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Specific prime movers' excitation during free-weight bench press variations and chest press machine in competitive bodybuilders

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ABSTRACT

The current study compared the muscle excitation in free-weight bench press variations and chest press machine. Ten competitive bodybuilders were recruited. The EMG-RMS amplitude of clavicular and sternocostal head of *pectoralis major*, long head of *triceps brachii* and *anterior* and *lateral deltoid* was recorded while performing horizontal (BP), inclined (45°) (IBP) or declined (-15°) bench press (DBP) and chest press machine (CP). Four non-exhaustive repetitions were performed using 80% of 1-repetition maximum of each exercise. Both concentric and eccentric phases were recorded. During the concentric phase, [*d* effect size: 2.78/7.80] clavicular head was more excited in IBP and less excited in CP (*d*: -9.69/-4.39) compared to all other exercises. The sternocostal head was similarly excited in DBP vs BP and BP vs CP and more excited (*d*: 2.42/9.92) compared to IBP. *Triceps brachii* excitation was overall greater (*d*: 2.01/6.75) in BP and DBP compared to all other exercises. *Anterior deltoid* was less excited (*d*: 3.84/19.77) in DBP compared to all other exercises. *Lateral deltoid* excitation was greater (*d*: 0.96/3.10) in BP, IBP and DBP compared to CP. Muscle excitation during the eccentric phase followed a similar pattern, with the exception of the greater (*d*: 3.89/11.32) excitation in the clavicular head in BP compared to all other exercises. The present outcomes showed that the excitation of the clavicular and sternocostal head of *pectoralis major* depends on the bench inclination angle. The use of BP variations vs CP allows overall greater *triceps brachii* and *lateral deltoid* excitation, due to the greater instability.

Keywords: EMG; root mean square; resistance exercise; pectoralis major; triceps; deltoids

INTRODUCTION

Resistance exercises are largely used by recreational or competitive athletes to increase muscle strength and hypertrophy. Since each weight exercise provides a mechanical stimulus to its targeted muscles, defining how these muscles excite (Vigotsky, Halperin, Lehman, Trajano, & Vieira, 2018) during a typical resistance exercise provides useful information for both trainers and athletes. Bench press (BP) and its variations are among the most effective exercises to stimulate the upper-body muscles (Statsny et al., 2017). More specifically, it is acknowledged that *pectoralis major, anterior deltoid* and *triceps brachii* act synergistically to lift the bar (Lauver, Cayot, & Scheuermann, 2016; Saeterbakken & Fimland, 2013; Saeterbakken, Mo, Scott, & Andersen, 2017; Statsny et al., 2017). However, some discordances in muscle excitation were found when BP was performed on a horizontal flat, inclined (IBP) or declined bench press (DBP) (Lauver et al., 2016; Saeterbakken et al., 2017). For example, the clavicular head of *pectoralis major* was shown to be more excited in IBP vs both BP and DBP performed by recreationally resistance-trained men (Lauver et al., 2016). In contrast, no difference in clavicular and sternocostal head of *pectoralis major* excitation was found between BP, IBP and DBP when performed by competitive athletes (Saeterbakken et al., 2017). Thus, it seems that the training experience might affect the targeted muscles excitation. Compared to other competitive athletes, bodybuilders focus on muscle excitation and metabolic stimuli through adequate exercises involving the prime movers (Hackett, Johnson, & Chow, 2013). Thus, they have a unique sensitivity to the muscle excitation (Maeo, Takahashi, Takai, & Kanehisa, 2013), so that they might be a reference population to investigate how each exercise stimulates its targeted muscles.

The free-weight BP variations involve practitioners in a 3-plane stabilization process to lift the bar vertically. Hence, to ensure an effective BP trajectory, a fine motor cooperation between the prime movers and stabilizers is required (Schick et al., 2010). Notwithstanding, practitioners could use guided chest press (e.g. Smith Machine) or chest press machines (CP), designed to mimic the BP movements with a straight trajectory without the 3-plane stabilization (McCaw & Friday, 1994). It was shown that the excitation of the stabilizer muscles (i.e., *lateral deltoid*) was higher in BP than guided chest press with moderate but not high loads (McCaw & Friday, 1994). Similarly, another study did not find any difference in the overall excitation of *pectoralis major* and *anterior deltoid* in BP vs chest press performed on a Smith machine, but greater *lateral deltoid* excitation (Schick et al., 2010). Thus, it seems that CP might effectively replace the free-weight BP prime movers excitation.

Traditional resistance training protocols are performed as a sequence of concentric-eccentric duty cycles. However, the unique mechanical (Herzog, Powers, Johnston, & Duvall, 2015) and neuromuscular (Duchateau & Enoka, 2016) characteristics of eccentric vs concentric phase suggest that the muscle excitation should be measured in both phases. Indeed, the muscular excitation during the eccentric vs concentric phase is lower when matched for the external resistance (Duchateau & Enoka, 2016; Herzog et al., 2015), thus a detailed description of the muscle work could be helpful to organize the resistance training protocol. To the best of the authors' knowledge, no study has investigated the muscle excitation during both concentric and eccentric phases in BP and its variations and CP in competitive body builders. Therefore, the aim of the present study was to compare the muscle excitation in the clavicular and sternocostal head of *pectoralis major*, *anterior* and *lateral deltoid* and *triceps brachii* during both concentric and eccentric phases in BP, IBP, DBP and CP performed by competitive bodybuilders.

METHODS

Experimental approach to the research question

The present investigation was designed as a cross sectional study. The whole procedure took a total of eight sessions. In the first session, participants familiarized with the maximum voluntary isometric excitation protocol, and the maximum excitation was recorded to each muscle. To reliability purposes, in the second session, the maximum voluntary isometric excitation of each muscle was recorded again. From session three to seven, the 1-repetition maximum (1-RM) of each exercise was measured separately in a randomized order. Each session was interspersed by at least two days. In the eighth session, muscle excitation during the five exercises was randomly recorded, separated by at least 30 min of passive recovery. The maximum voluntary isometric excitation was not recorded within the eighth session to avoid any possible effect of fatigue. The participants avoided any further form of strenuous physical involving upper-body muscles for the entire duration of the study.

Participants

The present procedures were advertised by the operators during some regional and national competitions and, to be included in the study, the participants had to compete in regional competitions for a minimum of at least 5 years. Additionally, they had to be clinically healthy, without any reported history of upper-limb and trunk muscle injury, neurological or cardiovascular disease in the previous 12 months. To avoid possible confounding factors, the participants competed in the same weight category (Men's Classic Body-Building <80 kg, <1.70 m) according to the International Federation of Body Building Pro-League. Thereafter, 10 male competitive body-builders (age 29.8±3.0 yrs; body mass 77.9±1.0 kg; stature 1.68±0.01 m; training seniority 10.6±1.8 yrs) were recruited for the present investigation. The participants were asked to abstain from alcohol, caffeine or similar beverages in the 24 h preceding the test. After a full explanation of the aims of the study and the experimental procedures, the participants signed a written informed consent. They were also free to withdraw at any time. The procedures were approved by the local University Ethical Committee and performed in accordance with the Declaration of Helsinki (1975) for studies involving human subjects.

Maximal voluntary isometric excitation

The maximal voluntary isometric excitation of *pectoralis major, anterior* and *lateral deltoid and triceps brachii* was recorded according to previous procedures and performed in a random order (Lauver et al., 2016). The participants lay supine on a horizontal bench with their hips secured by a strap to reduce any involuntary movement. They were asked to exert their maximal force against manual resistance. Each attempt lasted 5 s. Three attempts were completed for each movement interspersed by 3 min of passive recovery. The operators provided strong standardized verbal encouragements. For the clavicular and sternocostal heads of *pectoralis major*, the participants were instructed to horizontally abduct the arm with the shoulder and elbow flexed at 90°. Then, they provided maximal force while attempting to horizontally adduct the arm (Chopp, Fischer, & Dickerson, 2010). For the *anterior deltoid,* the participants were instructed to flex the elbow to 90° so that the hand was pointed upwards. Then, they were asked to make a closed fist with the hand of the flexed arm and provide maximal force to produce shoulder flexion against manual resistance (Chopp et al., 2010). For the *lateral deltoid*, the participants were instructed to flex the elbow to 90° and were asked to maximally abduct the flexed arm. For the *triceps brachii,* the participants were instructed to flex the elbow to 90°. Then, they provided maximal force attempting to extend the elbow against a manual resistance (Lauver et al., 2016).

1-RM and exercise protocol

The 1-RM was tested on the same equipment used for the surface electromyography (sEMG) recording and referred to previous procedures (Coratella & Schena, 2016). The testing protocol started with a standardized warm-up, consisting of 2 sets × 15 repetitions with a load equal to 70% of the participants' body mass. Then, based on the acknowledged participants' training experience, 2 sets with 80% (≈ 8 repetitions) and 2 sets with 90% (≈ 4 repetitions) of their self-reported 1-RM were performed. Afterwards, an additional load of 2.5 kg was added until the participants failed to successfully perform the 1-RM. Two minutes of passive recovery separated each trial. Each participant received standardized encouragements by the operators.

BP, IBP and DBP were performed on three specific benches (Flat, Inclined and Declined Bench Press, Technogym, Cesena, Italy). Specifically, the inclination angle for IBP was 45° and -15° for DBP above and below the horizontal plane (Lauver et al., 2016). To ensure a consistent exercise technique, the participants were instructed to exercise using the same relative bar (Vulcan Standard 20 kg, Vulcan Strength Training System, Charlotte, NC, USA) handgrips distance. Therefore, hands were placed on the bar at a distance that facilitated approximately a 90°-angle between arms and forearms when the bar was on the chest, approximately one-half length of sternum (Coratella & Schena, 2016). CP was performed on a selectorized seated unit (Chest Press, Technogym, Cesena, Italy). Since the maximum selectorized load was 100kg, further load was added when needed by using dumbbells on the selectorized plate.

During the sEMG recording, each exercise was performed following the same technique described for the 1-RM procedures. The participants performed 4 non-exhaustive repetitions with the 80%1-RM (Barnett, Kippers, & Turner, 1995; McCaw & Friday, 1994), a common training load among resistance trained-men that combines a large muscle recruitment with an appropriate technique (Statsny et al., 2017). Following previous procedures (Barnett et al., 1995; Lauver et al., 2016; Trebs, Brandeburg, & Pitney, 2010) each exercise was executed with a time under tension of 2 s for both the concentric and eccentric phase. Such a time under tension was reviewed as mostly used in this type of studies, thus easier to be compared with (Statsny et al., 2017). A metronome was used to pace the intended duty cycle.

sEMG recording

The sEMG signal was detected during the protocols of maximal voluntary isometric excitation and during the concentric and eccentric phases of each exercise from the clavicular and sternocostal head of *pectoralis major, anterior* and *lateral deltoid* and the long head of *triceps brachii.* The skin area under the sEMG electrodes was shaved, cleaned with ethyl alcohol, abraded gently with fine sand paper and prepared with a conductive cream (Nuprep®, Weaver and Co., Aurora, USA) to achieve an inter-electrode impedance below 2000 Ω. sEMG signal was detected by two Ag/AgCl rounded electrodes with solid hydrogel (mod H124SG Kendall ARBO; diameter: 10 mm; inter-electrodes distance: 20 mm; Kendall, Donau, Germany). Following the European Recommendations for Surface Electromyography (Hermens et al., 1999), the electrodes were placed along the direction of the muscle fibres, between the tendon and the motor point. Particular care to the electrodes placement was given, since it was recently shown that the innervation zone of the *pectoralis major* shifts as a function of shoulder position in the bench press (Mancebo, Cabral, de Souza, de Oliveira, & Vieira, 2019). For example, if the electrode shifted over the innervation zone during part of the movement, the muscle excitation is underestimated. Therefore, to overcome such a possible bias, a Fast-Fourier Transform approach was used, as suggested in a previous investigation (Merlo & Campanini, 2010). Briefly, the electrode placement on each muscle was checked during the warm up phase of each exercise analyzing the power spectrum profile of the EMG signal recorded. The correct electrode placement results in a typical belly-shaped power spectrum profile of the EMG signal, while noise, motion artifacts, power line, electrodes placed on the innervation zone or myotendinous junction generate a different power spectrum profile (Merlo & Campanini, 2010). The same experienced operator placed the electrodes and checked the power-spectrum profile. At the end of the first session, the electrode placement was marked on a transparent sheet, together with some skin landmarks (e.g. moles, scars, angiomas) for reliability purposes, following previous procedures (Bisconti et al., 2019).

The sEMG electrodes for *pectoralis major* were placed on the midclavicular line, midway between the acromioclavicular joint of the shoulder for the clavicular head (Trebs et al., 2010). For the sternocostal head, the electrodes were placed on the sternoclavicular joint of the sternum, over the second and fifth intercostals spaces (Trebs et al., 2010). The sEMG electrode for the *anterior deltoid* was placed over the mid-belly of the muscle approximately 4 cm below the clavicle (Lauver et al., 2016). The *lateral deltoid* had 2 electrodes placed on the lateral aspect of the deltoid, 3 cm below the acromion process (Schick et al., 2010). The sEMG electrode for the long head of *triceps brachii* was placed over the mid-belly of the long head midway between the acromion process of the scapula and the olecranon process of the ulna (Saeterbakken & Fimland, 2013). A ground electrode was placed on the seventh cervical spinous process.

The electrodes were equipped with a probe (probe mass: 8.5 g, BTS Inc., Milano, Italy) that permitted the detection and the transfer of the sEMG signal by wireless modality. sEMG signal was acquired at 1000 Hz, amplified (gain: 2000, impedance and the common rejection mode ratio of the equipment are $>10^{15}$ Ω//0.2 pF and 60/10 Hz 92 dB, respectively) and driven to a wireless electromyographic system (FREEEMG 300, BTS Inc., Milano, Italy) that digitized (1000 Hz) and filtered (band-pass 10–500 Hz) the raw sEMG signals.

Data analysis

The sEMG signals from both the maximal voluntary isometric excitation and from the concentric and eccentric phases of each exercise were analyzed in time-domain. Additionally, a 25-ms mobile window was used for the computation of the root mean square (RMS). For the maximal voluntary isometric excitation, the average of the RMS corresponding to the central 2 s was considered. During each exercise, the RMS was calculated and averaged over the 2 s of the concentric and eccentric phase. Thereafter, the sEMG RMS during each exercise was normalized for maximal voluntary isometric excitation for each muscle (Staudenmann, Roeleveld, Stegeman, & van Dieen, 2010) and inserted into the data analysis.

Statistical analysis

The statistical analysis was performed using a statistical software (SPSS 22.0, IBM, Armonk, USA). The normality of data was checked using the Kolmogorov-Smirnov test and all distributions were normal. Descriptive statistics are reported as mean(SD). The EMG RMS reliability was measured using an intra-class coefficient (Cronbach-α) and the standard error of the measurement expressed as percentage variability (SEM%) for each muscle maximum voluntary isometric excitation. The differences in 1-RM were calculated using a one-way ANOVA. The differences in the relative EMG RMS were separately calculated for each muscle between the exercises (4 levels: BP, IBP, DBP and CP) and phases (2 levels: concentric and eccentric) using a two-way repeated-measures ANOVA. When an interaction was found, a post-hoc analysis was performed using the Bonferroni's correction. Significance was set at $p<0.05$. The differences are reported as mean with 95% of confidence interval (95%CI). Cohen's *d* effect size (ES) with 95% confidence interval (CI) was reported and interpreted according to the Hopkins' recommendations: 0.00-0.19: *trivial*; 0.20-0.59: *small*: 0.60-1.19: *moderate*; 1.20-1.99: *large*; ≥2.00: *very large* (Hopkins, Marshall, Batterham, & Hanin, 2009).

RESULTS

The 1-RM measured in BP, IBP, DBP and CP were 120.2(11.4) kg, 113.5(9.5) kg, 117.8(12.3) kg and 123.7(13.4) kg respectively. No difference ($p>0.05$) neither in 1-RM, nor in 1-RM/body mass was found between the exercises.

The inter-session EMG RMS ICC ranged from $\alpha=0.918$ to $\alpha=0.992$ for all muscles. The SEM% ranged from 1.42% to 4.74%.

The normalized EMG RMS recorded in the clavicular head of *pectoralis major* was 83.7±1.5%, 94.3±5.2%, 75.0±3.3% and 60.8±3.2% during the concentric phase and 62.2±3.2%, 31.1±3.4%, 21.7±5.6% and 33.3±2.1% during the eccentric phase in BP, IBP, DBP and CP respectively. Exercise x phase interaction ($p=0.001$) was observed and main effect was found for factor exercise ($p<0.001$) and the post-hoc analysis is shown in Table-1.

Table-1 here

The normalized EMG RMS recorded in the sternal head of *pectoralis major* was 80.5±2.5%, 61.1±1.1%, 88.8±7.0% and 76.1±2.6% during the concentric phase and 35.7±2.8%, 27.3±4.6%, 46.3±4.1% and 33.4±2.8% during the eccentric phase in BP, IBP, DBP and CP respectively. Exercise x phase interaction (p=0.012) was observed and main effect was found for factor exercise (p<0.001) and the post-hoc analysis is shown in Table-2.

Table-2 here

The normalized EMG RMS recorded in *triceps brachii* was 92.5±3.0%, 80.8±7.7%, 94.5±3.5% and 66.1±4.8% during the concentric phase and 55.7±6.0%, 24.1±3.3%, 33.3±2.8% and 36.4±3.0% during the eccentric phase in BP, IBP, DBP and CP respectively. Exercise x phase interaction (p<0.001) was observed and main effect was found factor exercise (p=0.003) and the post-hoc analysis is shown in Table-3.

Table-3 here

The normalized EMG RMS recorded in *anterior deltoid* was 63.2±1.4%, 65.2±2.3%, 24.1±4.2% and 70.0±8.2% during the concentric phase and 25.1±2.0%, 21.8±2.7%, 14.2±3.5% and 22.8±3.5% during the eccentric phase in BP, IBP, DBP and CP respectively. Exercise x phase interaction (p<0.001) was observed and main effect was found for factor exercise (p<0.001) and the post-hoc analysis is shown in Table-4.

Table-4 here

The normalized EMG RMS recorded in *lateral deltoid* was 12.4±2.5%, 19.7±5.3%, 10.7±2.6% and 6.1±2.1% during the concentric phase and 11.3±2.5%, 9.2±3.6%, 8.4±2.2% and 4.1±2.2% during the eccentric phase in BP, IBP, DBP and CP respectively. No exercise x phase interaction (p=0.126) was observed and main effect was also found for factor exercise (p=0.002). Post-hoc analysis revealed that, during the concentric and eccentric phase respectively, BP [mean difference(95CI%): 5.6%(2.8/8.2), ES(95%CI); 2.26(0.91/3.37) and 7.2%(3.0/11.5), 1.04(0.26/2.22)], IBP [12.8%(4.6/21.0), 3.11(1.53/4.35) and 5.1%(0.4/9.9), 1.15(0.05/2.25)] and DBP [5.61%(1.1/10.2), 1.56(0.37/2.58) and 4.3%(0.9/7.6), 2.41(1.02/3.54)] had greater muscle excitation than CP.

DISCUSSION

The present findings show that, in competitive bodybuilders, differences in prime movers' excitation occur when varying the bench inclination angle or using a more stable single-plane trajectory. During the concentric phase, clavicular head was more excited in IBP and less excited in CP compared to all other exercises. The sternocostal head was similarly excited in DBP vs BP and BP vs CP and more excited in BP, DBP and CP compared to IBP. *Triceps brachii* excitation was overall greater in BP and DBP compared to all other exercises. *Anterior deltoid* was less excited in DBP compared to all other exercises. *Lateral deltoid* excitation was greater in BP, IBP and DBP compared to CP. Muscle excitation during the eccentric phase followed a similar pattern, with the exception of the greater excitation in the clavicular head in BP compared to all other exercises.

The excitation of the clavicular head of *pectoralis major* seems to change depending on the plane on which the movement is performed. Here, greater excitation was found in IBP (45°) compared to all other exercises. For example, a greater clavicular head excitation was reported with an inclination angle of 44° and 56° vs horizontal BP at 70% 1-RM in recreational resistance-trained men (Trebs et al., 2010). Similarly, greater clavicular head excitation was found when performing 45° and 30° IBP vs horizontal and -15° DBP at 65% 1-RM (Lauver et al., 2016). In contrast, no difference in clavicular head excitation when performing BP vs IBP vs DBP was also shown using 6RM (Saeterbakken et al., 2017). However, in the first instance the inclination angles used in this study were 25° and -25°, which could have led to different muscle recruitment patterns

(Saeterbakken et al., 2017). Additionally, the participants were competitive lifters that might have adjusted their body position on the benches according to their personal lifting technique (Saeterbakken et al., 2017). The stability offered by CP did not result in greater excitation of the clavicular head. The long-term training experience of the present participants might have accounted for a development of an effective free-weight technique (Schick et al., 2010). Interestingly, during the eccentric phase the excitation was greater in BP than IBP, DBP as also reported previously (Lauver et al., 2016) and CP. This allows a specific clavicular head activation, focusing on the concentric or eccentric phase of the BP variations.

The sternocostal head of *pectoralis major* was greater in DBP (-15°) than in all other exercises except BP. Similarly, no difference between DBP and BP was previously found (Lauver et al., 2016; Saeterbakken et al., 2017). Greater excitation of the sternocostal head in DBP vs IBP was already reported using (Lauver et al., 2016). The sternocostal head was also more excited in BP than in IBP, as shown previously using 65% or 70% 1-RM (Lauver et al., 2016; Trebs et al., 2010). However, no difference between DBP, BP and IBP was shown in competitive lifters using 6RM (Saeterbakken et al., 2017). The authors hypothesized that this might be ascribed to the adapted body position that they could have used to maximize their force exertion, together with the different inclination angles (Saeterbakken et al., 2017). Interestingly, no difference was found in BP vs CP, indicating a similar neuromuscular task, as also reported previously (McCaw & Friday, 1994; Saeterbakken, van den Tillaar, & Fimland, 2011; Schick et al., 2010). The sternocostal head excitation followed a similar scheme in the eccentric phase, as already shown (Lauver et al., 2016).

Although *triceps brachii* is an important prime mover in all bench press exercise variations, fewer studies have investigated its excitation, mostly using inconsistent excitation sEMG recording techniques (long, lateral or medial head sEMG), as recently reviewed (Statsny et al., 2017). This might make a comparison with the literature challenging. The overall results here suggest that the *triceps brachii* excitation during the free-weight press variations is greater compared to CP. Particularly, the long head extends both the elbow and the shoulder. This might have resulted in a greater excitation, partially due to the need to stabilize the arm on the sagittal plane. However, no difference in *triceps brachii* excitation was found comparing BP vs guided Smith-machine in non-competitive resistance-trained men (Saeterbakken et al., 2011). Interestingly, unstable surfaces resulted in lower long head *triceps brachii* excitation in non-competitive resistance-trained men (Saeterbakken & Fimland, 2013). Despite this apparent discordance with the literature, bodybuilders have shown a greater ability to increase muscle recruitment (Maeo et al., 2013). Additionally, they might have been more familiar with the free-weight exercises and could have developed a unique strategy to elicit excitation in all targeted muscles (Hackett et al., 2013). In line with a previous study with competitive athletes, BP and DBP showed greater *triceps brachii* sEMG than IBP (Saeterbakken et al., 2017), as also found in resistance trained men with a minimum of 2-years training experience (Barnett et al., 1995). On the contrary, contrasting findings were also found, given the greater *triceps brachii* excitation during IBP vs DBP (Lauver et al., 2016). This might have accounted for the different muscle investigated (lateral head) and the lower participants training experience (Lauver et al., 2016). This again supports the training experience and the selected exercise as factors that modulate the targeted muscles excitation.

Anterior deltoid is a strong *humerus* flexor, thus it plays a greater role when increasing the arm flexion (Lauver et al., 2016). It turns out that, when the arm flexion decreases, lower *anterior deltoid* excitation should be expected. This is what emerged here, since the lower *anterior deltoid* excitation recorded during DBP (-15°) compared to all other exercises, as previously reported using 65% or 70% 1-RM (Lauver et al., 2016; Trebs et al., 2010). Similar *anterior deltoid* excitation between BP and CP (both horizontal movements) vs IBP (45°) was found here. This was reported previously in competitive athletes (Saeterbakken et al., 2017), while greater *anterior deltoid* excitation was found during IBP in less experienced athletes (at least 1 year of generic resistance training) (Lauver et al., 2016; Trebs et al., 2010). Hence, it seems that very experienced athletes might be able to increase the *anterior deltoid* excitation also in horizontal movements. Lastly, the lack of difference in *anterior deltoid* excitation between free-weight vs CP shown here was reported previously both in experienced and in inexperienced resistance trained men (Schick et al., 2010). This lack of difference was shown in heavy vs light loads, as reported in a direct comparison between 60%1-RM vs 80%1-RM (McCaw & Friday, 1994). Thus, both the population and the selected load may have accounted for the similar *anterior deltoid* excitation in BP, IBP and CP.

During the concentric phase, the *lateral deltoid* excitation was greater in BP, IBP and DBP than in CP, during both concentric and eccentric phase. In all BP exercises, *lateral deltoid* acts as stabilizer muscle (McCaw & Friday, 1994; Schick et al., 2010). During BP, IBP and DBP the bar is potentially unstable and the shoulders have to fix the bar over the three planes to allow an effective press (Schick et al., 2010). Interestingly, although during DBP the arms lateral abduction is potentially lower compared to BP and IBP given the trunk-arm angle, this did not result in any difference in *lateral deltoid* excitation. Hence, it seems that the 3-plane vs straight trajectory stabilization plays the major role in the *lateral deltoid* excitation.

Methodological considerations need to be completed to properly interpret the differences in muscle excitation depending on the exercise. During a multi-joint exercise, the excitation of the main targeted muscles is strictly connected to the excitation of the synergistic muscles involved in that exercise. Thus, although each exercise has a series of targeted muscles, several additional muscles act to favour or modulate the joint movements, resulting in a compound neuromuscular pattern (Saeterbakken et al., 2017). Moreover, the muscle excitation depends on factors such as the movement trajectory being performed, joint stiffness and muscle architecture (Lauver et al., 2016). In the current exercises, a "reverse C" shape performed in the free-weight variations is compared to straight trajectory performed in CP. Lastly, here the muscle excitation was investigated while performing the same relative load, i.e, 80%1-RM. Since this relative load could turn into different absolute loads, the force requirement might have been different, and so the muscle excitation. However, the absolute loads recorded here were overall similar, so the present results might be interpreted confidently. Some additional limitations accompany the present procedures. Firstly, the present results referred to the population involved here and should be extended with caution to different populations. For example it was shown that the prime movers' excitation differs between men and women (Gołaś et al., 2018). Additionally, the current restrictive inclusion/exclusion criteria made the sample size difficult to be increased. However, the extents of the between-exercise differences in EMG activity should lead to a not-underpowered study. Secondly, no intermediate inclination angle was used here, and this might have brought further information. Thirdly, the set was not performed to failure, so that muscle excitation could have been different under these circumstances (Gołaś et al., 2017). Fourthly, classical deltoids division was used following the procedures mainly used in the literature (Statsny et al., 2017), although it was shown that deltoids could be divided in seven portions (Sakoma et al., 2011). Fifthly, the present results refer to the relative intensity and time under tension used here, since a manipulation of these independent parameters was reported to turn into different EMG activity (Golas et al., 2018). Lastly, recording EMG RMS in further muscles (e.g. *biceps brachii* and *latissimus dorsi*) could have helped to depict a more detailed neuromuscular pattern.

In conclusion, the present investigation shows that the muscle excitation prime movers during the press exercise variations performed by competitive bodybuilders depends on both the degrees of freedom and the inclination angle. *Pectoralis major* excitation is mostly affected by the inclination angle, with the clavicular and sternocostal heads showing an increasing and decreasing excitation in IBP vs DBP respectively. Similarly, *anterior deltoid* was more excited using inclined angles. Lastly, *triceps brachii* and *lateral deltoid* are mostly recruited when the stability decreases, since they were more excited during the BP vs CP.

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Table-1: The between-exercise differences in normalized EMG RMS of the clavicular head of *pectoralis major* are shown. Data are reported as mean difference (95%CI), calculated as mean difference = column (↓) – row (→). Effect size with 95%CI is also reported for each comparison.

	↓ →	BP	IBP	DPB	CP
Concentric phase	**BP**	---	-10.4%(-18.4/-2.4)* -2.78(-3.97/-1.29)	8.6%(3.2/14.1)* 3.36(1.70/4.64)	22.9%(18.4/27.4)* 9.69(5.84/12.48)
	IBP		---	19.2%(10.3/29.1)* 4.42(2.43/5.93)	33.5%(26.0/40.9)* 7.80(4.64/10.11)
	DBP			---	14.2%(6.5/21.9)* 4.39(2.41/5.89)
	CP				---
Eccentric phase	**BP**	---	31.0%(26.4/35.7)* 9.48(5.71/12.22)	40.5%(32.1/48.9)* 8.92(5.35/11.51)	29.9%(24.0/35.7)* 11.32(6.87/14.54)
	IBP		---	9.2%(1.0/19.1)* 2.03(0.74/3.11)	-1.2%(-7.7/5.3) 0.42(-0.59/1.39)
	DBP			---	-10.6%(-17.3/-4.0)* -2.52(-3.67/-1.10)
	CP				---

BP: Bench press; **IBP**: inclined bench press (45°); **DBP**: declined bench press (-15°); **CP**: chest press;

* = $p < 0.05$

Table-2: The between-exercise differences in normalized EMG RMS of the sternal head of *pectoralis major* are shown. Data are reported as mean difference (95%CI), calculated as mean difference = column (↓) – row (→). Effect size with 95%CI is also reported for each comparison.

	↓ →	BP	IBP	DPB	CP
Con cent	**BP**	---	19.4%(16.7/22.0)* 9.97(6.02/12.84)	6.8%(-1.3/14.9) 0.83(-0.25/1.89)	4.3%(-0.5/9.2) 0.77(-0.21/1.75)

	IBP		---	-27.7%(-37.8/-17.6)* -5.58(-7.35/-3.20)	-15.0%(-18.7/-11.4)* -7.53(-9.77/-4.46)
	DBP			---	12.7%(3.6/21.8)* 2.42(1.03/3.45)
	CP				---
Eccentric phase	**BP**	---	8.4%(2.0/14.8)* 2.23(0.89/3.33)	-10.6%(-18.9/-2.3)* -3.01(-4.24/-1.46)	2.3%(-2.6/7.2) 0.79(-0.27/1.76)
	IBP		---	-19.0%(-31.0/-7.1)* -4.30(-5.78/-2.35)	-6.2%(-11.3/-1.0)* -1.63(-0.42/-2.66)
	DBP			---	12.9%(3.9/21.9)* 3.70(1.94/5.05)
	CP				---

BP: Bench press; **IBP**: inclined bench press (45°); **DBP**: declined bench press (-15°); **CP**: chest press;

* = p < 0.05

Table-3: The between-exercise differences in normalized EMG RMS of *triceps brachii* are shown. Data are reported as mean difference (95%CI), calculated as mean difference = column (↓) – row (→). Effect size with 95%CI is also reported for each comparison.

	↓ →	**BP**	**IBP**	**DPB**	**CP**
Concentric phase	**BP**	---	11.7%(2.6/20.8)* 2.01(0.72/3.08)	-2.0%(-7.5/3.5) -0.61(-1.58/0.42)	26.4%(18.1/34.7)* 6.58(3.85/8.58)
	IBP		---	-13.7%(-25.0/-2.4)* -2.30(-3.41/-0.94)	14.7%(2.4/27.0)* 2.32(0.92/3.45)
	DBP			---	28.4%(18.4/38.4)* 6.75(3.96/8.80)
	CP				---
Eccentric phase	**BP**	---	31.6%(23.1/40.1)* 6.49(3.79/8.47)	22.4%(14.6/30.2)* 4.77(2.67/6.36)	19.3%(7.9/30.7)* 4.10(2.21/5.54)
	IBP		---	-9.2%(-15.2/-3.2)* -3.01(-4.24/-1.46)	-12.3%(-7.8/-16.8)* -3.87(-5.26/-2.06)
	DBP			---	-3.1%(-9.1/2.9) -0.81(-2.78/1.19)
	CP				---

BP: Bench press; **IBP**: inclined bench press (45°); **DBP**: declined bench press (-15°); **CP**: chest press;

* = p < 0.05

Table-4: The between-exercise differences in normalized EMG RMS of *anterior deltoid* are shown. Data are reported as mean difference (95%CI), calculated as mean difference = column (↓) – row (→). Effect size with 95%CI is also reported for each comparison.

	↓ →	BP	IBP	DPB	CP
Concentric phase	**BP**	---	-2.0%(-6.2/2.2) -0.80(-2.13/0.33)	39.1%(33.4/44.8)* 14.09(8.60/18.03)	-6.9%(-19.1/5.3) -0.66(-1.87/0.59)
	IBP		---	41.1%(34.3/47.9)* 12.64(7.70/16.21)	-4.9%(-15.0/5.3) -0.81(-1.78/0.25)
	DBP			---	-45.9%(-56.9/-34.9)* -7.53(-9.78/-4.47)
	CP				---
Eccentric phase	**BP**	---	3.2%(-0.6/7.1) 0.89(-0.24/2.02)	10.8%(6.1/15.6)* 3.81(2.02/5.19)	2.2%(-3.6/8.0) 0.85(-0.21/1.83)
	IBP		---	7.6%(0.5/14.7)* 2.46(1.05/3.59)	-1.1%(-6.6/4.5) -0.37(-1.33/0.64)
	DBP			---	-8.6%(-17.8/-0.5)* -2.60(-3.60/-1.16)
	CP				---

BP: Bench press; **IBP**: inclined bench press (45°); **DBP**: declined bench press (-15°); **CP**: chest press;

* = $p < 0.05$