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Original Article

Activation of pectoralis major and deltoid during bench press and pullover exercises until the concentric failure

MÁRCIO RABELO MOTA[1] , RODRIGO VIEIRA BOGÉA[2], EMERSON PARDONO[3], CIRO JOSÉ BRITO[4], MARCELO MAGALHÃES SALES [5], MARCELO GUIMARAES BOIA DO NASCIMENTO[6], IRANSÉ OLIVEIRA SILVA[7].

[1,2,3,6] Centro Universitário de Brasília, Brazil
[2] Universidade Federal de Sergipe, Brazil
[4,3] Universidade Federal de Juiz de Fora, Brazil
[1,5,7] UniEVANGÉLICA, Brazil
[5] Universidade Estadual de Goiás, Brazil

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Abstract
This study compares the electromyographic response in the activation of the pectoralis major and anterior deltoid in bench press and pullover exercises. For this, ten male volunteers (23.9 ± 4.4 years of age, 73.3 ± 11.6 kg of body weight, 1.7 ± 0.1 meters, 14.0 ± 4.2% of body fat) with resistance training (>1 year) were measured. In a crossover fashion. All volunteers performed the exercises with 70% of one maximum repetition until failure. An electromyographic comparison was performed between the bench press and pullover exercises, where the pectoralis major and anterior deltoid muscles were monitored. There was no significant difference in pectoralis major activation between the two exercises (384.8 ± 220.6 vs. 232.5 ± 175.3 RMS, p = 0.131). There was a significantly higher activation of AD in bench press exercise (666.9 ± 191.0 vs. 63.5 ± 19.8 RMS, p<0.001). In conclusion, for training the anterior trunk, the bench press showed to be more advantageous compared to the pullover exercise, bench press results in a higher activation of the anterior deltoid muscle fibers and similar activation in the pectoralis major.
Keywords: electromyography; weight training; concentric failure.

Introduction

The choice of exercises to compose a resistance training (RT) program depends on the objectives to be achieved, since the training performed results in different physiological and biomechanical stimuli (Brennecke et al., 2009). Whether for aesthetic purposes (Crispiniano et al., 2016) or sports performance (Escamilla & Andrews, 2009), the pectoralis major (PM) and anterior deltoid (AD) musculature are among those that are frequently included in TR programs.

The efficiency of an exercise regarding neuromuscular activation can be measured by electromyography (EMG) (Santana, Vera-Garcia, & McGill, 2007). In addition, the interpretation of the EMG signal can be used to aid in the prescription of RT (Crispiniano et al., 2016). Despite the studies studying the electromyographic signal of PM (Crispiniano et al., 2016; Golas et al., 2017; Stastny et al., 2017) however, as far as we know, there is still a lack of studies that investigated the exercise of pullover. Marchetti and Uchida (2011) found that pullover activates PM during execution and can be included in a training program for this muscle group, but the efficiency depends on the external load applied. To our knowledge, there is only one study that compared bench press and pullover exercises, Campos and Silva (2014) observed higher activation of PM and AD in the bench press and higher activation of the *triceps brachii* and *latissimus dorsi* in pullover exercise. However, the exercise was not performed until failure. It is known, however, that the exercise performed until failure can change the EMG signal when compared to the exercise with limited number of repetitions, since exercise until the failure increase the motor units activation (Nóbrega & Libardi, 2016). In view of the scarcity of studies that investigated these theme and the absence of studies that compared these two exercises until the failure, the present study aimed to investigate the activation of the PM and AD muscles during the bench press and pullover exercises in trained individuals. We hypothesized that the different stimuli performed differentiated activations in the muscles investigated.

Material & Method

Participants

This work consisted of an exploratory and transversal research. The present study was approved by the Ethics Committee of the School of Education and Health of the Brasilia University Center (CAAE 30184014.7.0000.0023, register 649.151). All participants were informed about the research aims, exercises to

Corresponding Author: CIRO JOSÉ BRITO, E-mail: cirojbrito@gmail.com

be performed and signed the Informed Consent Term. Ten active men, aged 20-30 yrs. (Table 1), with previous experience (>1 year) in the RT were submitted to the bench press and pullover bar exercises. The following inclusion criteria were adopted: a) no previous osteomioarticular injury that affect the performance of exercises; b) participate, for at least one uninterrupted year, in a resistance training program; c) be familiar with the exercises to be performed. Those who did not complete all the steps or wished to leave the study (n = 2) were excluded. All were instructed not to perform strenuous physical exercise 48 hours prior to data collection.

Table 1. Participants characterization (n=10).

Measures	**Mean ± standard deviation**
Age (years)	23.9 ± 4.4
Body Mass (kg)	73.3 ± 11.6
Height (m)	1.7 ± 0.1
Body Mass Index (kg/m^2)	24.7 ± 2.1
Body Fat (%)	14.0 ± 4.2

Experimental design

The present study was carried out through an observational cross-sectional comparing the action of the PM and AD muscles in bench press and pullover exercises in subjects adapted to resistance training. When performed until concentric failure. The participants appeared on three times in the biomechanical analysis laboratory to perform the experimental protocol. On the first day the volunteers performed a test to estimate the capacity of a maximum repetition (1 RM). For this, the indirect protocol of Baechle and Groves (1994). Three days after the 1RM performance, the participants were randomized and half of the sample performed the bench press; the others, pullover. Two days after the tests were inverted, characterizing the cross-over design. Before data collection, all participants performed a warm-up in both exercises (20 repetitions, 30% of weight load). Then, the exercises were performed until fatigue using as load 70% of 1RM. The concentric failure was determined when the performer presented the speed reduction below the cadence parameters. These study adopted the 2-0-2-0 cadence as described by Izquierdo et al. (2006).

In bench press exercise, the participant lay down on the bench using the pronation handgrip on the bar (hands were positioned following the ratio of 2x bi-acromial diameters) as described by Fees, Decker, Snyder-Mackler, and Axe (1998), starting the concentric phase until the total extension of the elbows. Immediately after, the eccentric phase was initiated, where the elbows were flexed until the bar aligned near the central region of the external (the participants were instructed not to let the bar touch the external to prevent any change in the position of the electrodes). To perform the pullover bar exercise, the subjects were instructed to maintain the same position of the bench press with the pronated handgrip in the bar, shoulder width, beginning the exercise with the elbows fully extended and, during the performance of the same, realized an extension of the shoulder until the arms reach the vertical position (Figure 1). During the exercises, a metronome (Pro Metronome, EUMLab, Berlin, Germany) was used, where 60 beats per minute (BPM) was set for the frequency, determining the rate of movement. Figure 1 shows the experimental design of the present study.

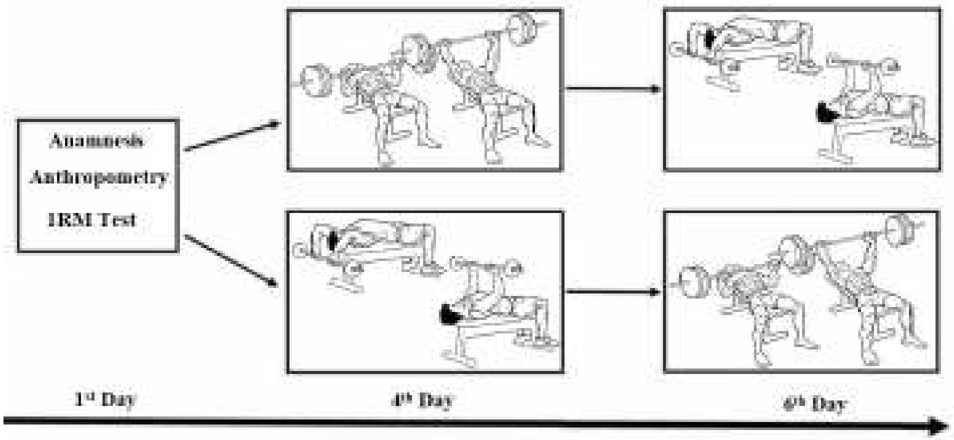

Figure 1. Cross-sectional experimental design for measurements.

After the evaluator's indication, the participants started the exercise and the electromyographic surface signal (EMG) was monitored throughout the exercise (concentric and eccentric phase) until failure. The EMG was collected using the EMG Pro 800® (EMG System, SP, Brazil) of six channels – 2000 Hz. The EMG signal obtained during a movement, according to time, was estimated by linear envelope, rectification, RMS (Root Mean Square) and integration. The rectification moderates the negative phases known as full-wave, or even excludes the negative values of the gross signal known as half-wave. By rectification in the negative phase, the absolute value of the EMG signal is used to retain its energy (Hermens et al., 1999; Marchetti & Uchida, 2011).

The window for determination of the EMG activation measure was set at 10 seconds, the initial 5 seconds – which corresponds to the period of adaptation to the equipment, in which the imbalances can be very variable, are neglected. In this way, the final 5 seconds correspond more faithfully to the desired one, in a more homogeneous way between subjects (Hermens et al., 1999). For the EMG signals the Buterworth bandpass filters were applied between 20-500 Hz and the notch (band rejects). In the three replicates of each test the RMS value was collected and the arithmetic mean of the three was calculated, resulting in a final value for each test (Parziale, 2017). The maximum voluntary isometric contraction (MVIC) was used as standard for the normalization of the values obtained in the tests, which can be compared, independent of the force, due to the electric activity of the muscle and not to the muscular strength between subjects. With this, the signals obtained in the tests were reported as a percentage of their maximum activity (% CIVM) (Hermens et al., 1999). The recommendations for the use of analogue filters for low-frequency (500 Hz) and high-pass, (<10 Hz) for spectral analysis and 10-20 Hz for motion analysis were adopted (Hermens et al., 1999). Two surface electrodes were used for the PM and 2 for the AD, both on the right side of the body. A reference electrode was placed in the acromion in order to eliminate any external interference. Data analysis was performed by WinDaq Acquistion software (DI-160, Dataq Instruments, Ohio, USA).

Statistical analysis

Normality was tested by the Shapiro-Wilk test. Having data presented standard distribution, they were expressed in mean and standard-deviation. The inferential analyzes were performed using the paired T test. For all comparisons, the effect size (d ') was calculated according to the propositions of Cohen (2007) and analyzed through recommendations for RT (Rhea, 2004). All analyzes were performed using the statistical package Statistical Package for the Social Sciences (SPSS version 21.0). In all tests, 5% was adopted as a level of significance ($p \leq 0.05$).

The reproducibility of the measurements (1MR) was evaluated from the analysis of the Intraclass Correlation Index (IC) between these two measures, IC ≥0.90 being adopted as acceptance criterion. The calculation of the sample was performed using the software version G * Power version 3.1.9.2 (Erdfelder, Faul, & Buchner, 1996, Kiel, Germany), with muscle activation (RMS) being the main variable of the study, considering the sample size of the present study ($n = 10$) and $\alpha = 0.05$, a power ($1-\beta$) of 0.80 for the analyzes performed.

Results

The participants performed 9.9±0.7 repetitions until they reached concentric failure in the bench press and 10.0±0.1 in the pullover bar ($p=0.76$). The data on the EMG activation of PM and DA in the two exercises are presented in Figure 2. There was no significant difference in the activation of PM ($p = 0.131$). On the other hand, there was a significant difference in the activation of AD ($p <0.001$, d '= 4.4).

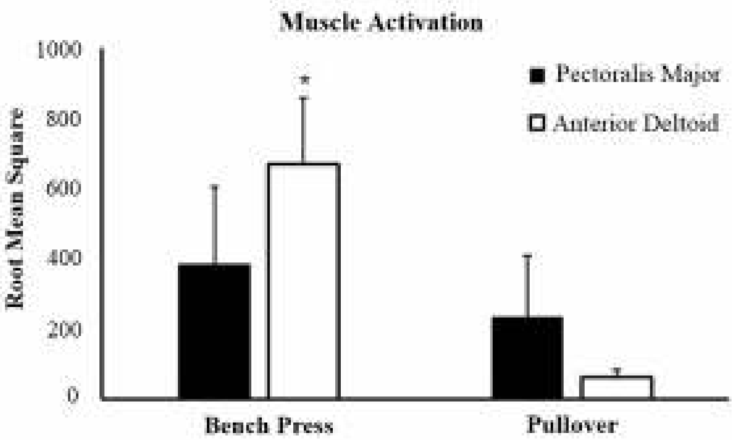

Figure 2. Electromyographic signs measured in the bench press and pullover exercises in the pectoralis major and anterior deltoid muscles, * p<0.001. Pullover bar.

Discussion

The observed values for the effect size showed moderate to high (Rhea, 2004) for the EMG means and the total number of repetitions. Exercises for the PM and DA muscles are part of the training routine of bodybuilders and athletes, so it is relevant to compare exercises that train these groups. The main findings of the present study indicated that there was no difference between PM activation in bench press and pullover exercises, but there was a greater activation of AD in the bench press, when the exercises were performed until concentric failure. The observed results for AD are in agreement with those observed by Campos and Silva (2014), however when comparing the results for PM there seems to be a difference between the submaximal and the performed exercise until failure. It should be noted, also, a possible larger number of active units for both PM and DA in our study, since exercise was performed until failure, differently from the design proposed by Campos and Silva (2014), that controlled the number of repetitions performed. Jenkins et al. (2015) observed a higher muscle activation when exercise was performed until failure using 80% vs. 30% of 1RM. However, there are studies that observe a similar level of activation when exercise is performed until failure or not (Nóbrega & Libardi, 2016; Sundstrup, Jakobsen, Andersen, Zebis, & Andersen, 2011).

Biomechanical aspects seem to influence the activation differences observed in the present study. While the bench press is composed of movements of adduction and abduction of the shoulder (Brennecke et al., 2009), the pullover, by movements of flexion and extension (Marchetti & Uchida, 2011). Our results indicate that, for the training of the anterior trunk, the bench press exercise seems to be the best option. However, this does not mean that the pullover is only an auxiliary exercise for the development of the chest only. Depending on the specificity of the training, the inclusion of this exercise may be critical. Chelly, Hermassi, and Shephard (2010) observed that the force expressed during pullover and bench press are directly correlated with the power of upper limbs in handball players. Similar results were observed by Valadés, Palao, Aúnsolo, and Ureña (2016) in volleyball players. It should also be noted that the pullover results in higher activation of the pectoralis in the concentric phase of the movement (Marchetti & Uchida, 2011), therefore, the appropriate training focus of this group can assist in the sporting performance as observed in volleyball and handball players.

Conclusion

The present results can be applied to the prescription of hypertrophy training, since stimuli to failure are recommended to achieve this aim (Jenkins et al., 2015). When it planned training aimed to the anterior trunk hypertrophy, both exercises can compose the prescription for the PM, but there will be a greater chance of AD hypertrophy when the subject performs the bench press. It should be emphasized, however, that our study has limitations regarding the monitoring of other muscles involved in the measured exercises, such as *latissimus dorsi* and *triceps brachii*. We recommended that future studies also compare the exercises measured here at different angles (eg. inclined and declined). Considering the aims and obtained results, it is concluded that, for training of the anterior trunk region, the bench press seems to be better compared to the pullover, since it resulted in greater activation of the muscle fibers of the anterior deltoid and similar activation in the pectoralis major.

Conflict of interest

The authors certify that they have NO affiliations with or involvement in any organization or entity with any financial interest, or non-financial interest in the subject matter or materials discussed in this manuscript.

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