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Original Article

Resistance training acute session: pectoralis major, latissimus dorsi and triceps brachii electromyographic activity

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Abstract:
We aimed to compare electromyographic activity of the external portion of the pectoralis major, latissimus dorsi and triceps brachii long head in an acute resistance training session between bench press (BP), lat pull down, pullover and triceps lying exercises. Concentric and eccentric phases electromyographic activity were compared. pectoralis major showed significantly higher activity in bench press (67.9 %) than in pullover (50.8 %), triceps lying (35.9 %) and lat pull down (14.1 %) in the concentric and eccentric phase (43.4 %, 27.5 %, 24.5 % and 7%, respectively). Latissimus dorsi showed significantly higher activity in lat pull down (59.5 %) than in pullover (22.7 %), triceps lying (10.7 %) and bench press (6.6 %) in the concentric and eccentric phase (37.4 %, 8.4 %, 7.6 % and 4.4 %, respectively). Triceps brachii long head showed significantly higher activity in triceps lying (67.7 %) than in bench press (49.2 %), pullover (34.3 %) and lat pull down (12.4 %) in the concentric and eccentric phase (37.6 %, 23.8 %, 20.5 % and 9.7 %, respectively). We found that bench press, lat pull down and triceps lying exercises are more effective to activate pectoralis major, latissimus dorsi and brachii long head muscles, respectively. Pullover exercise is more effective to activate pectoralis major (50.8 %) rather that latissimus dorsi (22.7 %). One should take into account such results while preparing a strength training periodization routine in order to avoid overtraining.
Key words: resistance training, pullover, bench press, lat pull down, triceps lying.

Introduction

Knowing muscular activation in resistance training (RT) is of great interest when one wants select the best strategy to improve performance (Calatayud et al., 2014) or rehabilitate an athlete (Escamilla, Yamashiro, Paulos, & Andrews, 2009). Shoulder and / or elbow injuries are common in overhead sports such as tennis, volleyball, handball and baseball (Andersson, Bahr, Clarsen, & Myklebust, 2017). Rehabilitation programs usually use electromyographic studies to elect the suitable exercises to strengthen shoulder and elbow muscles (Escamilla et al., 2009). For instance, bench press (BP) and lat pull down (LPD) exercises are employed in advanced phases of rehabilitation protocols since they help balance shoulder rotator cuff muscles (Reinold, Gill, Wilk, & Andrews, 2010). On the other hand, RT exercises are used to increase strength and muscular hypertrophy (Communications & ACSM, 2009) in athletes and even recreational weightlifters to increase performance (Kobal et al., 2016).

Comparing electromyographic (EMG) activity between RT exercises is a common way to compare exercises' efficiency (Andersen, Fimland, Wiik, Skoglund, & Saeterbakken, 2014; Brennecke et al., 2009; Calatayud et al., 2014; Campos & Da Silva, 2014; Chris Barnett, 1995; Marchetti & Uchida, 2011; Schick et al., 2010; Soncin et al., 2014; Youdas et al., 2010). It was found that LPD produced higher latissimus dorsi (LD) activity followed by pectoralis major (PM) and long head of the triceps brachii (TBl) activity (Andersen et al., 2014; Signorile, Zink, & Szwed, 2002) and that bench press (BP) shows higher PM and TBl activity (Stastny et al., 2017). Triceps lying (TL), as expected, presents high TBl activity (Soncin et al., 2014). Pullover (PO) exercise, in turn, seems to present higher PM activity followed by LD (Marchetti & Uchida, 2011) and TBl (Campos & Da Silva, 2014). However, no research has yet focused on comparing PM, LD and TBl EMG activity between BP, LPD and PO performed with 10 repetition maximum (10-RM) – the intensity recommended for strength and muscular hypertrophy gains (Communications & ACSM, 2009).

It seems that solely two studies accessed PO exercise muscle activity. Different experimental designs and EMG normalization procedures restrains a comparison between them. Marchetti and Uchida (Marchetti & Uchida, 2011) used 30 % of body mass as the experimental condition while Campos and Da Silva (Campos & Da Silva, 2014) used 70 % of 1-RM. Similarly, the first normalized EMG data by a maximum voluntary

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isometric contraction (MVIC) of PM and LD while the latter used PM, LD and TBl root mean square (RMS) peak to compare BP and PO exercises.

The biarticular nature of TBl, allowing the extension of the elbow and shoulder (Floyd, 1985), makes this muscle to be activated in BP (Stastny et al., 2017), PO (Campos & Da Silva, 2014) and in LPD (Signorile et al., 2002). It seems to be activated by 60 % of MVIC in LPD (Signorile et al., 2002), 59% in BP (Brennecke et al., 2009), 78 % in TL (Soncin et al., 2014) and in PO exercise its activity seems to be 62.5 % higher than in BP (125 µV versus 200 µV) (Campos & Da Silva, 2014). PM showed an activation of 77% of MVIC in BP (Brennecke et al., 2009), 65 % in LPD (Signorile et al., 2002) and 2500 % in PO (Marchetti & Uchida, 2011). The LD, in turn, seems to be activated by 110% of the MVIC in LPD (Signorile et al., 2002) and 250 % in PO (Marchetti & Uchida, 2011). This scenario does not allow to compare these muscles activation in a single strength training bout that makes use of BP, LPD and PO.

To the best of our knowledge, no study has yet investigated the muscle EMG activity in a single strength training bout aimed to increase strength and muscle hypertrophy. This gap in the literature may affect strength training response since the results might be unsatisfied or lead to overtraining. Therefore, our purpose was to compare LD, TBl and the external portion of the pectoralis major (PMe) EMG activation produced in PO, BP, LPD and TL.

Material & methods

Participants

Took part of this study thirteen male young adults (26.2 ± 2.6 years of age) with resistance training experience (2.3 ± 0.7 years of training) and no history of orthopedic injury. Seventy two hours prior the assessment, the subjects did not ingest alcoholic drinks nor did they underwent strength training sessions. All participants were informed of the study's procedures and gave their written consent to participate. This study was approved by the University's Ethics Committee (CAAE protocol number: 64976316.0.0000.5500).

Measures

Noraxon myotrace 400 (Noraxon USA Inc, Scottsdale, AZ) was used for EMG signal acquisition with sampling frequency of 1000 Hz and 16 bit resolution. This equipment has a 500x total gain (pre-amplifier 10x), an input impedance >100 MOhns, a common mode rejection >100dB and baseline noise < 1 uV RMS. Ag/AgCl Noraxon dual electrodes (Scottsdale, Arizona) with centers separated by 2 cm were used. The electrodes were placed on LD, PMe and in TBl. The dominant side was assessed. To assess the LD muscle activity were placed at half the distance between the vertebral spine and the edge of the lateral side of the trunk at 4 cm below the inferior scapulae angle. They were orientated at 25° from the transverse plane (Criswell, 2011).To assess the PMe muscle activity the electrodes were placed at 4 cm of the auxiliary field and in its direction (Schick et al., 2010). And to assess TBl muscle activity the electrodes were placed at 50 % on the line between the posterior crista of the acromion and the olecranon at 2 finger widths medial to the line (H.J. Hermens & B Freriks, 2017).

Skin preparation for the electrodes placement consisted of shaving, soft abrasion with sandpaper and cleaning with alcohol. EMG signal was filtered by a 4thorder band-pass Butterworth recursive filter with cutoff frequency of 20 and 450 Hz.

LPD, BP and TL were used for a dynamic normalization procedure of the LD, PMe and TBl muscles, respectively. A 200ms moving window RMS with steps of 100ms was calculated for all exercises. RMS highest value under each exercise condition was used to normalize the EMG signal.

RMS of the concentric and eccentric phases of each repetition was calculated and the mean value of each phase in each exercise was used for statistical analysis.

Design and Procedures

With a crossover design this study aimed to compare EMG activity of LD, PMe and TBl muscles between PO, LPD, BP and TL exercises. A week before the experimental session, all subjects performed, on three non-consecutive days, a familiarization procedure. These sessions were used to determine the 10-RM load in order to perform the exercises with proper form.

The study protocol demanded five sessions in the following order: body composition and anthropometric measures assessment, three familiarizations sessions and one experimental session. The exercises were performed in a random order and were supervised by an expert personal trainer. The movement speed was not controlled maintaining subjects' individual technique (Escamilla et al., 2001).

The familiarization sessions allowed the subjects to adjust the 10-RM individual load within a proper execution form. The experimental session took place 72 hours after the last familiarization session.

In the experimental session, the subjects firstly performed a specific warm-up with 10 repetitions at 50% of 10-RM in each exercise with one-minute rest. Afterward, for EMG analysis, they performed four repetitions at 10-RM for each exercise in a random fashion with three-minute rest between exercises.

Kinematic parameters were obtained with a digital camera (LifeCam Studio – Microsoft) with reflexive markers placed in both lateral epicondyle of the humerus, estyloid process of the ulna and in the acromion. These data were synchronized with EMG data through Myo Research 3.6 Master (Noraxon USA, Inc., Scottsdale, AZ) allowing to separate exercises concentric and eccentric phases and measure articular angles.
Standardization of the exercises

PO was performed with the subjects lying in a horizontal bench with feet touching the ground holding a 1.2-meter-"W" bar. Hands were held apart by 34 cm which corresponded to 83.7 % of the subjects' bi-acromial distance (40.6± 3.8 cm). Forearm pronation angle was set at 30° for all participants. The movement began with the arms vertically aligned with extended elbows and the bar positioned in the shoulder line. Then, the subjects flexed their shoulder until the bar reached the bench line and back to the initial position. A small (40°± 15°) elbow angular excursion was allowed while executing the exercise. The shoulder mean angular excursion was 76°± 5.8° and the mean load was 32 ± 7.8 Kg.

LPD was performed with pronated forearms and hands apart by two times the bi-acromial distance. Subjects were asked to retract their scapulae and limit trunk and hip movements. The movement started with elbows fully extended and was completed when the bar passed the chin (Andersen et al., 2014). Mean shoulder adduction was 94.0°± 4.3°, mean elbow flexion was 98.0°± 11.7°and the mean load was 65.8 ± 12.8 Kg.

BP was performed with the subjects lying in a horizontal bench with feet touching the ground holding a 1.8 m straight bar and with hands held at two times the bi-acromial distance. The movement initiated with the bar touching the chest and finalized with the elbows fully extended. Mean shoulder horizontal adduction was 78.0°± 5.6°, mean elbow extension was 90.0°± 13.3°and the mean load was 73.3 ± 12.8 Kg.

TL was performed with the subjects lying in a horizontal bench with feet touching the ground holding a 1.2-meter-"W" bar. The participants held the bar with the same technique as in the PO exercise. Initially, the arms stood aligned vertically and the bar positioned in the shoulder line. Then, they flexed their elbows until the bar reached approximately 2 cm of the subjects' forehead. Mean elbow flexion was 105.0°± 9.1°and the mean load was 37.7 ± 9.2 Kg.

Statistical Analyses

Komolgorov-Smirnov test was applied to check data normality and Mauchly test for the sphericity. For comparison of RMS among different exercises, one-way repeated measure analysis of variance (ANOVA) was performed for concentric and eccentric phases. When necessary the Student-Newman-Keuls test was applied. The significance level was set at 0.05. All statistical procedures were performed on Sigma Stat software 3.5 (Systat, USA). The ICC of the 10RM load was 0.89, 0.92, 0.93 and 0.84 for PO, LPD, BP and TL respectively.

Results

Mean and standard deviation normalized RMS values for the concentric and eccentric phases of each exercise is presented in figure 1 and 2, respectively.

Is was seen that PMe showed higher EMG activation in BP followed by PO, TL and LPD in the concentric (67.9 %, 50.8 %, 35.9 % and 14.1 %, respectively) and eccentric (43.4 %, 27.5 %, 24.5 % and 7.3 %, respectively) phases. This muscle also showed significant differences between movement phases in all exercises. However, in PMe eccentric phase there was no significant differences between PO and TL.

TBl showed higher EMG activation in TL followed by BP, PO and LPD in the concentric (67.7 %, 49.2 %, 34.3 % and 12.4 %, respectively) and eccentric (37.6 %, 23.8 %, 20.5 % and 9.7 %, respectively) phases, but there was no significant difference between PO and BP in the eccentric phase. In this muscle, there was a significant difference between movement phases in PO, BP and TL but not for LPD.

PO showed significant differences in the concentric and eccentric phases for all muscles. Higher EMG activation occurred in PMe followed by TBl and LD in the concentric (50.8 %, 34.3 % and 22.7 %, respectively) and eccentric (27.5 %, 20.5 % and 8.4 %) phases.

In the concentric phase of the LPD exercise LD muscle showed higher EMG activation followed by PMe and TBl (59.5 %, 14.1 % and 12.4 %, respectively). In the eccentric phase higher EMG activation occurred in LD followed by TBl and PMe (37.4 %, 9.7 % and 7.3 %, respectively). However, no significant differences were found between PMe and TBl in both phases.

BP presented significant differences for both phases in all assessed muscles. Higher EMG activation occurred in PMe followed by TBl and LD in the concentric (67.9 %, 49.2 % and 6.6 %, respectively) and eccentric (43.4 %, 23.8 % and 4.4 %, respectively) phases.

TL presented significant differences for both phases in all assessed muscles. Higher EMG activation occurred in TBl followed by PMe and LD in the concentric (67.7 %, 35.9 % and 10.7 %, respectively) and eccentric (37.6 %, 24.5 % and 7.6 %, respectively) phases.

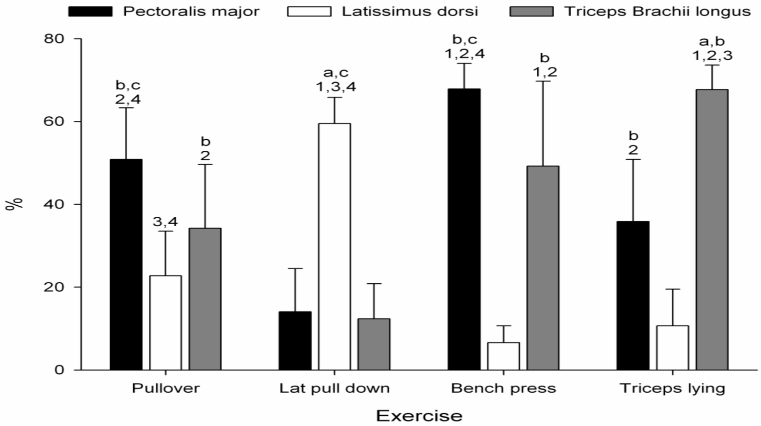

Fig. 1. Concentric phase normalized (%) root mean square in the exercises. 1 = pullover; 2 = lat pull down; 3 = bench press; 4 = triceps lying; a = external portion of the pectoralis major; b = latissimus dorsi; c = triceps brachii long head; 1, 2, 3 and 4 shows a significantly higher activation when comparing with the other exercises; a, b and c shows a significantly higher activation when comparing with the other muscles in the same exercise.

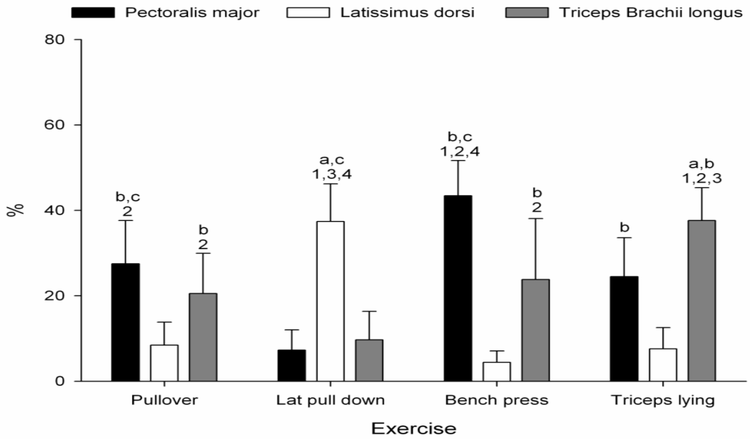

Fig. 2. Eccentric phase normalized (%) root mean square in the exercises. 1 = pullover; 2 = lat pull down; 3 = bench press; 4 = triceps lying; a = external portion of the pectoralis major; b = latissimus dorsi; c = triceps brachii long head; 1, 2, 3 and 4 shows a significantly higher activation when comparing with the other exercises; a, b and c shows a significantly higher activation when comparing with the other muscles in the same exercise.

Dicussion

We aimed to compare EMG signal magnitude of PMe, LD and TBl normalized by BP, LPD and TL in those exercises performed with a 10-RM load which is the recommended intensity for strength gains and muscle hypertrophy.

We saw higher PMe activity in BP when compared to PO in both concentric (25.2 %) and eccentric (36.7 %) phases. When assessing PMe EMG activation in PO, Marchetti and Ushida (2011) used 30% of body mass as the experimental load. They found values of 2500 % of the normalized integrated EMG in PO not allowing to compare it with the BP, the main exercise for this muscle. Campos and Silva (Campos & Da Silva, 2014) in turn, found 45% higher muscle activity in BP than in PO. Nonetheless, they did not treat concentric and eccentric phases separately. Thus, ours and Campos and Silva's (Campos & Da Silva, 2014) results suggest that the PO exercise produces PMe moderate EMG activity. Therefore, we suggest BP to target PMe rather than others. Notwithstanding, PMe was the main muscle in PO. Therefore, we understand that a RT session that uses BP and PO exercises will produce a high and moderate PMe muscle activity, respectively.

We also found that PMe activation in BP was 79.3 % and 83.2 % higher than PMe activation in LPD in the concentric and eccentric phases, respectively. The lower PMe muscle activity in LPD means that when this exercise is to be used in a RT program, its total volume for this muscle can be ignored. Nevertheless, Signorile et al. (2002) found 65% of PMe activity in LPD. Differently from our study, they used EMG signal normalized by a MVIC which could be the cause of this difference (Staudenmann, Roeleveld, Stegeman, & van Dieen, 2010).

Youdas et al. (2010) in turn, found 45% of PM MVIC EMG activity in the pull up exercise, which corroborates with our results. Although different from LPD both exercises have the same shoulder adduction pattern. Sorting the exercises by muscle activation allows to plan a given strategy in a RT program.

LD showed higher EMG activity in LPD that was 61.9 % and 77.6 % higher than in PO concentric and eccentric phases, respectively. These results are in accordance to the findings of Marchetti and Ushida (2011) that also found lower LD activity in PO. Indeed, our study shows that LD EMG activity in PO performed with 10-RM is very low when compared to LPD exercise. Therefore, when one wants to emphasize LD the LPD exercise should be selected. We understand that a RT session that uses LPD and PO exercises will produce a high and low LD muscle activity, respectively.

TBl showed higher EMG activity in TL than in BP and PO concentric (27,4 % and 49,4 %, respectively) and eccentric (36,8% and 45,5 %, respectively) phases. However, higher TBl activity was seen in BP than in PO, in the concentric phase (figure 1). Different from our findings, Campos and Silva (2014) found a higher TBl activity in PO than in BP. The elbow position might have caused these differences. While in Campos and Silva's (Campos & Da Silva, 2014) study this parameter seems not to have been controlled or monitored in ours the participants kept their elbows flexed (40° ± 15°), according to individual technique. The biarticular nature of TBl (Floyd, 1985) might allow it to perform a double task in PO exercise. This may justify the higher TBl EMG activity when compared to LD in the concentric (figure 1) and eccentric (figure 2) phases of PO exercise. We, therefore, suggest that when one wishes to emphasize TBl the TL exercise is more appropriate. Nevertheless, TBl activity in PO can be considered to be moderate to low once it has shown less than half of the TL EMG activity. In the meanwhile, TBl activity in BP was moderate to high. In a systematic review, Stastny et al. (Stastny et al., 2017) stated that TBl and PM exhibit similar EMG activation in BP being the two movement agonists. Therefore, we believe that a strength training session that uses BP and PO should not neglect the TBl muscle activation.

TBl activation in TL was 81.7 % and 74.3 % higher than in LPD concentric and eccentric phases, respectively, showing its low demand in this exercise. Contrary to this finding, Signorile et al. (Signorile et al., 2002) found high (60 % of the MVIC) TBl activity in the LPD. As stated before, we believe the methodological differences lead to these divergences. We suggest that the TBl activation can be neglected when using the LPD exercise.

We found that in a RT session with BP, LPD, TL and PO exercises there will be an emphasis in the TBl activity. We advise coaches to recognize this fact when prescribing their RT programs.

Conclusions

Selecting the appropriate strength training exercises to improve performance or rehabilitate an injured athlete is vital. Considering what we previously knew, BP is the most effective exercise to activate the PMe muscle while the LPD is the most effective exercise to activate the LD muscle and TL is the most effective exercise to activate the TBl muscle. We advise those exercises as the primary to strength gains.

PO seems to be an exercise that activates mainly PMe but also LD and TBl. Thus, we suggest that when PO is to be included in a RT program PMe activation must be accounted as a primary muscle for shoulder extension and TBl and LD as secondary muscles.

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