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ELECTROMYOGRAPHIC VALIDATION OF THE *TRAPEZIUS* AND *SERRATUS ANTERIOR* MUSCLES IN SUPINE AND FRONTAL ELEVATION EXERCISES

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ABSTRACT

The muscle activity developed by the *trapezius* (upper portion) and *serratus anterior* (lower portion) muscles in three modalities of supine exercises executed with two grips (open and middle), was compared with three modalities of frontal elevation in 24 male volunteers 18 to 25 years old. The *trapezius* muscle acted preferentially in all frontal elevation modalities and not in supine exercises. The *serratus anterior* muscle acted more significantly in frontal elevation exercises than in the supine horizontal and inverted plans with both grips, but there was no significant difference in the responses to frontal exercises and supine exercises in the inclined plan.

Key words: Electromyography, exercises, physical conditioning, *serratus anterior, trapezius*

INTRODUCTION

Supine exercises involve horizontal flexion and extension of the arms, while frontal elevation exercises involve anterior flexion and extension of these limbs. Moynes *et al.* [20] and Gowan *et al.* [10], studied baseball players and reported marked activity in the trapezius muscle during horizontal flexion, whereas stabilization of the scapula was controlled by the *trapezius, serratus anterior* and *rhomboideus* muscles [22]. According to Gowan *et al.* [10], the upper portion of the *trapezius* muscle showed weak activity during the beginning of horizontal extension with concomitant scapular retraction.

Jobe *et al.* [15] described the electromyographic activity of the *serratus anterior* muscle in the horizontal flexion and extension phases during baseball throwing. Similarly, Moynes *et al.* [20] and Gowan *et al.* [10], observed intense and increased activity in the *serratus anterior* muscle at the end of horizontal flexion. In tennis, this muscle reaches its maximum activity during the horizontal flexion [20], and in rowing this muscle shows very strong activity because of its action in flexion movements of the arm.

Scapular rotation is necessary during participation of the *trapezius* and *serratus anterior* muscles in anterior flexion movements of the arm. Inman *et al.* [13] and Rasch and Burke [23], reported that the lower fibers of the *serratus anterior* and the lower portion of the *trapezius* muscle provided the necessary lower component for scapular rotation. The lower portion of the *trapezius* relaxes during flexion while the lower portion of the *serratus anterior* is the most active component because the scapula needs to be moved forward [13].

If there is palsy of the *trapezius* muscle in the first years of life, the *serratus anterior* might hypertrophy and perform scapular rotation [23].

Lu [18], Kamon [16], Hagberg [12], Büll *et al.* [2,3], Freitas *et al.* [8] and Guazzelli Filho *et al.* [11] described activity mainly in the upper

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portion of the *trapezius*. Lu [18] commented that the *serratus anterior* and the *deltoideus* had weak activity during flexioning. On the other hand, Büll *et al.* [2,3], Campos *et al.* [4], Freitas *et al.* [8] and Guazzelli Filho *et al.* [11] observed that the upper portion of the *trapezius* was active in adduction and extension movements, whereas Scheving and Pauly [24] noted that the *serratus anterior* muscle was active in extension of the arm.

Textbooks [21,17] and practical manuals of physical preparation are not based on electromyographic studies and show a need of studies in this area. Ferreira *et al.* [5-7] pointed this out, when analyzing the *deltoideus* and *pectoralis major* muscles in a series of exercises. In this study, we examined the electromyographic activity of the *trapezius* and *serratus anterior* muscles during exercises which have been proposed for the development of these muscles in order to assess the validity of such physical conditioning programs.

MATERIAL AND METHODS

The *trapezius* (superior portion = ST) and *serratus anterior* (inferior portion = IS) were studied in 24 healthy male volunteers l8 to 25 years old with no previous technical-sport training. Electromyographic activity was recorded on a two-channel electromyograph TECA TE 4 fitted with two pairs of Hewlett Packard surface electrodes greased with electroconductor gel. The recorder was initially adjusted to a sensitivity of 500 µV, and a power speed of 370 ms/division.

The electrodes were positioned after depilating and cleaning the skin with 70% alcohol. One electrode was inserted at the mid point of the cephalic border of the *trapezius* muscle (superior portion) and the other at the 6th digitation of the *serratus anterior* muscle close to the posterior axillary pleat. The electrodes were connected to the electromyograph via pre-amplifiers. All the volunteers were "grounded" with a metal plate greased with electroconductor gel and fixed at the left wrist with a retention belt. The electromyographic tests were done in an electrostatic (Faraday)"cage" to avoid external interference.

The electrical potentials were documented using an Exa Thage Dresden camera fitted with an Isco-Gottingen Isconar l: 2.8 50 mm objective and loaded with Kodak Tri-X Pan (400 ISSO) film. The camera was coupled to the electromyographic equipment.

All the volunteers were trained to execute each one of the supine exercises with middle and open grips, i.e., supine horizontal, supine inclined and supine inverted. For the frontal elevation exercises, the tested modalities were frontal elevation, executed with a bar using open and middle grips, and frontal elevation with a hand halter.

For execution of the above movements, an adjustable supine bench, a straight board, a long bar (l.20 m) and two short bars (40 cm) made of light wood were used. The form of execution, with a strictly controlled posture, was standardized according to Machado [19].

The potentials recorded were analyzed according to the rating method of Basmajian [l] and were expressed as the median (Md), and the first and third quartiles (Q1 and Q3) for each exercise. The electromyographic results obtained in each modality of the supine exercises and of the frontal elevation exercises were analyzed using the non-parametric test of Friedman [27] for related samples, complemented with a comparison of each modality of elevation in the supine exercises. The level for significance was set at 5%.

RESULTS

Tables 1 and 2 show the frequency distributions of action potentials for the *trapezius* (superior portion) and *serratus anterior* (inferior portion) muscles in supine movements executed with open and middle grips, and in frontal elevation movements. Tables 3 and 4 summarize the statistical comparisons among the exercises performed.

Figures 1 and 2 show the execution patterns based on Machado [19].

DISCUSSION

When elevating the bar in supine exercises, the subjects performed a horizontal flexion of the arms with complete extension of the elbow articulation and, when returning to the initial position, there was horizontal extension of the arms with flexion of the elbow articulation.

The horizontal flexion occurred in the first of phase supine exercises, when the subjects began with the bar sustained near the chest, whereas the opposite occurred for horizontal extension.

Moynes *et al.* [20] and Gowan *et al.* [10] mentioned marked activity in the *trapezius* muscle during horizontal flexion, while in horizontal extension, Gowan *et al.* [10] noted weak activity at the beginning of this phase in the superior portion of this muscle. Our results showed that surprisingly the superior portion of the *trapezius* (ST) had only weak, constant activity during most of the exercises.

Table 1. Frequency of action potentials (%) in the *trapezius* muscle (superior portion) during supine and frontal elevation exercises.

Movement	Intensities				
	-	+	++	+++	++++
SInc/Og	29.2	54.2	16.7	-	-
SInc/Mg	16.7	41.7	25.0	16.7	-
SHor/Og	62.5	37.5	-	-	-
SHor/Mg	50.0	50.0	-	-	-
SInv/Og	54.2	45.8	-	-	-
SInv/Mg	66.7	33.3	-	-	-
FEB/Og	-	-	12.5	33.3	54.2
FEB/Mg	-	12.5	8.3	58.3	20.8
FEhalter	-	-	16.7	58.3	25.0

FEB/Og - frontal elevation with bar, open grip, FEB/Mg - frontal elevation with bar, middle grip, FEhalter - front elevation with hand halter, SHor – supine horizontal, SInc – supine inclined, SInv – supine inverted, Og – open grip, Mg – middle grip.

Table 2. Frequency of action potentials (%) in the *serratus anterior* (inferior portion) during supine and frontal elevation exercises.

Movement	Intensities				
	-	+	++	+++	++++
SInc/Og	-	-	20.8	41.7	37.5
SInc/Mg	-	-	29.2	41.7	29.2
SHor/Og	-	16.7	45.8	29.2	8.3
SHor/Mg	-	8.3	50.0	33.3	8.3
SInv/Og	-	16.7	58.3	25.0	-
SInv/Mg	-	16.7	62.5	20.8	-
FEB/Og	-	16.7	12.5	33.3	37.5
FEB/Mg	-	8.3	12.5	37.5	41.7
FEhalter	-	8.3	20.8	29.2	41.7

FEB/Og - frontal elevation with bar, open grip, FEB/Mg - frontal elevation with bar, middle grip, FEhalter - front elevation with hand halter, SHor – supine horizontal, SInc – supine inclined, SInv – supine inverted, Og – open grip, Mg – middle grip.

Table 3. Medians, 1st and 3rd quartiles (Q1 and Q3) and statistical significance (*) of the electromyographic variables for the *trapezius* (upper portion) in supine and frontal elevation exercises.

Supine	Frontal elevation		
	Bar Og	Bar Mg	Halter
Hor Og			
0.0	4.0*	3.0*	3.0*
(0, 1.0)	(3.0, 4.0)	(3.0, 3.0)	(3.0, 3.5)
Hor Mg			
0.5	4.0*	3.0*	3.0*
(0, 1.0)	(3.0, 4.0)	(3.0, 3.0)	(3.0, 3.5)
Inc Og			
1.0	4.0*	3.0*	3.0*
(0, 1.0)	(3.0, 4.0)	(3.0, 3.0)	(3.0, 3.5)
Inc Mg			
1.0	4.0*	3.0*	3.0*
(1.0, 2.0)	(3.0, 4.0)	(3.0, 3.0)	(3.0, 3.5)
Inv Og			
0.0	4.0*	3.0*	3.0*
(0.0, 1.0)	(3.0, 4.0)	(3.0, 3.0)	(3.0, 3.5)
Inv Mg			
0.0	4.0*	3.0*	3.0*
(0.0, 1.0)	(3.0, 4.0)	(3.0, 3.0)	(3.0, 3.5)

Frontal elevation exercises represented by (*) differ significantly from the supine exercises ($p<0.05$).
Halter – hand halter, Hor-horizontal, Inc-inclined, Inv-inverted, Og-open grip, Mg-middle grip

Table 4. Medians, 1st and 3rd quartiles (Q1 and Q3) and statistical significance(*) of the electromyographic variables for the *serratus anterior* (lower portion) in supine and frontal elevation exercises.

Supine	Frontal elevation		
	Bar Og	Bar Mg	Halter
Hor Og			
2.0	3.0*	3.0*	3.0*
(2.0, 3.0)	(2.0, 4.0)	(3.0, 4.0)	(2.0, 4.0)
Hor Mg			
2.0	3.0*	3.0*	3.0*
(2.0, 3.0)	(2.0, 4.0)	(3.0, 4.0)	(2.0, 4.0)
Inc Og			
3.0	3.0	3.0	3.0
(3.0, 4.0)	(2.0, 4.0)	(3.0, 4.0)	(2.0, 4.0)
Inc Mg			
3.0	3.0	3.0	3.0
(2.0, 4.0)	(2.0, 4.0)	(3.0, 4.0)	(2.0, 4.0)
Inv Og			
2.0	3.0*	3.0*	3.0*
(2.0, 2.5)	(2.0, 4.0)	(3.0, 4.0)	(2.0, 4.0)
Inv Mg			
2.0	3.0*	3.0*	3.0*
(2.0, 2.0)	(2.0, 4.0)	(3.0, 4.0)	(2.0, 4.0)

Frontal elevation exercises represented by (*) differ significantly from the supine exercise ($p<0.05$).
Halter – hand halter, Hor – horizontal, Inc – inclined, Inv – inverted, Og – open grip, Mg – middle grip.

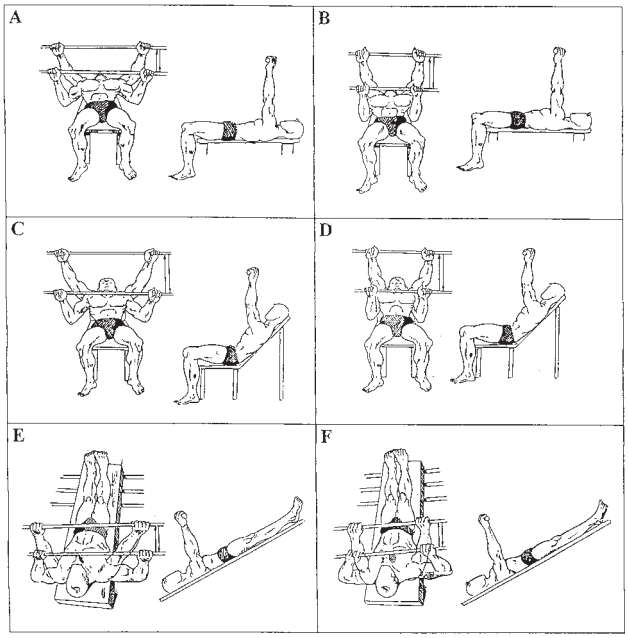

Figure 1. Execution pattern for the supine exercises: **A.** Supine, horizontal plane - open grip, **B.** Supine, horizontal plane – middle grip, **C.** Supine, inclined plane - open grip, **D.** Supine, inclined plane – middle grip, **E.** Supine, inverted plane - open grip, **F.** Supine, inverted plane – middle grip.

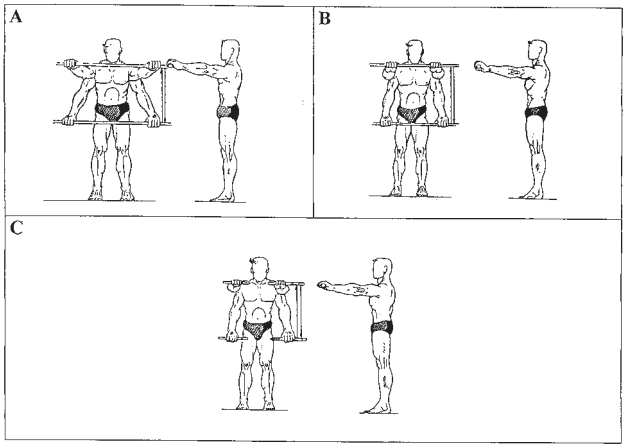

Figure 2. Execution pattern for the frontal elevation exercises: **A.** Frontal elevation with bar - open grip, **B.** Frontal elevation with bar – middle grip, **C.** Frontal elevation with halter.

Jobe *et al.* [15] reported that the *serratus anterior* muscle showed activity during horizontal flexion and horizontal extension. We recorded greater action potentials for the lower portion of the *serratus* (IS) than for ST.

In the supine inverted plane, the IS showed constant electromyographic activity throughout the exercise. In contrast, in the other modalities, the activity of the IS was greatest between 45º of horizontal flexion and 45º of horizontal extension.

Similar results were reported by Moynes *et al.* [20] and Gowan *et al.* [10] who described intense, increased activity at the end of horizontal flexion.

In frontal elevation exercises, the subjects developed anterior flexion of the arms initially at 90° and, in the return movement, showed anterior extension of these limbs.

In all combinations of frontal elevation exercises, the ST showed action potentials ranging from strong to very strong. The amplitude of the potentials increased rapidly soon after the beginning of the exercise and remained constant until 90° of flexion. The activity and amplitude of the potentials recorded for the *trapezius* muscle in frontal elevation exercises agreed with studies by Inman *et al.* [13], Yamshon and Bierman [26], Wiedenbauer and Mortensen [25], Lu [18], Kamon [16], Ito [14], Hagberg [12] and Büll *et al.* [2,3], who described the participation of this muscle in movements of anterior flexion.

As soon as the arms began the extension, the action potentials of ST decreased slowly or abruptly and disappeared by the end of the exercise. This decrease in activity agrees with data in the literature for the ST [2] and IS [3] in their role in returning the bones to their initial position in the hanging arm.

The action potentials for the IS were strong to very strong in all frontal elevation exercises, the ascending phase of the curve coinciding with the flexion and the descending phase with the extension of the arms. Inman *et al.* [13] reported that the ST and IS contributed to scapular rotation in flexions up to 90º, although Lu [18] stated that the angle of flexion could be greater.

Despite the fact that the frontal elevation exercises involve anterior flexion and anterior extension movements of the arms, and that the literature describes the role of the *trapezius* and *serratus anterior* muscles in these movements, frontal elevation exercises are mentioned for the development of these muscles only in the textbook by O'Shea [21].

In general way, frontal elevation exercises can be indicated for physical conditioning of the ST and IS. For the IS, supine exercises in the inclined

plane with both grips (open and middle) can be equally indicated. We thus agree with O'Shea [21] in recommending frontal elevation exercises for the *trapezius* and *serratus anterior* muscles.

Statistical comparisons between the supine and frontal elevation exercises showed that the ST acted significantly more in all of the frontal elevation modalities than in the exercises of supine. For the IS, the activity was significantly higher for all frontal elevation modalities than for supine exercises in the horizontal and inverted planes with both grips. There was no significant difference between any of the frontal elevation modalities and the supine exercises in the inclined plane, with both grips.

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