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Electromyographic Activation of Pectoralis Major and Triceps Brachii during Dumbbell Pullover

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ABSTRACT

Lacio ML, Teixeira JD, Vieira JG, Santana D, Amorim GD, Coelho MA, Campos YAC, Dias MR, Panza P, Novaes J, Vianna JM. Electromyographic Activation of Pectoralis Major and Triceps Brachii during Dumbbell Pullover. **JEPonline** 2021;24(4):1-11. The purpose of this study was to compare the electromyographic activity of pectoralis major (PM), sternal (PMS) and clavicular portions (PMC) and triceps brachii long portion (TB) muscles, with different elbow positions in the dumbbell pullover exercise. Thirteen males participated in this study. Initially, anthropometric measurements and 10 repetition maximum test (10-RM) were performed. After initial tests, on two non-consecutive days separated by 48 hours, the electromyographic signal was collected in the dumbbell pullover exercise with 90% 10-RM load, performed with elbow extension or elbow flexion. In both elbow positions, the electromyographic activation of TB was greater than PMC ($P<0.05$). However, in relation to PMS, TB showed greater activation with elbow flexion ($P = 0.002$). Greater activation was found in PMS compared to PMC performed with elbow extension ($P = 0.039$). It was concluded that TB showed greater muscle activation in the dumbbell pullover exercise, regardless of elbow position. Also, the dumbbell pullover with elbow extension showed greater PMS muscle activation.

Keywords: Resistance Training, Pectoralis Muscles, Surface Electromyography, Torque

INTRODUCTION

Resistance training (RT) is recommended for promoting musculoskeletal adaptations that result in muscle hypertrophy and an increase in strength (1). However, as the individual becomes experienced in RT, muscle growth tends to be attenuated (25). To reduce attenuation and ensure maximization of muscle adaptations, the scientific literature has proposed the manipulation of such variables as volume (26), intensity (24), duration of the recovery interval between sets (10), exercise order (29), velocity of movement (9), range of motion (20,23), and weekly training frequency (11). In addition, other strategies include variation of implements through the use of different barbells and dumbbells (6,33), as well as changes in handholds in which the exercises are performed (8,16,28).

The pullover exercise is characterized by flexion and extension of the glenohumeral joint (5,6,15,18), and can be prescribed as a complementary exercise for the development of the muscles of the anterior trunk (5). In this context, Marchetti and Uchida (18) and Borges et al. (4) found a greater muscle activation of the pectoralis major (PM) when compared to the latissimus dorsi. Yet, interestingly, Campos et al. (6) found no differences in the muscle activity of the sternal fibers of the PM (PMS), the clavicular fibers of the PM (PMC), the long head of the triceps (TB), the anterior and posterior fibers of the deltoid, the latissimus dorsi, and the serratus anterior.

The exercise can be performed in different ways with handholds. The studies by Campos and Silva (5) and Marchetti and Uchida (18), for example, used a straight bar with the elbows extended. Campos et al. (6) used the dumbbell and the straight bar, both with elbow extension. However, considering that the perpendicular distance between the movement axis (joint center) to the point of resistance application (resistance arm) alters the muscular demand (13), extending elbows during pullover execution can result in an increase in the resistance arm that leads to greater torque in the target musculature. In contrast, when flexing elbows, there is an increase in the activation of the TB due to the constant isometric muscle work to maintain the 90° elbow angle (12). Thus, different elbow positions can change the patterns of muscle activation and modify the magnitude of neuromuscular adaptations (32), justifying the conduction of studies that evaluate muscle activation during movement variations typical of RT.

Thus, considering that muscle activity plays a fundamental role in the selection of exercises (30) and that its response can guide coaches and physiotherapists in choosing the most appropriate movement in RT and rehabilitation programs (7), the purpose of the present study was to compare the electromyographic activity of PMS, PMC, and TB muscles with different elbow positions in the dumbbell pullover exercise.

The alternative hypothesis considers that there will be greater muscle activation in the PM fibers with elbow extension due to the greater torque generated. However, for the TB, we understand that due to the sustained isometric contraction throughout the movement with elbow flexion, greater activation in this muscle is expected.

METHODS

Subjects
Thirteen male university students participated in this study (age: 25.9 ± 3.0 years; body mass: 75.3 ± 10.4 kg; height: 175.1 ± 6.6 cm; BMI: 24.4 ± 2.0 kg·m^{-2}) with a minimum experience of 12 months in RT. As inclusion criteria, the participants could not have any history of pain, muscle and/or joint injury in the lower and upper limbs, and no limitations in the shoulder joint range of motion. All participants negatively responded to the PAR-Q questions (27). After agreeing to participate in the study, the participants signed the Free and Informed Consent Form that was previously approved by the Research Ethics Committee Involving Humans at the Federal University of Juiz de Fora (approval number 3.749.878).

Experimental Design
To compare the muscle activation of the PMS, PMC, and TB, the present study used a crossover design with randomized order. During the first session, the participants were assessed for body mass and height and, then they were informed of all procedures that involved the data collection. During the second session, 10 repetition maximum test (10-RM) with elbow extension and elbow flexion occurred to determine the load that would be used in experimental sessions. During the third and fourth sessions, muscle activation data were collected in the different ways of dumbbell pullover execution (Figure 1). For all sessions, an interval from 48 to 72 hours was applied. All participants were instructed not to eat any type of food containing alcohol or caffeine, and they were told not to perform any vigorous exercise within a 24-hour period prior to the tests.

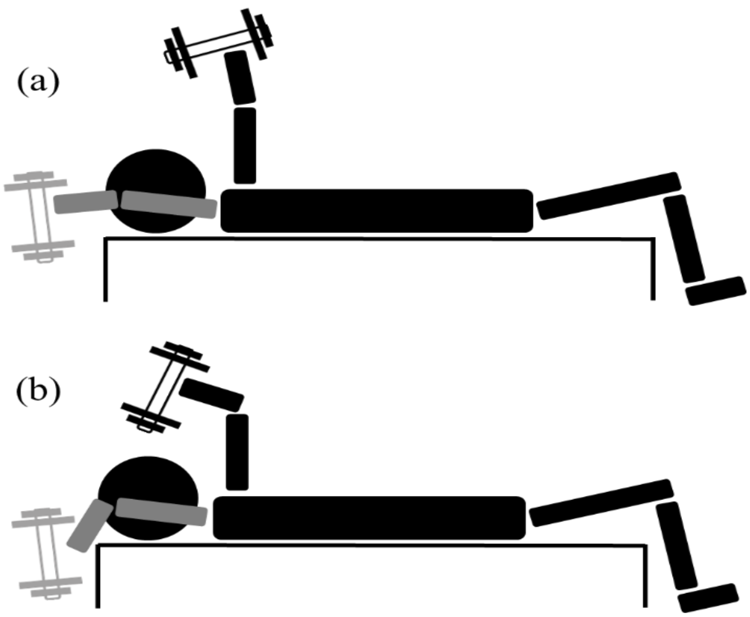

Figure 1. Dumbbell Pullover with Elbow Extension (a) and Elbow Flexion (b).

Anthropometric Evaluation
Initially, the participants performed anthropometric assessment for sample characterization. Total body mass was measured using a digital scale (HBF-514C, OMRON®, Brazil). Height

was determined using a wall stadiometer (Standard, Sanny®, Brazil). All measurements were performed by a single evaluator experienced in the evaluation procedures.

Ten Repetition Maximum Test - 10-RM

The 10-RM test was performed using the dumbbell pullover exercise with elbow extension and flexion. Tests were conducted in randomized order on non-consecutive days separated by 48 hours. The test protocol followed the National Strength and Conditioning Association recommendations (21). The participants were instructed to not exercise during the test days. The 10-RM values were determined within 5 attempts with a 4-min rest interval.

To perform the exercises, the participants laid down on their backs on a bench (SMAB, LifeFitness, Hungary). The head, back, and hips were in contact with the bench and the feet were resting on the floor at all times. Each participant held the end of the dumbbell with both hands at 90º angle between the arms and the trunk. The eccentric phase of the movement consisted of shoulder flexion, keeping the elbows at 90º flexion during the entire range of motion until the angle of 180º of the glenohumeral joint was reached, which was controlled by a string that the participants touched when they reached full range of motion.

After reaching 180°, the concentric phase began, where the participants performed shoulder extension until the dumbbell returned to its initial position (15). During both exercises, movement was controlled using a digital goniometer (New Miotool, Miotec®, Brazil). To minimize errors during the tests, all the participants received standard instructions on the correct technique for performing the exercise. The tests were supervised by researchers, and during the exercise the participants received verbal encouragement. In addition, standard specific warm-up exercises consisting of 3 sets for 10, 5, and 3 repetitions with an estimated progressive load (low, moderate, and high, respectively) were performed.

Experimental Sessions

At the beginning of the experimental sessions, the participants performed 10 repetitions of each exercise as a warm-up, with loads adjusted to 45% of the 10-RM. After a 4-min rest interval (21), the participants performed a single series of 10 repetitions with loads adjusted to 90% of the 10-RM to collect electromyographic activity data. In both exercises, the same range of motion was used. During all exercises, the movement speed (cadence) was maintained at (2/0/2/0), that is, eccentric phase of 2-sec, 0-sec, or no interruption in the transition phase, concentric phase of 2-sec, and 0-sec, that is, no rest before the next repetition (34) using a digital metronome (DM50, Seiko S-Yard CO, Japan). The dumbbell pullover was performed as described in the 10-RM test. For the execution of the dumbbell pullover, the following materials and equipment were used: (a) dumbbells (Physicus®, Auriflama, Brazil) with 20 cm in diameter, sizes ranging from 23 to 32.5 cm and a load from 12 to 32 kg, respectively; and (b) an adjustable bench (SMAB, LifeFitness, Hungary).

Electromyography Signal

The participants underwent trichotomy, abrasion, and skin cleaning with gauze and isopropyl alcohol. Then, surface electrodes (model 2223 BR, 3M®, Campinas, Brazil) with conductive gel and 1-cm diameter AgCl capture surface with 2-cm center-to-center distance were placed in the direction of muscle fibers of the PMS, the PMC, and the TB muscles on the dominant side (3) according to the recommendations of the electromyography atlas (2). For the PMS, the electrodes were placed at a distance corresponding to 76% of the distance between the acromion process of the scapula and the xiphoid process of the sternum. For PMC, the electrodes were placed at a distance corresponding to 40% of the distance between the acromion and the xiphoid process. For the TB, the electrodes were placed at a distance corresponding to 48% of the distance between the acromion and the medial epicondyle of the humerus. A reference electrode was placed on the lateral epicondyle of the elbow on the dominant side in each participant. To collect the electromyographic signal, a electromyograph (New Miotool, Miotec®, Brazil) with 8 input channels, 16 bits of resolution, and a sampling rate of 2000 Hz was used.

To analyze the data, the first and last repetitions were removed, starting from the raw signal, in order to avoid interference from body adjustment and neuromuscular fatigue, respectively. The electromyographic signal was processed using 4th order bandpass butterworth filter with zero phase delay, cutoff frequency of 20-500 Hz and 60 Hz notch. Electromyographic signal normalization occurred from the dynamic peak method, where the largest signal found in dynamic contractions was used to relativize values (22). The signal amplitude was calculated using root mean square with 100-ms movable window. For data analysis and processing, the MiotecSuite 1.0 software (New Miotool, Miotec®, Brazil) was used.

Statistical Analyses

To adopt the type of statistics and sample distribution, the probability distribution function was tested by the Shapiro-Wilk Test. To check homoscedasticity, the Levene Test was used. Subsequently, descriptive parametric statistic was adopted through mean ± standard deviation. Then, two-way ANOVA (position x muscles) was used to verify differences in muscle electromyographic activation, followed by *post-hoc* Tukey analysis. Cohen f^2 was applied to estimate the effect size (ES), with effect magnitude classified as small (0.2), moderate (0.6), or large (1.2) (14). For all analyses, the significance level adopted was 5% ($P<0.05$), using the GraphPad statistical software (Prism 8.0.1, San Diego, CA, USA).

RESULTS

Electromyographic activation values are presented in the mean percentile of the root mean square. Two-way ANOVA showed no interaction of the muscles with elbow positions [F (3, 36) = 1.2; P = 0.312] and between elbow positions [F (1, 12) = 1.0; P = 0.332] (Table 1), but effect among the muscles was observed [F (3, 36) = 11; P<0.001].

Table 1. Comparison of the Electromyographic Activation between Elbow Positions.

	Extension (%)	Flexion (%)	P-value	ES
PMC	39.59 ± 12.17 (46.94 – 32.23)	40.88 ± 7.76 (45.57 – 36.19)	0.967	0.123 (small)
PMS	48.41 ± 5.14 (51.51 – 45.30)	43.96 ± 6.78 (48.06 – 39.87)	0.409	0.715 (moderate)
TB	54.22 ± 6.38 (58.07 – 50.36)	56.09 ± 7.90 (60.86 – 51.32)	0.910	0.253 (small)

Data presented as mean ± SD (95% CI); **RMS** = Root Mean Square; **PMC** = Pectoralis Major Clavicular Portion; **PMS** = Pectoralis Major Sternal Portion; **TB** = Triceps Brachii Long Portion; **ES** = Effect Size

In both positions, the electromyographic activation of the TB was greater than that of the PMC (extension: $P<0.001$; flexion: $P<0.001$) (Figures 2 and 3). When compared to the PMS, the TB showed greater activation with elbow flexion ($P = 0.002$) (Figure 3) and not with elbow extension ($P = 0.283$) (Figure 2). Greater activation was found in the PMS when compared to the PMC in elbow extension position ($P = 0.039$) (Figure 2).

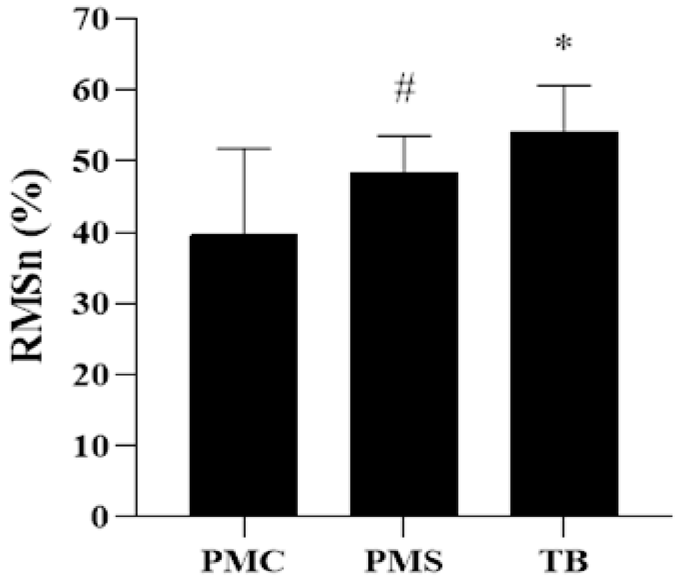

Figure 2. Electromyographic Activation with Elbow Extension. Data presented as mean ± SD; **RMS** = Root Mean Square; **PMC** = Pectoralis Major Clavicular Fibers; **PMS** = Pectoralis Major Sternal Fibers; **TB** = Triceps Brachii Long Head; *Significant difference in relation to the clavicular fibers of the pectoralis major ($P<0.05$); # Significant difference in relation to the clavicular fibers of the pectoralis major ($P<0.05$).

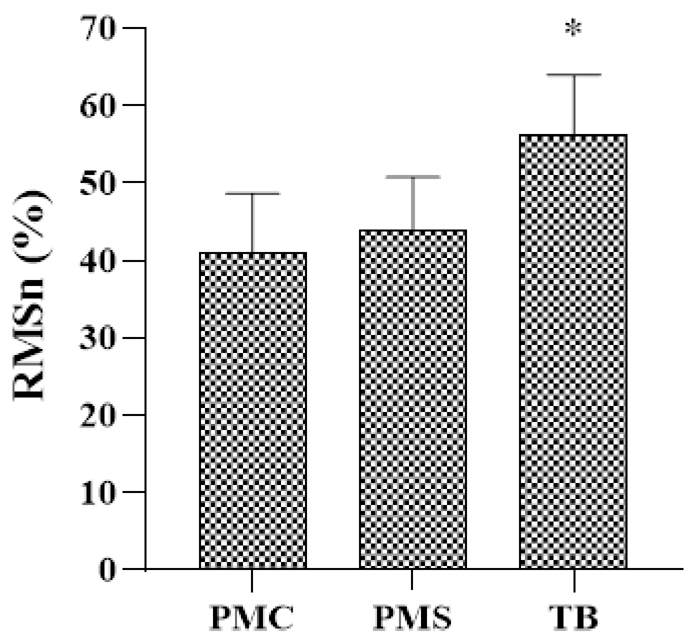

Figure 3. Electromyographic Activation with Elbow Flexion. Data presented as mean ± SD; **RMS** = Root Mean Square; **PMC** = Pectoralis major Clavicular Fibers; **PMS** = Pectoralis Major Sternal Fibers; **TB** = Triceps Brachii Long Head; *Significant difference in relation to the clavicular and the sternal fibers of the pectoralis major ($P<0.05$).

DISCUSSION

The purpose of the present study was to compare the electromyographic activity of PMS, PMC, and TB muscles with different elbow positions in the dumbbell pullover exercise. The results found rejected the experimental hypothesis, since no significant differences were observed in the muscles in the different elbow positions in the dumbbell pullover exercise. However, when comparing the different muscles, it was observed that the TB had a greater demand than the PMC, regardless of the elbow position.

The activation of the TB is substantially increased when the elbows are flexed against gravity due to the constant isometric muscle work to maintain the elbow angle at 90° (12). The constant isometric action of the TB may explain, in part, the greater muscle activation when compared to the other muscles evaluated in this study, especially when under the action of an external load (6). Similar results were found by Campos and Silva (5) who compared the muscular activation of TB between the pullover exercise and the bench press exercise, both performed with a barbell. These results highlight the importance of the TB in the extension movement of glenohumeral joint (31).

Previous studies have shown a great difference in the activation of the PM when compared to the latissimus dorsi, and the activation difference was approximately 90% (4,6,18). Campos et al. (6), in addition to finding a higher activation in the TB, also demonstrated a greater activation in the PM compared to the latissimus dorsi, while Borges et al. (4) demonstrated greater activation in the PMS followed by the TB and the latissimus dorsi, respectively. Considering these results, the small contribution of the latissimus dorsi in the extension movement starting from 180º of the glenohumeral joint flexion can be highlighted (18), which justifies the prescription of the dumbbell pullover movement for the development of the upper and anterior body muscles.

The lack of studies comparing the electromyographic activation of the PMS and the PMC in the dumbbell pullover prevents us from better understanding these results. Campos and Silva (5) showed no differences in electromyographic activation among the different parts of the PM. It could be speculated, as contextualized in our hypothesis, that the greater activation in the PMS with elbow extension occurred due to a possible change in the length-tension relationship provided by the dumbbell pullover exercise. Thus, different joint positioning strategies adopted in the handling of implements may imply different muscular demands, being of great relevance in the practical context.

Other factors may also influence the results when using the electromyography method. As an example, electromyographic signal normalization is essential since it is used to normalize the signal and the electrode placement reference point may directly interfere with the results. Other studies (5,6) have reported different results in the same exercises. Borges et al. (4) and Campos and Silva (5) used the method to normalize the electromyographic signal through the dynamic peak, and Campos et al. (6) used the maximum voluntary isometric contraction. According to Robertson et al. (22), the best way to normalize the signal during dynamic contractions is through the dynamic peak, which was used in the present study. The technique of using the maximum isometric voluntary contraction to normalize the electromyographic signal may not be ideal, especially when the investigation requires dynamic contractions. In fact, interpretation errors may be the result of normalization by maximum isometric voluntary contraction (19). An alternative to dynamic contractions is to use the maximum electromyographic activity during some reference part of the contraction itself. The maximum electromyography amplitude is represented as 100%, and the EMG amplitudes in other parts of the movement cycle are normalized to this maximum value (22).

This is the first study to compare different positions of the elbow joint when performing the dumbbell pullover exercise. Other studies have reported comparisons between different exercises, such as the barbell pullover versus the barbell bench press (5), different positions in the Ab Wheel Rollout (17), the barbell pullover versus the dumbbell pullover (6), and the barbell bench press, the lat pull-down, and the triceps extension exercises (4).

Practical Application

Dumbbell pullover allows for a variation of movement for exercises aimed at developing the chest musculature (specifically, the anterior and upper trunk muscles). Since most exercises work by performing horizontal shoulder adduction, this exercise provides different stimuli for muscle fibers by using shoulder extension. In addition, for individuals with some movement limitation, discomfort or pain in the shoulder joint, the possibility of performing the exercise with elbow flexion, that is, with better lever arm and without significant decrease in muscle activation may be safer and more comfortable.

Limitations in this Study

Some limitations of the present study are the sample size, the use of other handholds, and the way in which the electromyographic signal normalization should be highlighted (especially since this procedure is still the reason for great divergence in the literature when dynamic exercises are analyzed).

CONCLUSIONS

The triceps brachii showed great activation in the extension movement of the glenohumeral joints during the dumbbell pullover exercise, regardless of the elbow position. However, it is important to emphasize that the dumbbell pullover exercise with elbow extension presents strong request from the sternal fibers of the pectoralis major. Therefore, the action of the pectoralis major can be an important factor that should be taken into account when designing training programs aimed at increasing maximal strength and muscle hypertrophy to the upper and anterior trunk. However, further studies should be carried out with pullover exercise and its many execution techniques and handholds (barbell, dumbbell, and cable), as well as with different amplitudes to better explain its application in RT programs.

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