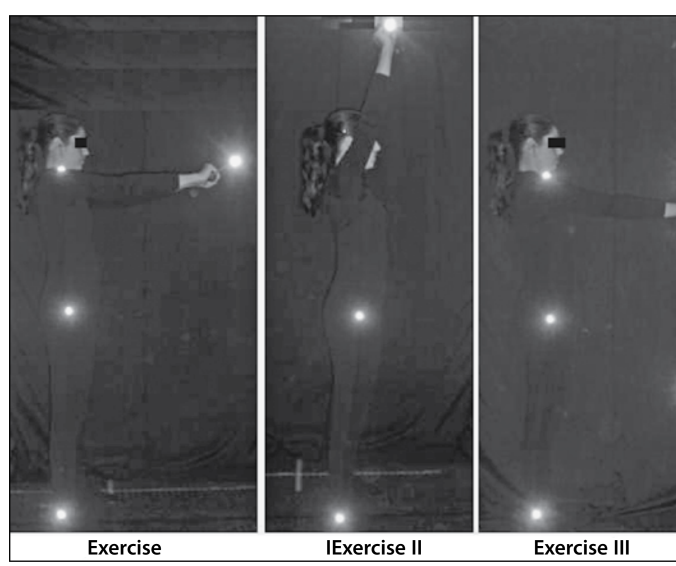

Figure 2. A) Exercise I bimanually performed with shoulders at approximately 90º of flexion and pole oscillation on transversal plane, parallel to the ground. B) Exercise II bimanually performed with shoulders at approximately 180º of flexion and pole oscillation on frontal plane, parallel to the ground. C) Exercise III performed with the dominant upper limb, shoulders at approximately 90º of flexion and pole oscillation on sagittal plane, perpendicular to the ground.

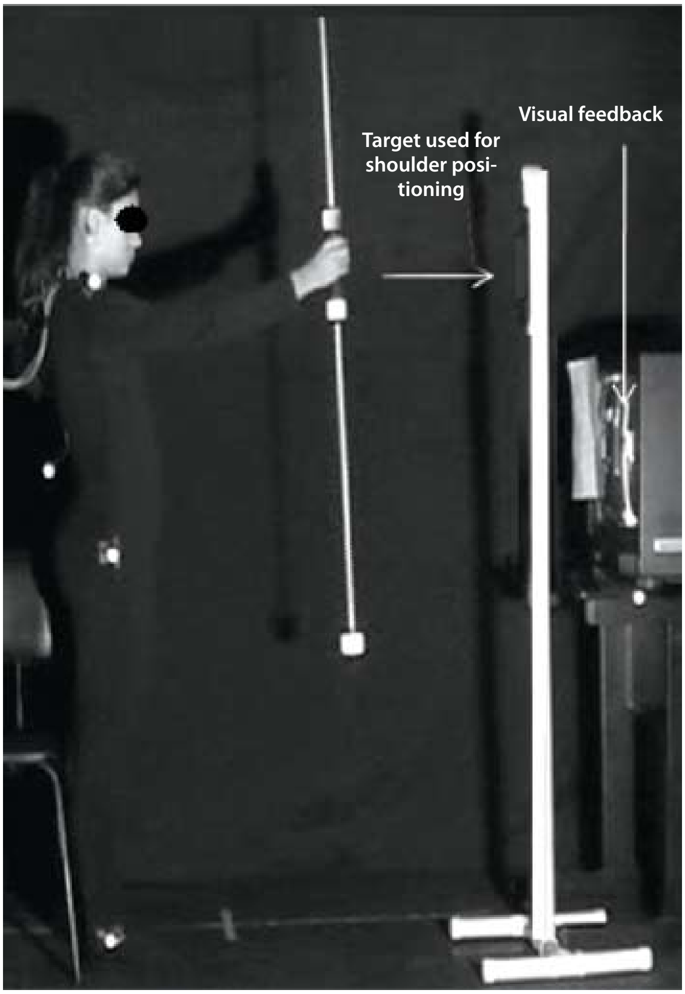

Figure 3. Monitor and target used respectively for standing posture adequation and maintenance of shoulder positioning.

site where the reference electrode was placed, with the aim to avoid interference on the electromyographic sign[24].

The electromyographic sign was picked up by the biological signal acquisition module by telemetry of 16 channels by Myoresearch (Noraxon® – USA) and with the use of the specific MRXP 1.07 software from this equipment (Noraxon® – USA), calibrated with sampling frequency of 1,000Hz, total gain of 2,000 times (20 times in the sensor and 100 times on the equipment), high-pass filter in 20Hz and low-ass filter in 500Hz.

Kinematic analysis

The kinematic data were collected to determine the period with greatest stability of the oscillation frequency of the pole, as well as to guarantee the efficiency of the use of the metronome in maintaining the same oscillation frequency for all volunteers (between 4 and 5Hz).

Photo-reflexive markers were placed on the central gripper and on the extremities of the pole. The images were taken with a software by Myoresearch (Noraxon) and a digital camera (Panasonic® NV GS320) positioned 5m away at a height referring to 50% of the height of each volunteer.

The kinematic analysis was performed with the Vicon Peak 9.0 software (Peak Motus® – USA). The frequency of movement of the oscillatory pole during the exercises was calculated by the dislocation of the points of the gripper and the extremity of the pole, according to the following formula:

F = number of cycles Time (s).

Figure 4 presents the period of highest stability of the oscillation frequency of the pole in exercises I, II and III.

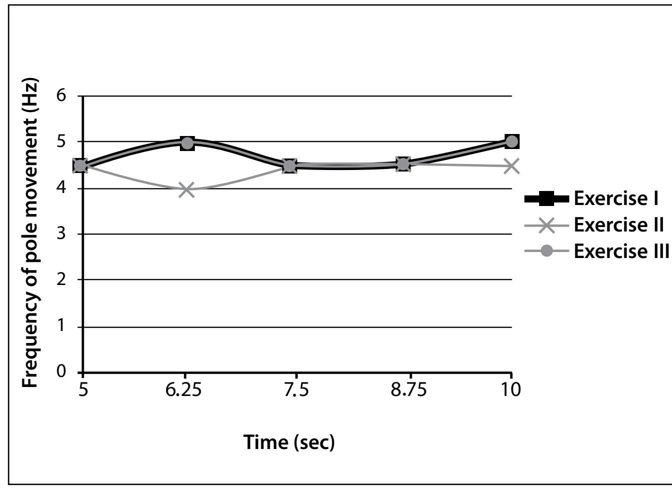

Figure 4. Pole oscillation frequency between the fifth and tenth second of performance of exercises I, II and III.

Data analysis

In order to analyse the electromyographic data, the five seconds of exercise comprehended between the fifth and tenth minute were considered, since this was the period of highest stability of oscillation frequency of the pole (figure 4).

The electromyographic analysis was performed by routines developed in MatLab environment. The calculation of the root mean square (RMS) was done in movable windows of 250ms. The ratio between the UT and LT muscles for each exercise was calculated from the RMS values obtained and subsequently, the Shapiro-Wilk, repeated measures ANOVA and Bonferroni post hoc were applied through the statistical package PASW Statistics 17.0. The significance level adopted was $p < 0.05$.

RESULTS

The results show that, in all exercises performed with oscillatory pole, the UT/LT ratio was lower than 1 (table 1). There was significant difference of the UT/LT ratio in the three exercises performed with oscillatory pole ($p < 0.000$ for all comparisons).

Table 1. Mean and standard deviations of the UT/LT ratio during performance of exercises I, II and III with the oscillatory pole.

Exercises	Mean	Standard deviation
I	0.876	0.013
II	0.995	0.019
III	0.722	0.007

Exercise III was the one which presented the lowest UT/LT ratio (0.722), followed by exercises I and II, respectively (0.876 and 0.995). Figure 5 illustrates the behavior of the UT/LT ratio concerning time during exercises I, II and III.

Figure 6 presents the electromyographic behavior concerning time of the UT and LT muscles for exercises I, II and III.

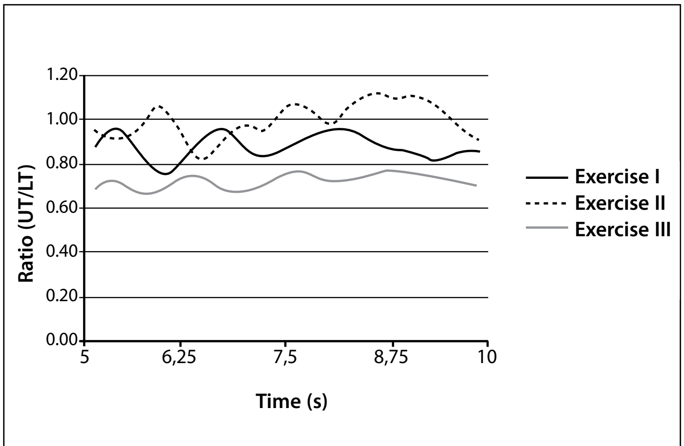

Figure 5. UT/LT ratio behavior concerning time for exercises I, II and III.

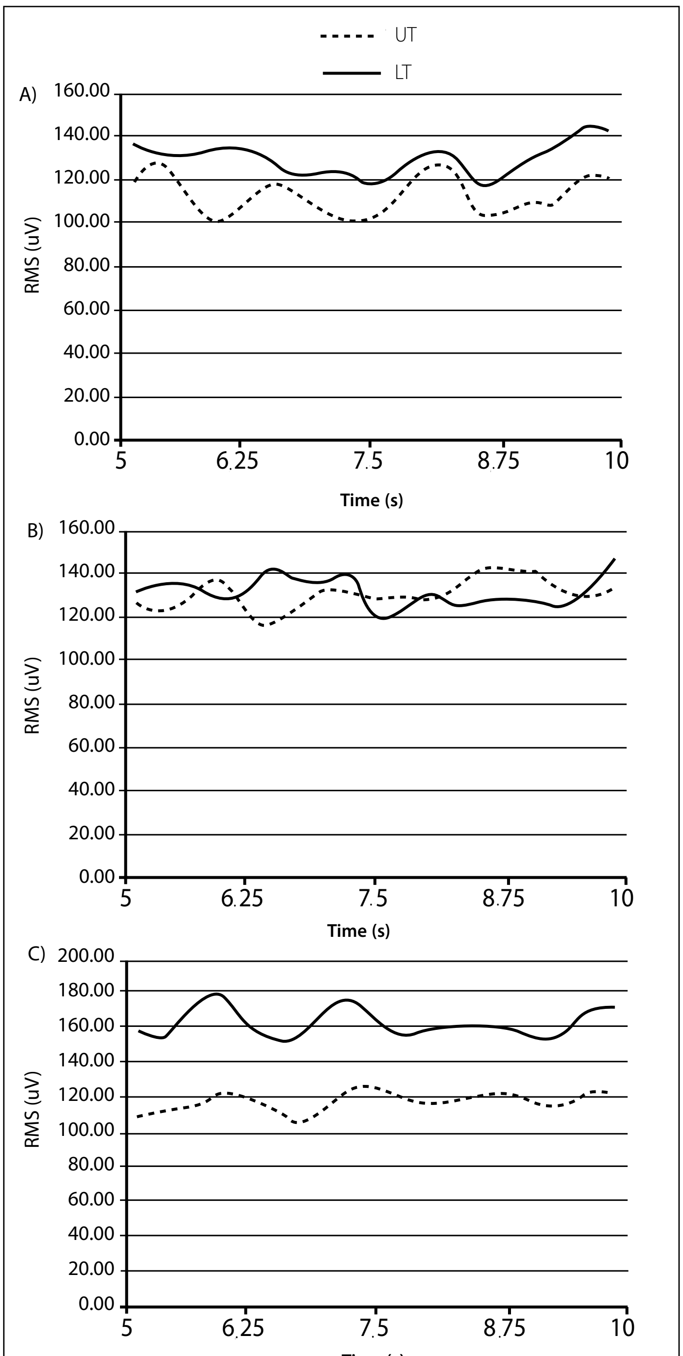

Figure 6. A) Electromyographic behavior of UT and LT concerning time in exercises I (A), II (B) and III (C).

DISCUSSION

The exercises which promote excessive activation of UT compared to LT have been referred as contributors to the abnormal movement of the scapula [14]. Considering the importance of training of the stabilizer muscles of the scapula in the treatment and prevention of shoulder instability injuries, the results of the present study corroborate the hypothesis that prescribed exercises with the use of oscillatory pole may be selected according to the activation UT/LT ratio.

Three exercises with the oscillatory pole commonly used in shoulder muscular training and rehabilitation were selected for the study. The exercise was bimanually performed with shoulders at approximately 90º of flexion and pole oscillation on transversal plane, parallel to the ground. Exercise II was also bimanually performed with shoulders at approximately 180º of flexion and pole oscillation on frontal plane, parallel to the ground. Exercise III was performed with the dominant upper limb, shoulders at approximately 90º of flexion and pole oscillation on sagittal plane, perpendicular to the ground.

The lowest UT/LT ratio was found during performance of exercise III. According to Ballantyne ***et al.***[25], when the shoulder is externally rotated with the volunteer at prone position, higher levels of electromyographic activity of LT are observed. However, in the present study, exercise III was performed with shoulder at neutral rotation position to maintain the pole perpendicular to the ground. Thus, the increase of LT activation compared to UT in this exercise may have not been caused by the shoulder position, but by the articular instability during the unilateral movement, which demanded greater activation of LT for maintenance of adduction of the scapula[26].

Exercise I presented the second lowest UT/LT ratio. Bilateral performance of exercise I can have guaranteed greater stability of the shoulder joint, requiring hence lower activation of the LT compared to exercise III. The literature states that exercises performed with horizontal shoulder abduction are frequently used in rehabilitation[18,27].

Nevertheless, for correct performance of exercise I, the volunteers kept shoulders at horizontal adduction during the entre exercise as a way of keeping both hands on the central gripper of the oscillatory pole, which could have influenced on the electromyographic behavior of the studied muscles.

The highest UT/LT ratio found in the present study was during exercise II performance. The positioning of the upper limb adopted for the correct performance of this exercise was favorable to the activation fo the UT muscle, since the shoulders were kept at approximately 180º of flexion combined with adduction for maintenance of the hands on the central gripper of the pole. According to Kendall ***et al.***[26], with the origin steady, the UT fibers raise the scapula making the acromial extremity and the occipital close; thus, the shoulders at 180º of flexion favor the UT activity.

Despite the maximum standardization adopted in the methodological procedures of the present study, some limitations should be considered. In the clinical and sports practice, equipment such as elastic bands and free weights are usually combined with many exercises to improve physical capacities. Nevertheless, for the present study, three exercises with oscillatory pole were used for comparison for being considered the most specific for the shoulder joint and are of easy performance; moreover, despite the increasing use of the oscillatory pole in gyms and rehabilitation clinics, it is a new tool and has been recently inserted in the clinical and sports environment.

The volunteers selected for the present study were young, healthy females with no history of injury of the upper limbs. Thus, the extrapolation of the results presented here to individuals with injuries in the shoulder joint should be carefully done. However, our study can be considered a pioneer in the assessment of the UT/LT ratio in exercises performed with oscillatory pole and hence, will be possibly useful in the clinical and sports practice, as well as encourage further investigation on this issue.

Having the raised questions and the found results as grounding, further studies with individuals of different age groups and genders, having had specific shoulder injuries should be carried out. Additionally, similar studies approaching the rotator cuff muscles as well as other muscles responsible for the scapular stability such as the anterior serratus, would be of great scientific contribution to the field.

CONCLUSION

In the present study, the electromyographic ratio of the UT/LT muscles in three different exercises with use of oscillatory pole was determined in order to identify which promote the lowest UT activation compared to LT. The results show that during exercise III performance lower UT/LT ratio was observed when compared to exercises I and II. Therefore, we suggest that the use of oscillatory pole in exercises performed with only one hand may be recommended to training and rehabilitation of the scapular stabilizer muscles to promote lower activation of the UT muscle compared to the LT muscle.

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All authors have declared there is not any potential conflict of interests concerning this article.

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