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Influence of different attentional focus on EMG amplitude and contraction duration during the bench press at different speeds

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ABSTRACT
The purpose of this study was to investigate whether using different focus affects electromyographic (EMG) amplitude and contraction duration during bench press performed at explosive and controlled speeds. Eighteen young male individuals were familiarized with the procedure and performed the one-maximum repetition (1RM) test in the first session. In the second session, participants performed the bench press exercise at 50% of the 1RM with 3 different attentional focuses (regular focus on moving the load vs contracting the pectoralis vs contracting the triceps) at 2 speed conditions (controlled vs maximal speed). During the controlled speed condition, focusing on using either the pectoralis or the triceps muscles increased pectoralis normalized EMG (nEMG) by 6% (95% CI 3–8%; $p = 0.0001$) and 4% nEMG (95% CI 1–7%; $p = 0.0096$), respectively, compared with the regular focus condition. Triceps activity was increased by 4% nEMG (95% CI 0–7%; $p = 0.0308$) at the controlled speed condition during the triceps focus. During the explosive speed condition, the use of different focuses had no effect. The different attentional focus resulted in comparable contraction duration for the measured muscles when the exercise was performed explosively. Using internal focus to increase EMG amplitude seems to function only during conditions of controlled speed.

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Instruction; power; strength; EMG; internal focus

Introduction

Explosive muscle strength is a relevant performance measure in sport practice (Andersen & Aagaard, 2006; McMaster, Gill, Cronin, & McGuigan, 2014). A variable that can modify the performance of a movement, consequently making it more explosive, is the use of verbal instructions. Instructions can externally focus the attention on the effect of the action, i.e. the length of the long jump, or internally focus the attention on the action or movement, i.e. how the movement is executed (Greig & Marchant, 2014). Different studies have reported reduced force production and explosive performance during vertical jump (Wulf & Dufek, 2009; Wulf, Dufek, Lozano, & Pettigrew, 2010) and standing long jump (Porter, Ostrowski, Nolan, & Wu, 2010) when participants were internally focused compared with externally focused. Plausible explanations as to why external focus yields greater results include a reduced conscious control of movement inducing less "noise" in the motor system (Zachry, Wulf, Mercer, & Bezodis, 2005) and greater coherence between sensory input and motor output (McNevin & Wulf, 2002). However, utilizing an external focus does not always result in enhanced force production. Greig and Marchant (2014) demonstrated that electromyography (EMG) amplitude was enhanced with internal focus during high velocity (180° and 300°s^{-1}) isokinetic elbow flexions, yet the authors only found differences in force production in favor of the external focus at the slowest speed condition (60°s^{-1}), in spite of lower EMG amplitude. These results indicate that the effect of using a certain attentional focus is dependent on movement velocity and thus more research is needed to understand this relationship. In addition, the use of different exercises such as multi-joint vs single joint or machine-based vs. free weights may be the cause of these contrasting results. In this sense, free weight training can be especially relevant since these exercises produce greater transference and performance to functional activities and sports movements than guided machines, which are limited for more complex and multi-joint movements (Stone, Plisk, & Collins, 2002) with accelerations and decelerations (Kawamori & Newton, 2006). To our knowledge, there are no studies using different attentional focus during a typical free-weight exercise for the upper-body, as for example the bench press, when performed at different speeds. The bench press exercise has been widely used to assess and improve upper-body strength and power (McMaster et al., 2014). In fact, greater bench press performance is associated with better athletic skills (Miyaguchi & Demura, 2012). We have recently shown that internal focus – using the so-called mind-muscle training principle – can enhance EMG amplitude at intensities from 20 to 60% of one-repetition maximum (1RM) during bench press at controlled speeds (Calatayud et al., 2016; Snyder & Fry, 2012). This has relevance when focusing on building larger muscle mass, which can be desired for bodybuilders as well as a range of athletes in sports where muscle mass is crucial. By contrast, athletes in explosive type of sports prefer to perform strength training in an explosive type of manner. Whether these two types

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of training can be combined, i.e. having an internal focus to increase the level of muscle activity and at the same time performing the strength training in an explosive manner, remains unknown. Thus, to provide guidance for athletes, we aimed to investigate how attentional focus affects EMG amplitude and contraction duration when participants are asked to perform this exercise at maximal intentional speed and controlled speed. We hypothesized that the use of an internal focus would not have an effect on EMG amplitude and contraction duration during explosive speeds.

Methods

Participants

A total of 18 young male volunteers participated in the study (Table 1). Participants' training status was considered to be advanced according to the National Strength and Conditioning Association (NSCA) classification, as they reported a minimum of 1 year of resistance training experience, performing at least 3 sessions per week at moderate-to-high intensity (Baechle & Earle, 2008). In addition, they were familiarized with the bench press exercise, but not engaged in explosive-type resistance training. Exclusion criteria were blood pressure above 160/100mmHg, disc prolapse, or serious chronic disease. All participants were informed about the purpose and content of the study and gave their written informed consent to participate. The study conformed to The Declaration of Helsinki and was approved by the Local Ethical Committee (H-3–2010-062).

Experimental procedures

Each participant took part in one familiarization session with a 1RM bench press determination and one experimental session. A minimum of 2 days separated the sessions. Participants received instructions to avoid physical activity that was more intense than normal daily activities 24 h before the sessions. To control the influence of external factors possibly affecting bench press performance, no music was allowed and all measurements were made by the same two investigators and were conducted in the same facility. Only the two investigators and the particular participant were at the facility at the same time during the measurements. The data collection was performed during April–May 2014. Data reported in the present study forms part of a research project investigating the effects of using different instructions during resistance training. Previous load-response data from this project has already been published (Calatayud et al., 2016).

Table 1. Demographics and resistance training variables (n = 18, all men).

	Mean (SD)
Age (years)	31 (8)
Height (cm)	179 (8)
Body weight (kg)	82 (10)
Body fat percentage	15 (5)
BMI ($kg{\cdot}m^{-2}$)	26 (3)
Resistance training experience (years)	8 (6)
1 RM Bench Press (kg)	103 (25)
150% biacromial distance (cm)	66.3 (3.2)

1RM determination and familiarization

Initially, height (Seca model 217, Hamburg, Germany), body mass, body fat percentages (Tanita model MC-180MA, Tokyo, Japan) and biacromial width were obtained. Before the 1RM determination, the participants performed mobility drills without ballistic movements as warm up (i.e., forward and backward arm circles and 3 push-ups). The 1RM test was performed with the same technique and body position that would later be used during data collection. The measurement of the 1RM for the bench press was performed according to an established protocol (Baechle & Earle, 2008). Assessment of 1RM enabled calculation of the precise training load used in the bench press during the following experimental session (50% of 1RM). After the 1RM determination, the participants were familiarized with the different conditions, exercise technique and velocity of movement that would later be used during data collection (see below). Participants practiced the exercise at 50% of 1RM, at least 3 times for each condition, until the participant felt confident and the researchers were satisfied that the correct technique had been achieved.

Experimental session

The protocol started with the preparation of participants' skin, followed by electrode placement and exercise performance. Hair was removed with a razor from the skin overlying the muscles of interest, and the skin was then cleaned by rubbing with cotton wool dipped in scrubbing gel (Acqua gel, Meditec, Parma, Italy) to reduce impedance (Vinstrup et al., 2015). Afterwards, electrodes were placed according to recommendations of Criswell and Cram (Criswell & Cram, 2011) on the following muscles: the lateral head of the triceps, long head of the triceps, clavicular portion of the pectoralis major and sternocostal portion of the pectoralis major. Additional electrodes were placed two cm apart from the sternum in the clavicular portion of the pectoralis major and two cm apart from the sternum the sternocostal portion of the pectoralis major. In addition, electrodes were placed on the muscle belly of the medial triceps brachii portion. Pre-gelled bipolar silver/silver chloride surface electrodes (Blue Sensor M-00-S, Medicotest, Olstykke, Denmark) were placed with an interelectrode distance of 2 cm. The reference electrode was placed approximately 10 cm away from each muscle, according to the manufacturer's specifications. Once the electrodes were placed, participants performed one standard push-up on the floor in order to check signal saturation and quality. All signals were acquired at a sampling frequency of 1500 Hz, amplified and converted from analog to digital. All records of myoelectrical activity (in microvolts) were stored on a hard drive for later analysis.

The participants started all the bench press trials in an extended arm position with radioulnar pronation and feet at biacromial (shoulder) width. In the flexed position, the forearm and wrists were kept pronated, whereas the elbow was flexed until the bar touched the chest with the shoulder abducted approximately 45º. The hips and spine were maintained neutral during all repetitions. Elbow joint angle was continuously measured using an electronic inclinometer (2D DTS inclination sensor, Noraxon, Arizona, USA) placed at the lateral side of the humerus. It was assumed that the forearm maintained a perfectly vertical orientation for the entire duration of the lift. The inclinometer data was synchronously sampled with the EMG data, using a 16-channel 16-bit PC-interface receiver (TeleMyo DTS Telemetry, Noraxon, Arizona, USA). The dimension of the probes was 3.4 cm x 2.4 cm x 3.5 cm. During subsequent analysis, the inclinometer signals were digitally lowpass filtered using a 4th order zero-lag Butterworth filter (3 Hz cutoff frequency). The concentric and eccentric phases were defined as periods with negative or positive angular velocity, respectively, (going from 90º-0º or 0º-90º, respectively).

Participants performed 2 speed conditions, randomly assigned, during the bench press at 50% of the 1RM: 1) controlled speed, were participants were instructed to maintain a 2-second rate for descent and 2-second rate for ascent (with the speed of movement monitored, providing verbal feedback if any variance was noted) and 2) explosive speed, were participants were instructed to push the barbell as fast as they could during the concentric phase, and then return to the bottom position at a 2-second rate. Full range of motion was required and countermovement was not allowed during the transition from the eccentric-concentric phase.

Furthermore, participants performed 3 different conditions in a randomized order at the 2 aforementioned speeds: regular focus and focus on selectively using the pectoralis major and triceps brachii, respectively (internal focuses). In the regular focus condition the instruction was as follows: "during this set, lift the barbell in a regular way". The pectoralis major instruction was as follows: "during this set, try to focus on using your chest muscles only". The triceps brachii instruction was as follows: "during this set, try to focus on using your triceps muscles only". Before starting the first condition, the researcher identified the location of the muscles by palpating the participant to avoid misunderstandings. Each participant performed only 3 consecutive repetitions (with no pause between them) in all conditions to avoid the influence of fatigue on subsequent measurements. A 1-min rest interval was given between conditions. Using tape as a marker on the barbell, standardized grip widths of biacromial width distance +50% (distance in centimeters between the tips of right and left third digits) was maintained during all conditions. A trial was discarded and repeated if participants were unable to perform the exercise with the correct technique or if a participant stated that he had forgotten the instruction.

Data analysis

The wireless probes pre-amplified the signal (gain: 400). The sampling rate was set to 1500 Hz with a bandwidth of 10 to 500 Hz and a common mode rejection ratio better than 100 dB. During later analysis all raw EMG signals obtained during the exercises were digitally filtered, consisting of 1) high-pass filtering at 10 Hz, and 2) a moving root-mean-square (RMS) filter of 500 ms. For each individual muscle, peak RMS EMG of the 3 repetitions performed at each level was determined, and the average value of these 3 repetitions was then normalized to the maximal RMS EMG obtained during the experimental session (maximal maximorum EMG of each muscle) (Calatayud et al., 2016; Vinstrup et al., 2016). Normalized values for each muscle were averaged for the 4 different portions of the pectoralis muscle (pectoralis) and the 3 different portions of the triceps brachii muscle (triceps). Contraction duration for each individual muscle was identified from the point of eccentric-concentric transition to the point where the EMG amplitude was lower than 5% of the muscle activity range ((max-min)*0.05) within the concentric phase.

Statistical analyses

A linear mixed model (Proc Mixed, SAS version 9.4, SAS Institute, Cary, NC) was used to determine if differences existed between instruction (regular focus, pectoralis focus, triceps focus) and speeds (controlled, explosive) for the pectoralis and triceps muscles separately. Normalized EMG (nEMG) was the dependent variable. Participant was entered in the model as a random factor. Values are reported as least square means (95% CI) and differences of least square means between conditions (95% CI) unless otherwise stated. P-values <0.05 were considered statistically significant.

Results

Table 2 shows the normalized EMG values of the pectoralis and triceps muscles, respectively, during the 3attentional focus conditions at the different speeds. During the controlled speed condition, focusing on using either the pectoralis or the triceps muscles increased pectoralis activity by 6% nEMG (95% CI 3–8; p = 0.0001) and 4% nEMG (95% CI 1–7; p = 0.0096) respectively, compared with the regular focus condition. Triceps activity was increased by 4% nEMG (0–7; p = 0.0308) at the controlled speed condition during the triceps focus compared with the regular focus condition. During the explosive speed condition, EMG values were greater than during the controlled speed condition, but the use of the different focuses had no effect.

The results showed that the different attentional focuses resulted in comparable contraction duration for the pectoralis and triceps when the exercise was performed explosively. Table 3 shows complete contraction duration (ms) for the different conditions.

Discussion

The main findings of the present study were that the use of different attentional focuses during contractions performed with explosive speed resulted in comparable EMG values and contraction duration.

Table 2. Normalized EMG values of the pectoralis and triceps muscles respectively, during the 3 attentional focus conditions at the different speeds.

Muscle	Speed	Regular focus	Focus pectoralis	Focus triceps	Δ Focus pectoralis − Regular	P	Δ Focus triceps − Regular	P
Pectoralis EMG	Controlled	52 (48–55)	57 (53–61)	55 (52–59)	6 (3–8)	0.0001	4 (1–7)	0.0096
	Explosive	61 (57–65)*	63 (59–67)*	62 (59–66)*	2 (0–5)	0.1012	2 (−1–4)	0.2724
Triceps EMG	Controlled	55 (51–59)	54 (50–58)	59 (55–63)	−1 (−4–3)	0.6031	4 (0–7)	0.0308
	Explosive	69 (65–73)*	66 (62–70)*	69 (65–73)*	−3 (−6–1)	0.1039	0 (−3–4)	0.859

*Denotes greater muscle activity during the explosive speed than during the controlled speed.

Table 3. Contraction time (ms) during the concentric phase of the explosive speed at the different conditions.

Muscle	Regular focus	Focus pectoralis	Focus triceps	Δ Focus pectoralis – Regular	P	Δ Focus triceps – Regular	P
Pectoralis	1263 (1098–1427)	1167 (1002–1331)	1229 (1065–1394)	−96 (−203–10)	0.0762	−34 (−140–73)	0.5339
Triceps	1282 (1112–1451)	1175 (1006–1345)	1234 (1065–1404)	−107 (−230–17)	0.0903	−48 (−171–76)	0.449

In agreement with previous research from our group and others (Calatayud et al., 2016; Snyder & Fry, 2012), EMG amplitude was increased by using an internal focus when the speed was controlled. Specifically, we found that an internal focus on using the pectoralis and the triceps muscles, respectively, increased pectoralis activity compared with the regular focus condition performed at controlled speed. In the same vein, an internal focus on triceps resulted in greater triceps EMG amplitude compared with the regular focus condition at controlled speed. Some authors have proposed that an internal focus enhances conscious control of the movement, inducing "noise" in the motor system (Zachry et al., 2005) and reducing the coherence between sensory input and motor output (McNevin & Wulf, 2002). In the present study, increased EMG amplitude was found when explosive speeds were used compared with controlled speeds, regardless of the attentional focus. In line with this, Sakamoto & Sinclair (2012) found that faster speeds during the bench press exercise increased average EMG amplitude throughout the entire concentric phase compared with slower speeds. Compared with slower speeds, explosive contractions have demonstrated higher discharge rate at the onset of the muscle action (Van Cutsem & Duchateau, 2005) and lower recruitment thresholds (Desmedt & Godaux, 1977).

In regards to using different attentional focuses during the explosive speed conditions, we found no differences in EMG amplitude. Greig and Marchant (2014) showed that only the slowest speed (60°s^{-1}) was affected by an attentional focus, increasing force production during externally focused isokinetic elbow flexions, while no changes were noted at faster speeds (180° and 300°s^{-1}). The authors suggested that movements of <1 second are not affected by an external focus because they are mostly executed using automatic processes and less affected by conscious control. Partly similar, we found that during contraction duration of <1.3 seconds, the use of different attentional focuses did not influence EMG amplitude. Interestingly, we found that during explosive speed contractions, not only EMG amplitude but also contraction duration was comparable in spite of the different attentional focuses. Overall our results suggest that internal focus – the so-called mind-muscle principle – does not function according to its purpose during explosive movements. However, Greig and Marchant (2014) did not find a similar relation in terms of EMG amplitude. Indeed, they found greater EMG amplitude regardless of the speed when the participants were internally focused. The different results could be explained by the use of participants with different training experience (<3 years vs. 8 years) and especially due to using different exercises (single-joint vs. multi-joint) and resistance training modes (isokinetic vs. free-weight resistance). For instance, multi-joint exercises are more complex movements than single-joint machine-based exercises (Stone et al., 2002). Furthermore, isokinetic training allows maximal force production at various velocities, while free-weights are affected by the inertial properties of the load and mechanical advantages/disadvantages at specific joint angles (Frost, Cronin, & Newton, 2010). As a consequence, participants may not maximally activate the primary movers throughout the entire range of motion during free-weight exercises (Foran, 1985).

The explosive condition in our study consisted of asking the participants to push the barbell as fast as they could during the concentric phase, which may have acted as an external-type focus. It seems that participants subconsciously had to prioritize between lifting as fast as they could or focusing on a muscle. The ability to produce force in the very early time interval (<40 ms from the onset of contraction) primarily depends on the intrinsic contractile properties of the muscle as well as a high rate of EMG rise whereas longer durations are mostly explained by maximal muscle strength (Andersen & Aagaard, 2006; Folland, Buckthorpe, & Hannah, 2014). As less-voluntary neural mechanisms are present at the early phase of a rapid force contraction (Andersen & Aagaard, 2006; Folland et al., 2014), it may be difficult to influence EMG amplitude at this phase by using an internal focus. Additional difficulty focusing on a muscle could also occur at the end of the concentric action, since a fall in EMG amplitude has been reported in this phase when the bench press is performed at explosive speeds compared to slower speeds (Sakamoto & Sinclair, 2012), likely due to force reductions as velocity increases (Komi, 2000). These findings highlight that interference exists between explosive speeds and conscious control. Moreover, a cognitive limitation for multitasking must also be considered, since the ability to perform different tasks rapidly and accurately is reduced when these are performed simultaneously due to central interferences (Dux et al., 2009).

The present results may not be generalized to other exercises (e.g., single-joint), resistance training modes (e.g., isokinetic machines) or a different cohort of participants. Studies are needed to understand the benefits of using different attentional focus during explosive actions. However, this study provides novel results about the use of different attentional focuses during explosive upper-body multi-joint resistance training.

In conclusion, internal focus neither impacts EMG nor muscle contraction duration when the bench press exercise is performed at maximal speed. When the exercise is performed at controlled speeds, an internal focus enhances activity at the respective muscle. Based on these findings, the use of an internal focus or a regular focus is not relevant as long as maximal intended speeds are performed during the bench press.

Geolocation information

Copenhagen (Denmark).

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Disclosure statement

No potential conflict of interest was reported by the authors.

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