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ORIGINAL ARTICLE

Importance of mind-muscle connection during progressive resistance training

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Abstract
Purpose This study evaluates whether focusing on using specific muscles during bench press can selectively activate these muscles.
Methods Altogether 18 resistance-trained men participated. Subjects were familiarized with the procedure and performed one-maximum repetition (1RM) test during the first session. In the second session, 3 different bench press conditions were performed with intensities of 20, 40, 50, 60 and 80 % of the pre-determined 1RM: regular bench press, and bench press focusing on selectively using the pectoralis major and triceps brachii, respectively. Surface electromyography (EMG) signals were recorded for the triceps brachii and pectoralis major muscles. Subsequently, peak EMG of the filtered signals were normalized to maximum maximorum EMG of each muscle.
Results In both muscles, focusing on using the respective muscles increased muscle activity at relative loads between 20 and 60 %, but not at 80 % of 1RM. Overall, a threshold between 60 and 80 % rather than a linear decrease in selective activation with increasing intensity appeared to exist. The increased activity did not occur at the expense of decreased activity of the other muscle, e.g. when focusing on activating the triceps muscle the activity of the pectoralis muscle did not decrease. On the contrary, focusing on using the triceps muscle also increased pectoralis EMG at 50 and 60 % of 1RM.
Conclusion Resistance-trained individuals can increase triceps brachii or pectarilis major muscle activity during the bench press when focusing on using the specific muscle at intensities up to 60 % of 1RM. A threshold between 60 and 80 % appeared to exist.

Keywords Muscle activation · Internal focus · Strength training · Bodybuilding

Abbreviations

EMG	Electromyography
pectoralis	Pectoralis major
Triceps	Tricepsbrachii
1RM	One-maximum repetition
RMS	Root-mean-square

Introduction

For years bodybuilders have used the principle of focusing on contracting specific muscles to enhance muscle size and increase 'the pump'. Indeed, the American College of Sports Medicine considers the technique of voluntarily squeezing the muscles as a way to provide self-resistance during resistance training (Ratamess 2011). However, scientific literature evaluating the effectiveness of selectively focusing on specific muscles during exercise performance is scarce (Snyder and Fry 2012). Different verbal instructions have provided greater EMG response during maximal isometric contractions of both the elbow flexors and leg muscles (Sahaly et al. 2003). Instructions to selectively activate specific

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muscles also yielded greater core muscle activity compared with non-instructed conditions during a squat performed at 50 % of the one-maximum repetition (1RM) (Bressel et al. 2009). Similar results have been observed for low-intensity exercises such as trunk curls (Karst and Willett 2004) and the abdominal hollowing exercise (Critchley 2002).

In a recent study, untrained individuals were able to selectively increase the activity of the latissimus dorsi muscle during a pull-down exercise performed at 30 % of maximal force compared to the normal condition (Snyder and Leech 2009). In addition, Snyder and Fry (2012) found that male Division III football players selectively increased the muscle activity of the prime movers during bench press performed at 50 % of 1RM, following verbal instructions to focus on activating either the pectoralis major or triceps brachii. However, verbal instructions performed at the highest intensity (80 % 1RM) did not consistently lead to increased muscle activity (Snyder and Fry 2012). While the aforementioned study only used two different intensities, a wide range of intensity levels are required to understand the potential dose–response relationship between verbal instructions and specific muscle activation.

Based on the aforementioned studies, voluntarily focusing on specific muscles to increase muscle activity may be possible at low to moderate intensities, whereas the voluntary recruitment of muscles may be more difficult at high intensities. Nevertheless, the dose–response relationship between intensity and the ability to selectively activate specific muscles remains unknown. Higher levels of EMG activity during resistance training in general lead to greater muscular strength adaptations in both rehabilitation and condition programs by providing additional neural drive to the muscle and increased local muscle fatigue (Andersen et al. 2006; Folland and Williams 2007). Hence, the possibility of selectively increasing muscle activity during certain exercises without increasing the external load could serve potential benefits during both rehabilitation and conditioning programs.

Thus, the aim of the present study was to evaluate whether focusing on using the pectoralis major and triceps brachii muscles, respectively, during bench press can selectively increase activity of these muscles. Especially, we were interested in measuring the relationship between exercise intensity and the magnitude of selective activation. We expected that the ability to selectively activate these muscles would decrease with increasing intensity in a dose–response fashion.

Methods

Participants

A total of 18 young male subjects voluntarily participated in the study. Participants' were considered recreationally trained since they had a minimum of 1 year of resistance training experience, performing at least 3 sessions per week at moderate-to-high intensity. In addition, they were familiarized with the bench press exercise. Exclusion criteria were blood pressure above 160/100, disc prolapse, or serious chronic disease. All participants were informed about the purpose and content of the investigation. Informed consent was obtained from all individual participants included in the study. 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 2 sessions: a 1RM bench press determination with familiarization session and 1 experimental session. A minimum of 2 days separated the sessions. Participants received instructions to avoid physical activity more intense than normal daily activities 24 h before the sessions. To control the influence of external factors possibly affecting bench press performance, all measurements were made by the same two investigators and were conducted in the same facility. Only the two investigators and the particular subject were at the facility at the same time during the measurements. The study was done during April–May 2014.

At the 1RM bench press determination and familiarization session, 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 to warm up. 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 the protocol described by the National Strength and Conditioning Association (Baechle and Earle 2008). At the same time, a researcher was located at the head end of the bench during the test to assist in raising the bar on a failed attempt and to help the participant place the bar back on the rack. Assessment of 1RM enabled calculation of the precise training loads used in the bench press during the following experimental session (20, 40, 50, 60 and 80 % of 1RM). After the 1RM determination, the participants were familiarized with the different conditions, movement amplitude, body position, and speed of movement that would later be used during data collection. 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.

The experimental session 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 (Jakobsen et al. 2013). Afterwards, electrodes were placed according to recommendations of Criswell and Cram et al. (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 forearms and wrists pronate 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 and the shoulder was abducted to approximately 45°. The hips and spine were maintained neutral during all repetitions. If exercise technique did not meet required expectations the set was discarded and another attempt was made after explaining the procedure to the subject. 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. The inclinometer data was synchronously sampled with the EMG data, using the 16-channel 16-bit PC-interface receiver (TeleMyo DTS Telemetry, Noraxon, Arizona, USA). The dimension of the probes was 3.4 cm × 2.4 cm × 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 90° to 0° or 0° to 90°, respectively).

Participants performed the following conditions, randomly assigned: bench press at 20, 40, 50, 60 and 80 % of the 1RM. Furthermore, participants performed 3 different conditions performed in a randomized order with each of the aforementioned exercises and intensities: regular bench press as described above, and bench press focusing on selectively using the pectoralis major and triceps brachii, respectively. 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 focus on using your triceps muscles only". The researcher made sure to show by palpation where these muscles were located on the subject to avoid misunderstandings. In the regular bench press condition the instruction was as follows: "during this set, lift the barbell in a regular way". A 1-min rest interval was given between all the conditions except during the 80 % of the 1RM condition, where 3-min rest interval was provided to avoid any influence from fatigue. Each participant performed only three consecutive repetitions in all conditions and with all relative loads to avoid the influence of fatigue on the subsequent condition (Jakobsen et al. 2013). Subjects were instructed and practiced during the familiarization trial how to maintain a pace of 2-second descent and 2-second ascent. The speed of movement was closely monitored by the researcher using the EMG software, and feedback was provided to correct the subjects if any variance was noted. Using tape as 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 the conditions. A trial was discarded and repeated if participants were unable to perform the exercise with the correct technique or if a subject stated that he had forgotten the instruction.

Data analysis

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). Normalized values for each muscle were averaged for the 4 different portions at the pectoralis muscle (pectoralis) and the 3 different portions at the triceps brachii muscle (triceps).

Statistical analyses

A two-way repeated measures linear mixed model (Proc Mixed, SAS version 9, SAS Institute, Cary, NC, USA) was used to determine if differences existed between condition (regular bench press, pectoralis focus, triceps focus) and relative intensity (20, 40, 50, 60, 80 % of 1RM) for

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 m^{-2})	26 (3)
Resistance training experience (years)	8 (6)
1RM Bench Press (kg)	103 (25)

the pectoralis and triceps muscles separately. Normalized EMG was the dependent variable. Subject was entered in the model as a random factor. Values are reported as least square means (SE) unless otherwise stated. P values <0.05 were considered statistically significant.

Results

Table 1 shows that the 18 men of the present study had 8 (SD 6) years of resistance training experience, with a 1RM bench press of 103 (SD 25) kg.

Table 2 as well as Figs. 1 and 2 show the normalized EMG values of the pectoralis and triceps muscles, respectively, during the three conditions, i.e. regular bench press, and bench press focusing on using the pectoralis and triceps muscles, respectively. The normalized EMG values agreed well with the relative load, e.g. during regular bench press at 50 % of 1RM the normalized EMG of the pectoralis and triceps were 52 and 55 %, respectively. For both the pectoralis and triceps muscles, focusing on using the respective muscles increased muscle activity at relative loads between 20 to 60 % of 1RM, but not at 80 % of 1RM. There was no strong indications that the ability to selectively increase activity decreased in a dose–response fashion, but rather that a threshold between 60 and 80 % existed. The increased activity did not occur at the expense of decreased activity of the other muscle, e.g. when focusing on using the triceps muscle, the activity of the pectoralis muscle did not decrease. On the contrary, focusing on using the triceps muscle also slightly increased pectoralis EMG at 50 and 60 % of 1RM.

Discussion

The study shows that experienced participants can selectively activate pectoralis and triceps muscles during the bench press when this exercise is performed at low to

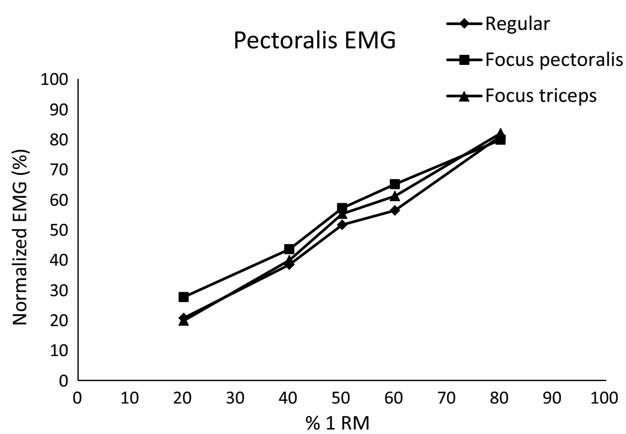

Fig. 1 Illustration of the dose–response relationship between intensity (% of 1RM) and muscle activity (normalized EMG) for the pectoralis during the three different conditions

Table 2 Normalized EMG of the pectoralis and triceps muscles, respectively, during regular bench press and bench press with focus on using the pectoralis and triceps muscles, respectively

	% 1RM	Regular bench press	Focus pectoralis	Focus triceps	Δ Focus pectoralis-regular	P	Δ Focus triceps-regular	P
Pectoralis EMG	20	21 (16–25)	28 (23–32)	20 (15–24)	7 (3–10)	<0.0001	–1 (–4–3)	0.6288
	40	38 (34–43)	44 (39–48)	40 (35–44)	5 (2–9)	0.0037	1 (–2–5)	0.3973
	50	52 (47–56)	57 (53–62)	55 (51–60)	6 (2–9)	0.0018	4 (0–7)	0.0383
	60	56 (52–61)	65 (61–70)	61 (57–66)	9 (5–12)	<0.0001	5 (1–8)	0.0072
	80	81 (77–86)	80 (75–84)	82 (77–87)	–1 (–5–2)	0.4888	1 (–3–4)	0.6082
Triceps EMG	20	31 (26–36)	32 (27–36)	42 (37–47)	1 (–3–4)	0.6141	11 (8–15)	<0.0001
	40	47 (42–52)	46 (41–50)	53 (48–58)	–1 (–5–2)	0.499	6 (3–10)	0.0004
	50	55 (50–60)	54 (49–59)	59 (54–64)	–1 (–4–3)	0.6002	4 (0–7)	0.0296
	60	60 (55–65)	59 (54–64)	64 (60–69)	–1 (–4–3)	0.7365	5 (1–8)	0.0082
	80	80 (75–85)	81 (76–85)	82 (78–87)	1 (–3–4)	0.7031	3 (1–6)	0.1408

Between-condition differences (95 % CI) and P values are provided in the last columns

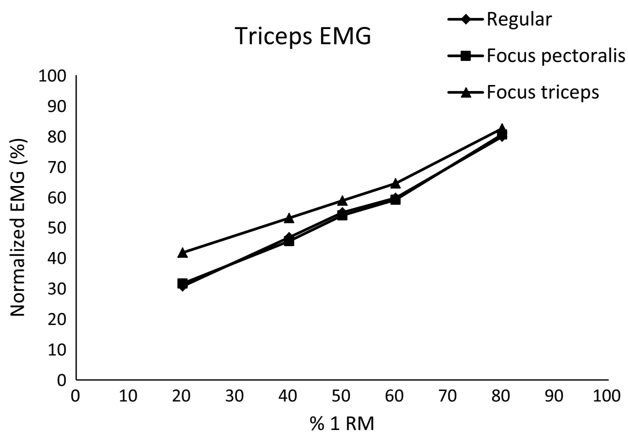

Fig. 2 Illustration of the dose–response relationship between intensity (% of 1RM) and muscle activity (normalized EMG) for the triceps during the three different conditions

moderate intensities. Specifically, a selective activation was possible at loads between 20 and 60 %, but not at 80 % of 1RM.

In contrast to our initial expectations, we found no strong indications that the ability to selectively increase activity decreased in a dose–response fashion, but rather that a threshold between 60 and 80 % existed. Thus, only for the triceps at 20 % was the selective activation higher than the other intensities. For the remainder intensities below 80 % the selective activation ranged between 5 to 9 %.

Our results are in line with the findings reported by Snyder and Fry (2012),—although they used only two intensities—who found that a group of footballers with at least 6 months of experience with the exercise were able to selectively increase muscle activity in pectoralis and triceps muscles during the bench press performed at 50 % of 1RM after the respective verbal instructions. However, in contrast to our findings, Snyder and Fry (2012) found that instruction to use pectoralis muscles during the 80 % of 1RM increased pectoralis and anterior deltoid muscle activity while triceps remained unchanged. Even though we used experienced participants, it seems that the effort required by the prime movers to lift heavy weights (i.e. 80 % of 1RM) makes selective activation of muscles difficult, probably because of the greater force production and motor unit recruitment required to lift heavy weights. The values of the firing rates and recruitment thresholds of motor units vary among muscles and can occur below 100 % of MVIC (De Luca and Kline 2012). However, the three submaximal-maximal repetitions performed with each condition may not have been enough to reach a maximum threshold of motor unit recruitment even though the EMG signal progressively increased through the different conditions for both muscles (see Figs. 1, 2). It is plausible that subjects are mainly and involuntarily focused on lifting the weight when high intensities are reached. It may thus be more difficult to dissociate between the naturally required and the selective or voluntary activation. Indeed, the majority of studies that reported greater muscle activity after specific instructions in dynamic movements used body weight as resistance (Critchley 2002; Karst and Willett 2004) or loads ranging from 30 to 50 % of the maximal intensity (Snyder and Leech 2009; Bressel et al. 2009).

A surprising finding was that concurrent muscle activity of the pectoralis also increased for when focusing on the triceps at moderate intensities. When the participants focused on using the triceps only, a slightly increased pectoralis activity at 50 and 60 % of 1RM was observed. However, when participants were focused on using the pectoralis, the activity of the triceps remained unchanged during all the intensities. While results provided by Snyder and Fry (2012) did not report relaxation of the concurrent muscle during specific instructions in the bench press exercise, other authors showed that it is possible to voluntarily decrease muscle activity in some situations at low contraction intensity (Karst and Willett 2004). For instance, following instruction participants were able to increase external and internal oblique activity while concurrently decreasing rectus abdominis activity during the trunk curl exercise (Karst and Willett 2004). However, the contrary case was not possible, probably because of the dominant role of the rectus abdominal muscle during this exercise (Karst and Willett 2004). In the same vein, another study found that participants using only the load of the arm as resistance at different shoulder joint positions were able to decrease EMG after concrete instructions to reduce upper trapezius activity together with the use of EMG biofeedback, while activity of the transverse trapezius muscle and rhomboids major and minor increased (Palmerud et al. 1998). Thus, the majority of these studies used relatively low levels of resistance that may have limited practical value.

A primary reason explaining our findings could be found in the "constrained action hypothesis" described by Wulf et al. (2001), which explains the comparative benefits of adopting an external (i.e., when the attention is focused on the effect of the action or outcome) or internal focus of attention (i.e., when the attention is just focused on the action or movement as in our study). According to this theory, less muscle activity would be induced by the external rather than internal focus due to a greater coherence between sensory input and motor output (McNevin and Wulf 2002). Thus, only the minimum required amount of motor units would be recruited to produce a certain movement (Vance et al. 2004). The use of different focus of attention during an action has been investigated during the last years during different sport skills in field-like conditions (Wulf et al. 1999) and during typical resistance training movements (Vance et al. 2004; Marchant et al. 2009; Greig and Marchant 2014). For example, Vance et al. (2004) found that the neuromuscular activity in the biceps brachii during the biceps curl exercise was generally lower during the external focus condition, where the participants were focused on the movement of the bar instead of the muscle and arm movements (internal focus). More recently, Marchant et al. (2009) found that the external focus during isokinetic elbow flexions decreased peak and mean biceps brachii EMG values in comparison to internal condition. Similarly, Greig and Marchant (2014) reported that an external focus significantly decreased lower biceps brachii activity at all speeds when compared to an internal focus during an isokinetic elbow flexion. Since the verbal instructions provided in our study supposes the use of an internal focus, our results are in line with the previously mentioned literature.

Our study has both strengths and limitations. A limitation is that we did not measure antagonist muscle activity as in the study by Snyder and Fry. Furthermore, this study was conducted in a group of recreationally trained participants and results may not be extrapolated to other populations or different exercises and muscles. The EMG amplitude reflects a combination of motor unit recruitment, firing rates and degree of motor unit synchronization (Aagaard 2003). Thus, we cannot know whether EMG increases in our study were due to increases in firing rates or in motor unit recruitment. Increased motor unit synchronization occurs mainly during fatiguing muscle contractions and is therefore unlikely to influence the present findings using only three repetitions per set. Despite EMG cross-talk may be present, we consider that the use of an averaged value for the different portions of the pectoralis major and triceps brachii is a strength of our study, providing more representative EMG values for the entire muscle. This is especially relevant in the present study, where participants were to focus on the entire muscle and not a certain portion.

Conclusions

Experienced participants can increase muscle activity at low and moderate intensities without increasing external load after receiving instructions to focus on activating specific muscles during the bench press exercise. Verbal instruction not only increases muscle activity without subsequent decreases in the concurrent muscle activity, but also may provide additional activity to some extent of the concurrent muscle. The practical application is that intensity of muscle activity can be increased to some extent simply by focusing on using that muscle without increasing external load.

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Compliance with ethical standards

Conflict of interest No conflicts of interest or sources of funding are declared by the authors of this article.

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