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Full Length Article

Effect of instructions on EMG during the bench press in trained and untrained males

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ABSTRACT

Strength and rehabilitation professionals strive to emphasize certain muscles used during an exercise and it may be possible to alter muscle recruitment strategies with varying instructions. This study aimed to determine whether resistance trained and untrained males could selectively activate the pectoralis major or triceps brachii during the bench press according to various instructions. This study included 13 trained males (21.5 ± 2.9 years old, 178.7 ± 7.0 cm, 85.7 ± 10.7 kg) and 12 untrained males (20.3 ± 1.6 years old, 178.8 ± 9.4 cm, 74.6 ± 17.3 kg). Participants performed a bench press one-repetition maximum (1-RM) test, 3 uninstructed repetitions at 80% 1-RM and two more sets of three repetitions with instructions to isolate the chest or arm muscles. Electromyography (EMG) was obtained from the pectoralis major, anterior deltoid, and the long head and short head of the triceps brachii. Maximum EMG activity normalized to 1-RM for each muscle was averaged over the three repetitions for each set and compared between the uninstructed, chest-instructed and arm-instructed conditions among the groups. The trained participants had a greater 1-RM (126.2 ± 30.6 kg) than the untrained participants (61.6 ± 14.8 kg) ($P < 0.01$). EMG activity was not different between the groups for any of the instructions ($P > 0.05$). When the group data was combined, short head of the triceps activity was significantly lower in the chest instruction (80.1 ± 19.3%) when compared to the uninstructed (85.6 ± 23.3%; $P = 0.01$) and arm-instructed (86.0 ± 23.2; $P = 0.01$) conditions. It can be concluded that instructions can affect muscle activation during the bench press, and this is not dependent on training status.

1. Introduction

Personal trainers, strength and conditioning coaches, and physical and occupational therapists are often interested in the extent to which muscles are activated in an exercise. It is in their best interest that their instructions are effective in eliciting the muscular response they are trying to achieve. Clinicians work with untrained individuals and athletes, and they need to be sure to give proper instructions to accomplish desired training goals in each population.

Since acute muscle activation during resistance training may be a good predictor of subsequent muscle hypertrophy (Wakahara, Fukutani, Kawakami, & Yanai, 2013; Wakahara et al., 2012) it is useful to determine how muscle activity can be altered to achieve the desired training response in an exercise. Previous research has investigated how to alter muscle activity during exercises by varying the exercise itself. One method to accomplish this is by changing body position, such as alternating hand grip orientation or grip width in a lat pulldown or bench press exercise (Lehman, 2005; Lusk, Hale, & Russell, 2010). Furthermore, it has been found that an internal focus during an exercise (focusing on the muscles contracting) is effective at increasing EMG activity while an external focus

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(focusing on the outcome of the contraction such as jumping on a box) decreases EMG activity (Marchant, Greig, & Scott, 2009; Vance, Wulf, Töllner, McNevin, & Mercer, 2004; Wulf, Dufek, Lozano, & Pettigrew, 2010; Wulf, Shea, & Park, 2001).

Recent research has found that some people may be able to voluntarily redistribute muscle activity during resistance training when given proper instruction (Karst & Willett, 2004; Snyder & Leech, 2009). This can be achieved by either relaxing or activating certain muscles, through selectively inhibiting or activating individual motor units with conscious motor control (Basmajian, 1963; Smith, Basmajian, & Vanderstoep, 1974). For instance, Snyder and Fry (2012) found that healthy male athletes given specific instructions to increase either arm or chest muscle drive could preferentially affect the EMG activity such that the subjects could push more with their triceps or pectoral muscles than without instruction.

However, further research has found that this may not occur in all subjects and muscle groups. For example, in a study by Holtermann, Mork, Andersen, Olsen, and Søgaard (2010), both instruction and biofeedback were used in learning to activate selective parts of the serratus anterior muscle in a static position. Despite instruction and feedback, not all subjects could selectively activate certain parts of the serratus anterior. In another study by Holtermann et al. (2009), similar findings were true for the trapezius, in which not all subjects could selectively activate its subdivisions, likely due to the fact that voluntary control of the neuromuscular compartments is not seen during functional tasks. Therefore, subjects may only be able to learn how to alter EMG muscle activity with instruction in certain muscle groups during certain activities such as more functional movements.

There also may be differences in the ability of beginners and advanced trainees in learning how to activate specific muscles when instructed. In one study by Snyder and Leech (2009), untrained women were able to voluntarily increase the EMG activity of the latissimus dorsi during a lat pulldown exercise at 30% one-repetition maximum (1-RM) following instruction. However, they were not able to decrease biceps brachii activity or increase teres major activity. Since there was no comparison group, it is unknown whether trained women would be able to decrease biceps brachii activity or increase teres major and latissimus dorsi activity when instructed. Conversely, another study by Snyder and Fry (2012) determined that male athletes could correctly respond to instruction by preferentially activating the pectoralis muscles to a greater extent during a bench press at 80% 1-RM, while Calatayud et al. (2016) found that resistance-trained men could only alter muscle activation at lower loads in a similar protocol. However, neither study compared the resistance-trained males to untrained males. Based on the limited research conducted thus far, it is undetermined if there is a difference between resistance-trained and untrained populations in correctly responding to instruction as assessed by EMG. Since the muscle activity during exercise may affect the training response and adaptations, it is essential to find out whether or not instructions typically given to resistance-trained and untrained people are effective in eliciting the desired response.

This study aimed to determine whether the electrical activity of the agonist muscles during a bench press exercise differed between resistance-trained and untrained individuals. It was hypothesized that the resistance-trained individuals would exhibit greater relative EMG activity than the untrained individuals during a high load bench press exercise. A secondary purpose of this study was to determine whether resistance trained and untrained individuals responded similarly to instructions in the bench press. It was hypothesized that resistance-trained individuals would be able to respond to instruction by appropriately increasing muscle activation according to instructions, but untrained individuals would not have that ability.

2. Methods

2.1. Experimental approach to the problem

A two-way repeated measures analysis of variance (ANOVA) was used to assess muscle activation during variations of the bench press and compared between resistance trained and untrained males. Participants visited the laboratory on two occasions with the first serving to collect anthropometric data and assess bench press one-repetition maximum (1-RM) and the second to perform the bench press during the experimental conditions. Muscle activity of the pectoralis major, triceps and anterior deltoid muscles were recorded via EMG under three conditions: no instructions, instructions to emphasize the use of the chest muscles and instructions to emphasize the use of the arm muscles.

2.2. Subjects

Twenty-five college-age individuals volunteered to participate in this study (Table 1). Prior to testing, all participants completed an informed consent approved by the university Institutional Review Board. The trained participants' (n = 13) experience entailed training at least three days a week for two years or more and regularly performing the bench press exercise. Twelve participants were

Table 1
Descriptive statistics displayed as mean (95% confidence interval) of trained and untrained participants. $P < 0.05$ is significant and effect size (*d*) is displayed. BMI = body mass index.

	Trained	Untrained	P	*d*
Age (years)	21.9 (20.1–23.6)	20.3 (19.3–21.4)	0.13	0.51
Height (cm)	178.7 (174.5–182.9)	178.8 (172.8–184.7)	0.98	0.01
Mass (kg)	85.7 (79.3–92.2)	74.6 (63.6–85.5)	0.06	0.77
BMI (kg·m^{-2})	26.8 (25.0–28.7)	23.2 (20.8–25.5)	0.01	1.10
Body fat (%)	9.8 (7.0–12.6)	15.8 (9.5–22.1)	0.06	0.77

considered untrained as they had not participated in a regular resistance training program within the last year. All subjects were free of upper body orthopedic injuries or limitations.

2.3. Procedures

The testing procedure consisted of two separate days, 2–14 days apart. On the first day, each participant's informed consent and health history were obtained and anthropometric measures of height, body mass, and body composition via seven-site skinfolds were conducted. The participants were prepped for EMG as described below. The participant was familiarized to the bench press exercise used for the study (Star Trac, Lake Forest, CA). They were instructed to keep the upper back, head, and buttocks in contact with the bench, and feet in contact with the floor, and the bench press 1-RM test was performed according to the methods described by the National Strength and Conditioning Association (Baechle & Earle, 2008). The subjects' bench press 1-RM was assessed while the EMG activity of the short and long head of the triceps, pectoralis major and anterior deltoid was recorded. Grip width was measured, recorded and kept consistent among the participants in all trials.

On the second day of testing, subjects were again prepared for EMG data collection as described below. Participants first completed a warm up set of 10 repetitions at 50% 1-RM, followed by a set of 3 repetitions on the bench press at 80% 1-RM. Participants were instructed to perform the bench press in the way they were most comfortable with no specific instructions. They maintained full range of motion from the chest to extended arms and proper form to the pace of 45 beats per minute (1.3 s for the eccentric contraction and 1.3 s for the concentric contraction). Electronic markers were placed on the EMG data at the beginning and end of the bench press concentric range of motion for subsequent analysis. After a two-minute rest period, subjects performed two more sets of 3 repetitions at 80% 1-RM with specific instructions to use the chest or arm muscles. There was a two minute rest period in between the sets. The order of instructions was randomized between subjects. Instructions to emphasize the chest muscles were said as follows: "*During this set, try to use only your chest muscles, and not your arm muscles. To do this, attempt to push your hands together, while still maintaining your grip on the bar*" as done in the study of Snyder and Fry (2012). Instructions to emphasize the triceps will be said as follows: "*During this set, try to use only your arm muscles, and not your chest muscles. To do this, attempt to push your hands apart, while still maintaining your grip on the bar*" (Snyder & Fry, 2012). Fig. 1 is a schematic depicting the intended movements corresponding to the

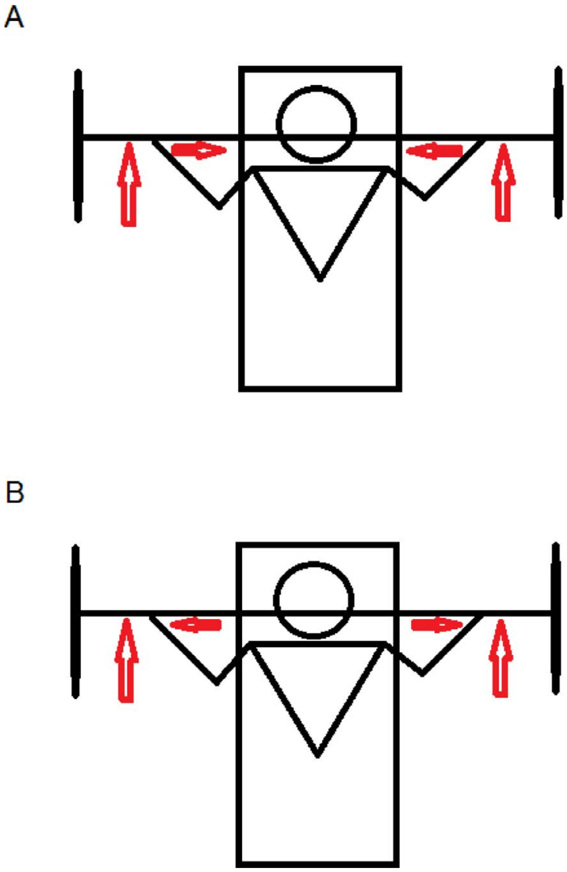

Fig. 1. Free body diagrams of forces involved in different instruction conditions. A: chest-emphasizing condition with medially directed forces in response to "push your hands together, while still maintaining your grip on the bar". B: arm-emphasizing condition with laterally directed forces in response to "push your hands apart, while still maintaining your grip on the bar". Vertical arrows in both figures represent the net force used to push the bar.

bench press instructions.

2.4. EMG collection and analysis

The subjects were then prepared for EMG data collection by shaving, abrading and cleaning the skin. Electrodes (Kendall Medi Trace 530) were placed on the sternal division of the pectoralis major, the short head and long head of the triceps brachii, and the anterior deltoid on the right side of the body while standing according to (Warfel, 1985). Electrode placement was traced with an indelible marker to ensure accurate placement on the subsequent testing day. A digital voltmeter was used to ensure skin impedance was less than 5 kOhms between electrodes at each site. Two reference electrodes were placed along the acromion process. EMG was measured for each muscle using dual wireless BioNomadix matched transmitter and receiver module (BN-EMG2, BIOPAC Inc., Goleta, CA, USA). The signal was transmitted at a rate of 2000 Hz and bandpass filtered from 5 to 500 Hz. The transmitted data were recorded using the Acqknowledge MP150 software (BIOPAC Inc., Goleta, CA, USA) with a sampling rate of 1000 Hz. The EMG signal was rectified and integrated every 50 samples during data collection. The maximum EMG amplitude within the approximately one second concentric bench press exercise was obtained for each repetition. This epoch was determined from the electronic markers placed within the EMG data at the beginning and the end of the bench press concentric range of motion. The maximum EMG activity for each muscle contraction was averaged over the three repetitions for each exercise condition (none, chest-instructed and arm-instructed conditions) and used in the analysis. All values for each subject from the second testing day were normalized to the subject's maximal integrated EMG activity during the concentric portion of the 1-RM test on the first day and expressed as a percentage of maximum integrated EMG activity. Due to the low skin impedance after the electrode preparation and leanness of some of the trained subjects, oversaturation of the EMG amplifiers occurred in the triceps brachii and anterior deltoid in two of the subjects. This oversaturation in those muscles made us unable to determine the maximum EMG achieved by the subjects during the different conditions and they were therefore excluded.

2.5. Statistical analyses

The proposed sample size for this study was based on a previous study by (Snyder & Fry, 2012) in which trained males performed the bench press under no instruction, chest instruction and arm instruction conditions. The number of subjects needed for each group was 11 participants (alpha = 0.05, power = 0.8, effect size = 0.26, correlation between measures = 0.6; G*Power 3.1.0, Universitat Kiel, Germany). A repeated measures analysis of variance was used to compare the differences in EMG activity for each muscle (pectoralis major, anterior deltoid and long and short head of the triceps) between the uninstructed, chest-instructed and arm-instructed conditions among the groups. T-tests with appropriate adjustments for familywise error rate were conducted to assess significant interactions and main effects. Independent t-tests were used to compare descriptive data between groups. Mean differences between the groups, 95% confidence intervals (95% CI), and Cohen's *d* were computed. Effect sizes, as estimated through *d*, were categorized as small (0.10), moderate (0.30), or large (0.50) (Cohen, 1988). SPSS 22.0 was used to analyze the data with the significance level set to $P < 0.05$.

3. Results

Descriptive statistics of the participants can be seen in Table 1. BMI differed significantly between the trained and untrained groups while the differences in body mass and percent body fat neared significance. The 1-RM of the trained participants was more than double the 1-RM of the untrained subjects (Table 2). Differences in grip width between the groups approached significance with trained participants self-selecting a grip 8.7 cm wider than untrained participants ($P = 0.06$). A sample of the EMG data collection from the long head of the triceps brachii can be seen in Fig. 2. There were no significant interactions in EMG activity of the four muscles and instruction conditions between the trained and untrained groups (Table 3; $P > 0.05$). This was accompanied by low effect sizes (all < 0.3; data not shown). The average EMG activity for all conditions at 80% 1-RM was 83.9% for the short head of the triceps, 84.4% for the pectoralis major, 83.4% for the long head of the triceps and 79.1% for the anterior deltoid. The combined data can be seen in Fig. 1. There was 5.9% higher activity in the short head of the triceps during the arm-instructed set than the chest-instructed set ($P = 0.01$). Short head of the triceps activity during the chest-instructed set was significantly lower than the no instruction conditions ($P = 0.01$). Long head of the triceps activity was 2.3% higher during the arm-instructed set from the no instruction condition and was 5.3% lower during the chest-instructed set from the no instruction condition but failed to reach significance ($P = 0.06$). Pectoralis major activity was not different across the no instruction condition, chest-instructed and arm-

Table 2
Bench press data displayed as mean (95% confidence interval) of trained and untrained participants. $P < 0.05$ is significant and effect size (*d*) is displayed. 1-RM = one repetition maximum.

	Trained	Untrained	P	*d*
Grip Width (cm)	66.1 (60.1–72.2)	57.4 (49.9–64.9)	0.06	0.80
Exercise Load (kg)	101 (86.3–115.8)	49.4 (42.0–56.9)	< 0.01	2.70
1-RM (kg)	126.2 (107.7–144.7)	61.6 (52.2–70.9)	< 0.01	2.70

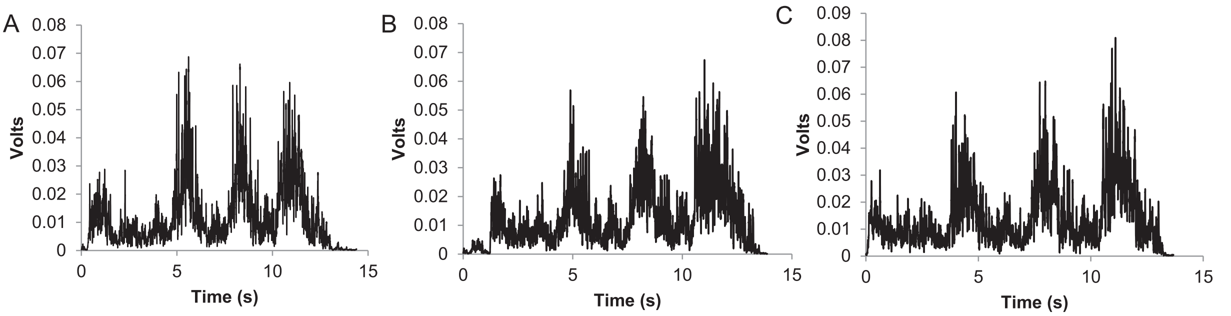

Fig. 2. Sample subject rectified and integrated EMG activity of the longhead of the triceps brachii over three repetitions. A: No instruction, B: Chest emphasizing instructions, C: Arm emphasizing instructions.

Table 3
Average normalized root mean square electromyographic activity displayed as mean (95% confidence interval) at 80% 1RM in trained and untrained participants. Pec Major = Pectoralis major, Ant Delt = anterior deltoid, SH Triceps = short head of the triceps and LH Triceps = long head of the triceps. There were no significant interactions or main effects of the data ($P > 0.05$).

	Trained			Untrained		
	None	Chest	Arm	None	Chest	Arm
Pec Major	86.5 (68.7–104.4)	88.5 (72.5–104.6)	88.9 (67.6–110.2)	82.9 (68.2–97.7)	84.3 (64.2–104.5)	80.9 (61.1–100.8)
Ant Delt	82.0 (61.7–102.3)	86.1 (66.8–105.4)	83.6 (63.9–103.2)	74.8 (60.0–89.7)	76.2 (62.7–89.7)	78.0 (65.1–90.9)
SH Triceps	86.7 (70.3–103.1)	83.0 (69.0–97.1)	84.0 (68.6–99.4)	86.0 (69.1–103.0)	79.9 (67.2–92.6)	84.0 (68.6–99.4)
LH Triceps	87.5 (65.8–109.2)	80.3 (58.6–101.9)	86.1 (65.0–107.1)	81.1 (70.2–92.0)	78.4 (62.5–94.4)	87.7 (67.6–107.7)

instructed conditions at 83.0 ± 23.8%, 86.3 ± 25.7%, and 83.9 ± 29.4%, respectively ($P = 0.53$). Anterior deltoid activity was also not different across conditions with EMG values at 77.0 ± 24.9%, 80.4 ± 24.6%, and 80.0 ± 22.9% for the no instruction, chest-instructed and arm-instructed conditions, respectively ($P = 0.30$) (Fig. 3).

4. Discussion

This study aimed to determine whether the muscle activity of the agonist muscles in the bench press differed between resistance-trained and untrained individuals, with the hypothesis that trained individuals would have higher relative EMG activity than the untrained participants. Contrary to our hypothesis, there were no differences in EMG activity of the muscles assessed between resistance trained and untrained males. Also contrary to our hypothesis, it was also demonstrated that the trained individuals did not increase pectoralis major activation or triceps activation in response to the chest and arm specific instructions.

Previous studies have documented increases in EMG between 11% and 43% following training periods of 8–24 weeks (Narici, Roi, Landoni, Minetti, & Cerretelli, 1989). Since the resistance trained males recruited for this study had a training age of at least two years, it was expected that they would have greater EMG activity at a given load than the untrained subjects. However, since the EMG

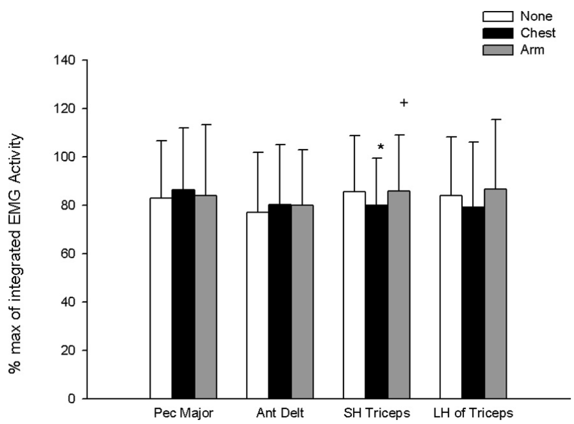

Fig. 3. The average percent of maximum integrated electromyographic activity in the pectoralis major (Pec Major), anterior deltoid (Ant Delt), short head of the triceps (SH Triceps) and long head of the triceps (LH Triceps) during no instructions (None), chest-emphasizing instructions (Chest) and arm emphasizing instructions (Arm) at 80% one repetition maximum for trained and untrained subjects combined. * denotes significant difference from None condition ($P < 0.05$). + denotes significant difference from Chest condition.

was normalized to each individual subject rather than between subjects there were no differences detected due to training status.

Interestingly, our findings indicate that both trained and untrained males are able to relax the triceps muscles to some extent at high loads of 80% 1-RM when given instructions to emphasize the chest muscles. The short head of the triceps activity was 5.5% less than the control condition when given the instructions *"try to use only your chest muscles, and not your arm muscles."* Though not significant, the long head of the triceps activity was also 5.3% lower than the control condition. Despite the lower arm activity, pectoralis major activity was only 3.3% higher, indicating that the subjects were unable to significantly alter chest muscle activity, even though the instructions given were meant to emphasize chest activity. While previous studies found that an internal focus enables subjects to increase muscle activity significantly during resistance exercises (Marchant et al., 2009; Vance et al., 2004), our subjects did not. However, these studies evaluated the effects of changes in focus during elbow flexion at either 50% of the subjects' maximum force (Vance et al., 2004) or using an isokinetic dynamometer (Marchant et al., 2009), which is a simpler task than a high load compound exercise. Since an external focus generally results in greater and more efficient force production than an internal focus (Marchant et al., 2009), an internal focus is likely to be far less effective with more demanding loads such as 80% 1-RM. More motor-units are recruited to lift heavy loads in compound movements and thus, it is possible that the greater motor-unit recruitment left fewer motor units left to be selectively activated (Schoenfeld & Contreras, 2016), which may account for the lack of increased muscle activation. At loads as high as 80% 1-RM, it is possible that due to the already very high activation of motor units, it is easier to decrease activation of certain muscles than increase activation of active muscles.

Interestingly, Snyder and Fry (2012) found that trained subjects were able to increase pectoralis major activity when given identical chest-emphasizing instructions by 13.3% at 80% 1-RM, but were unable to alter triceps activity. Snyder and Fry (2012) also found that anterior deltoid activity increased 17.3% with chest-emphasizing, whereas the subjects in our study had no change in anterior deltoid activity when given the same instructions. The results of the Snyder and Fry (2012) study may be indicative that the individuals became less efficient at performing the bench press with an internal attentional focus, as described by the constrained action hypothesis. Since our subjects were unable to voluntarily increase muscle activity at 80% 1-RM, this may indicate that the untrained and recreationally trained males recruited for this study were less accustomed to the 80% 1-RM load than the trained athletes that participated in the previous study.

Calatayud et al. (2016), on the other hand, found that recreationally active subjects were unable to alter muscle activity at 80% 1-RM load. They attributed this to the greater motor recruitment and force production required to lift high loads that may cause subjects to involuntarily focus on lifting the weight rather than selectively activating different muscle groups. Furthermore, Calatayud et al. (2016) found that subjects were able to increase pectoralis major activity during chest-focused instructions at 20–60% 1-RM and increase the activity of all three heads of the triceps with triceps-focused instructions at 20–60% 1-RM, without decreasing the activity of the other muscle groups with instruction, which agrees with the findings of Snyder and Fry (2012) at 50% 1-RM.

Grip width is a factor that could explain some discrepant findings. For example, Calatayud et al. (2016) standardized grip width for all subjects, whereas Snyder and Fry (2012) and the present study allowed self-selected grip width. Interestingly, the trained subjects of this study had an 8.7 cm wider grip than the untrained subjects, yet there were no significant differences in muscle activity between the groups, even though Lehman (2005) reported that narrowing grip width increases the activation of the triceps. This suggests that self-selecting grip width may make it easier for subjects to alter muscle activity when performing the exercise because the form is more comfortable. Self-selected grip width increases external validity and makes the findings more applicable to normal training settings. Therefore, participants should be encouraged to choose their grip width to improve compliance when training with instructions.

Finally, this study did not collect EMG on the antagonist muscles. Vance et al. (2004) found that increases in antagonist EMG can occur while using an internal focus that may alter the ability to produce force. However, Snyder and Fry (2012) did not find any differences in posterior deltoid or biceps brachii activity during any of the conditions assessed in their study, indicating that this may not be necessary in the bench press exercise. It also may have been helpful to evaluate how well participants understood the instructions similar to Marchant et al. (2009) did with a post-task questionnaire, to determine whether all subjects clearly understood what they were being asked to do. Additionally, subjects were instructed to maintain the same form of the exercise and supervised to ensure they completed the task correctly. Since there were no noticeable changes in joint movement during the instructed repetitions, it is unlikely kinematics were altered. However, significant changes in the form of the exercise would alter muscle activity more than instructions.

This study was unique in that it evaluated muscle activation during various bench press instructions in trained and untrained individuals. Overall, our findings suggest that it is possible to manipulate muscle activity at 80% 1-RM from instruction and both resistance trained and untrained males are able to respond. Thus during exercise, clinicians striving to alter triceps muscle activity in a specific way during exercise may use instructions to accomplish this purpose even at high loads, regardless of the client's training status.

It remains unclear whether the alterations in muscle activity occur more consistently by increasing or decreasing activation of certain muscles, or whether this ability can result in adaptations with instructed training. Previous research indicates that altering muscle activation is more difficult at higher loads than lighter intensities, but it is also yet to be determined whether training with low or high loads with various instructions yields differences in strength and hypertrophy gains than uninstructed training.

Future training studies are warranted to evaluate whether individuals are able to improve their ability to selectively activate or relax prime movers of the bench press, or whether any learned muscle activity alterations are capable of resulting in improvements in strength and hypertrophy from a control group. Future research should investigate these possibilities. It seems that there is some value in giving instructions at higher load intensities in the bench press when trying to elicit a desired training response in both trained and untrained males, though using lower loads of 60% 1-RM or less may be more useful when trying to achieve larger differences in EMG with instruction.

5. Conclusions

During exercise, clinicians and coaches should be aware that instructing clients to bench press in a certain way may affect muscle activity and therefore words should be chosen with that in mind. Furthermore, specific instructions appear to be effective for both trained and untrained populations, and can be worded similarly for both groups. Although it may be possible to alter muscle activity at high loads in trained and untrained males, more evidence is needed to determine whether these alterations are enough to cause significant differences in hypertrophy.

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