

## Original Research

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# Type of Encouragement Influences Peak Muscle Force in College-Age Women

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### ABSTRACT

*Int J Exerc Sci* 3(4) : 165-173, 2010. To investigate if the type of encouragement during a maximal voluntary isometric contraction (MVIC) had an influence on peak muscle force in strength-trained versus untrained collegiate women. Eleven strength-trained ( $20 \pm 1$  y) and twelve untrained ( $21 \pm 1$  y) women participated in three, five-second MVICs of seated knee extension. The three trials consisted of verbal only encouragement, verbal + visual encouragement, and verbal + pain avoidance encouragement. In all three trials, the participants received the same verbal encouragement. Trials were counterbalanced to minimize any possible order effects. A repeated measure ANOVA was used to analyze data. Any significant main effects were further analyzed using Tukey post hoc tests. There was no interaction between training status and encouragement type for all subjects  $F(2,42) = 1.5474$ ,  $p = 0.22$ ). For all subjects, a main effect for encouragement type was detected ( $F(2,42) = 6.616$ ,  $p < 0.05$ ) with significant differences found in MVIC between the verbal encouragement and verbal + visual feedback ( $99.5 \pm 29$  ft-lbs and  $115.6 \pm 29$  ft-lbs,  $p < 0.01$ ). No significant differences were found between the verbal only and the addition of pain avoidance ( $99.5 \pm 29$  ft-lbs and  $109.9 \pm 26.3$  ft-lbs,  $p = 0.069$ ) or the visual and pain avoidance trials ( $115.6 \pm 29$  ft-lbs and  $109.9 \pm 26$  ft-lbs,  $p = 0.43$ ). In this study, training status did not significantly influence the response to type of encouragement. Individuals produced the most force during a MVIC with verbal and visual encouragement. The incorporation of verbal encouragement and visual feedback is an important factor in eliciting peak force in college-aged women. This may have important implications in training and rehabilitation models that incorporate resistive loading of the skeletal muscles.

KEY WORDS: Central Activation Ratio, Electrical Stimulation, Resistance Training

## INTRODUCTION

The ability of skeletal muscle to generate maximal force during a single muscle contraction relies on the ability to recruit all available fibers within the muscle at a maximal rate (5). Attempts to maximally activate a muscle can be influenced by many factors. Age, disease state, and inactivity tend to reduce the ability to recruit all available fibers resulting in reduced muscle performance (19,23) while

resistance training can improve neural activation and muscular performance chronically (13). In contrast to training, during single muscle contractions, motivation, and self-efficacy may be able to increase muscular performance acutely (32). Self-efficacy has been described as an individual's confidence in their capabilities to perform specific tasks (4). Multiple factors related to increasing self-efficacy are reviewed elsewhere (32). The use of positive verbal messages and interpretation

of physiological signals have been shown to improve self-efficacy and physical performance (30,32). Specifically, positive verbal messages and encouragement have been shown to improve the dynamic (32) and isometric (22) strength of the biceps.

The uses of biofeedback and electrical stimulation have taken on prominent roles in both the clinic and laboratory setting. Biofeedback is a type of visual stimuli that translates the force a subject produces to a computer displayed graph for the subject to view in real-time during the muscle contraction (17). Visual feedback combined with verbal encouragement increases quadriceps and hamstrings torque values during isokinetic movements (9). Additionally, visual feedback combined with chronic exercise increased the activation of the quadriceps muscles compared to an exercise-only group (25). The use of visual biofeedback has often focused on the effects of training programs and not on single muscle contractions (11,12,20).

Electrical stimulation has long been used as a modality in the clinical setting as a means to encourage the rehabilitation process as well as a method for assessing muscle contractions (26). Electrical stimulation protocols have improved quadriceps femoris, anterior cruciate ligament, and rotator cuff strength (3,27,28). A potential limitation to the use electrical stimulation is that it often results in mild discomfort or pain (23). To date, limited research has focused on the acute effects of visual biofeedback and electrical stimulation or the associated discomfort on muscle performance, specifically muscle strength. In addition, limited research has been done on the effect of these modalities on

strength-trained versus untrained collegiate women during single muscle contractions. The purpose of this study is to determine if verbal encouragement combined with visual feedback or the avoidance of pain during a maximal voluntary isometric contraction (MVIC) has an influence on the muscle strength in strength-trained versus untrained female college students. It is hypothesized that the effects of the verbal and visual encouragement will result in trained women producing the greatest amount of force.

## METHODS

### *Participants*

Twenty-three college women (19-23 y), classified as strength-trained (ST, n=11) or untrained (UT, n=12), from a university in the southern United States participated in this study. Subjects were recruited by email, word-of-mouth, and use of a social networking site. Subjects were excluded from the study due to a major lower body injury within the last six months. In addition, subjects were not allowed to participate if they had any cardiorespiratory, metabolic, or physical disabilities. Participants classified as "trained" were members of a division 1 basketball team that participated in lower body resistance training meeting the ACSM guidelines (1) and monitored by the same strength and conditioning coach at least two days a week for the previous six months. Participants were classified as untrained if they had no resistance training experience in the last year. All participants completed informed consent. All procedures described in this study were approved by the university institutional review board.

*Protocol*

Participants provided information on their aerobic and resistance training through a health and physical activity questionnaire (16). In addition, all subjects were asked not to discuss the components of the study with anyone else until all of the data was collected.

Following the completion of the informed consent form and health questionnaire, Participants sat in the Nautilus custom-made knee extension machine and, using established protocols (6,7), were assessed for peak force during a maximal voluntary isometric contraction (MVIC) with a 136 kg S-beam load cell (SBO300, Transducer Techniques, Temecula, CA). The seat and leg pads were adjusted to ensure 90° flexion of the hip and the right leg at 75° flexion (24). This joint angle is commonly used in isometric strength testing as it allows for easily detected force levels and is well tolerated by participants (6,24). A strap was placed across the participant's waist and right ankle in order to minimize extraneous movements during the maximal knee extension effort. The participants were also instructed to hold onto the handles on either side of them.

The researcher gave a familiarization session on knee extension MVIC and the electrical stimulation protocol. Each subject participated in three trials of a 5-sec MVIC of the right leg (6,24) with different types of encouragement. Participants attempted MVIC during verbal encouragement only (V), verbal plus visual feedback (V+V), or verbal + pain avoidance (V+PA). The order in which the participants completed these trials were counterbalanced. There was a 3-min rest period in between each maximal contraction.

All trials consisted of the measurement of knee extension MVIC for 5-sec with standardized instructions and verbal encouragement given. Each subject sat quietly with the limb secured to the lever arm. Any measurable force output during the period of quiet sitting was recalibrated to zero to correct for the weight of the limb in the isometric testing position. Each participant was instructed to straighten or "kick" the leg as hard as possible for the full 5-sec and given the prompt "ready, set, kick" to initiate the MVIC (ft-lbs). Verbal encouragement consisted of the researcher speaking in a loud voice, "kick hard, kick, kick..." until the 5-sec MVIC was completed. The control condition consisted of a single isometric knee extension with the standardized verbal encouragement only.

The verbal + visual encouragement trial was accomplished by allowing the subject to perform an isometric knee extension exercise while viewing a real-time data stream (1,000 Hz sampling rate) of force output (y axis) and time (x axis) on a computer screen. The participant was instructed to focus on the height of the force output line as the participant performed her knee extension. The participant was further instructed that the more force produced during the knee extension, the higher the force output line would migrate on the computer screen. Each participant was directed to attempt to move the line as "high" as possible. Standardized verbal encouragement was also provided, and force output was recorded.

Encouragement by verbal + pain avoidance was accomplished through the use of a percutaneous superimposed electrical

stimulation technique (PST) (26). Two 6.98 x 10.16 cm surface electrodes (Superior Silver, 620SS, Wabasha, MN) were placed on the gaster of the vastus medialis oblique and vastus lateralis muscles of each individual (2). A 100 ms, 10-pulse train of electrical stimulation was administered at 125 mA (21). This type of brief (100 ms) electrical stimulation has been shown to produce safe but mild levels of pain during knee extension MVIC (24). Participants were instructed that the more force produced during the knee extension, the less the electric stimulation and consequent discomfort she would experience. Participants were familiarized with varying amounts of reduced electrical stimulation (10, 20, 30, and 40 mA) before the actual MVIC and full 125mA of electrical stimulation used for the assessment.

Following the explanation of electrical

Table 1. Descriptive Statistics of Participants

	UT (n=12)		ST (n=11)	
	M	SD	M	SD
Age (yrs)	20.8 ± 0.8		20.4 ± 1.4	
Ht. (cm)	165.5 ± 8.5		170.4 ± 7.8	
Wt. (kg)	67.4 ± 19.5		68.8 ± 8.7	
BMI (kg/m <sup>2</sup> )	24.4 ± 6.0		23.7 ± 2.1	
stimulation,				
# of Days with >15min of Activity				
Very Light	6.9 ± 0.3		7.0 ± 0.0	
Light	5.5 ± 1.9		7.0 ± 0.0*	
Moderate	3.8 ± 2.1		4.0 ± 2.1	
Heavy	1.3 ± 0.5		5.9 ± 0.7*	

UT, untrained females, ST, strength trained females  
 Very Light (reading, sitting, driving, eating, etc.); Light (walking, bicycling (easy), playing piano, etc.), Moderate (fast walk, dancing, skating, etc.), Heavy (swimming, running, basketball, etc.) (ref. 16)

\*Significantly Different from Untrained, P<0.05.

the subject performed a single, maximal voluntary contraction for five seconds. After holding the contraction for two seconds, the 125 mA electrical stimulation was administered. The 2-sec delay allows the participant time to reach peak force while minimizing the possibility of fatiguing from a constant peak effort. Following the 5-sec MVIC, each participant was asked to rate her pain on a visual analog pain scale (VAS) from 0 to 100 mm with 0 meaning least possible pain to 100 meaning the most possible pain (10). Participants drew a line on the 100 mm scale and the distance in mm from 0 was recorded as the pain score. Standard verbal encouragement was also provided, and force output was recorded.

In addition to providing the stimulus for the perception of pain, this method can also be used to measure the ability to contract a muscle at a maximal level (26). An estimate of the ability to maximally contract the quadriceps muscles was determined dividing the force output during the MVIC by the MVIC plus the stimulated force. This ratio is a measure of central activation (CAR) with 1.0 indicating complete activation of the muscle (29). A CAR of less than 1.0 indicates central activation inhibition or failure (29). All data was collected using Chart 5 V.5.5.5 (AD Instruments, Colorado Springs, CO).

*Statistical Analysis*

The effect of type of encouragement (V, V+V, V+PA) was examined for the impact on muscle force output in strength-trained versus untrained college-age women. Data were presented as means and standard deviations. A 2 x 3 (training status x MVIC condition) Repeated Measure ANOVA and One-Way (training status) ANOVA (CAR

and pain score) were used. Any significant main effects were further explored using the Tukey post hoc test. Statistical analysis was completed using Statistica 8.0 (StatSoft, Inc., Tulsa, OK). Significance as set at  $P < 0.05$ .

**RESULTS**

Eleven strength-trained subjects and twelve untrained subjects completed this study (Table 1). There were no differences between groups for age, height, weight, or body mass index. In addition to reporting of strength training (for determining group status), the strength trained individuals reported more days of at least 15-min of heavy activity (Table 1) but not moderate activity ( $P = 0.82$ ).

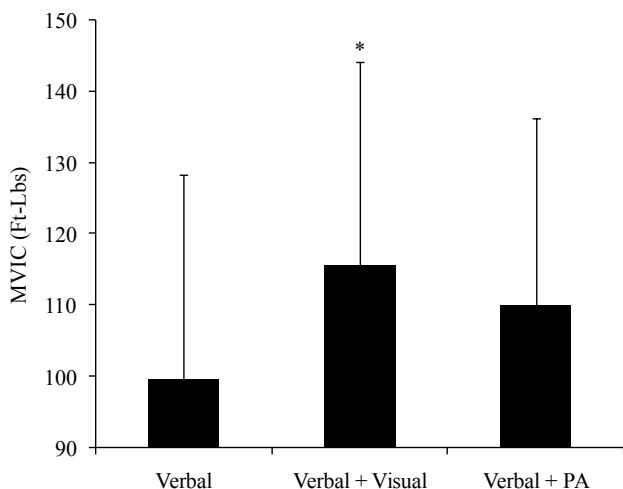


Figure 1. Maximal voluntary isometric contraction (MVIC) force output during knee extension for all participants (n=23). Verbal, verbal encouragement only, Verbal + Visual, verbal and visual encouragement, Verbal + PA, verbal and pain avoidance (PA) encouragement. \*Significantly different from Verbal,  $P < 0.05$ .

We did not detect a significant interaction between trained and untrained participants and the type of encouragement utilized during MVIC ( $F(2,42) = 1.545, P = 0.22$ ). The type of encouragement had a significant effect on force output in all participants ( $F(2,42) = 6.160, P < 0.01$ ) (Figure 1). The

Tukey post hoc test revealed a 16% increase in force output when visual feedback was combined with verbal encouragement (V+V) compared to verbal encouragement only (V) ( $P = 0.01$ ). There was a trend of increasing force output by 10%, but no statistical difference between the verbal (V) and verbal + pain avoidance (V+PA) ( $P = 0.069$ ). There was no difference between verbal only and verbal + pain avoidance encouragement ( $P = 0.43$ ).

For all subjects, a main effect of training status approached significance ( $F(1,21) = 4.2786, P = 0.051$ ) as strength trained participants ( $118.8 \pm 27.3$  ft-lbs) tended to have greater force output than untrained participants (UT,  $98.8 \pm 26.0$  ft-lbs). For the verbal + pain avoidance trial, we assessed the similarity of treatments between training status groups. There was no significance found for the CAR ( $P = 0.87$ ) or the pain scores ( $P = 0.44$ ) reported by either strength-trained or untrained women during the trial (Table 2).

Table 2. Parameters of Verbal + Pain Avoidance Trial for Each Training Status Group.

	UT (n=12)		ST (n=11)	
	M	SD	M	SD
CAR (%)	81.6	± 8.5	82.2	± 8.1
Pain (mm)	45.9	± 27.1	39.9	± 17.0

UT, untrained, ST, strength trained, CAR, central activation ratio.

**DISCUSSION**

The primary finding of the current investigation is that all participants, regardless of training status, produced the greatest amount of force during the verbal and visual encouragement trial. As expected, strength-trained participants

tended to produce the greatest amount of force in each of the three conditions (V, V+V, V+PA). Contrary to our hypothesis, we did not detect a significant interaction between type of encouragement and training status. All participants significantly improved force output when visual encouragement was combined with verbal encouragement.

The influence of the V+V indicates that individuals benefit from visual feedback when attempting to produce the greatest amount of isometric muscle force possible. Previous research has shown that visual feedback increased muscle force production during isokinetic movements of the quadriceps and hamstrings and dynamic exercise during rehabilitation from patellofemoral pain syndrome (9,25).

In focusing on the addition of pain avoidance to verbal encouragement, a pain scale was used to assess whether the electrical stimulation paradigm was perceived as painful by the participants when performing a MVIC. There was no significant difference in the reporting of pain by training status. The average pain score was a  $44 \pm 28$  mm out of a possible 100 mm, with 100 mm being the worst possible pain. A pain rating of 30 mm or greater is considered moderate pain (10). A large sample ( $n=736$ ) experiencing moderate pain due to various reasons, on average, reported pain levels to be 49 mm (10). This sample reported a very similar level of pain during the brief electrical stimulation pulse as those who experience chronic moderate pain. Thus, the sensation of the electrical stimulation should have been of an appropriate intensity (moderate) to encourage pain avoidance during the trial. However, it would appear that the

avoidance of pain based on the electrical muscle stimulation was not a significant factor for increasing muscle output in either trained or untrained women. Participants did show a 10% increase in muscle strength but this was not statistically significant. However, we most likely had poor statistical power to detect this change. Future studies involving larger samples should continue to examine this potential influence of pain avoidance on muscle strength.

The Central Activation Ratio (CAR) was assessed to determine the ability to maximally activate the quadriceps muscle. Strength training results in neural adaptations that may result in the ability to maximally recruit a muscle (15). The strength-trained group was predicted to have a greater CAR; however, activation levels for the strength-trained and untrained group were similar. The lack of a familiarization with the isometric exercise could have influenced these results as neither group had experience with the novel movement of isometric knee extension. Despite being trained in dynamic movements, the lack of experience in performing isometric knee extension may have limited the strength-trained sample in activating additional muscle as previously reported (15). However, both groups activated approximately 81% of the available muscle. The upper limit of motor unit recruitment typically occurs around 85% MVC (reviewed in 13). Thus, both groups were very close to achieving the threshold of maximal recruitment. Given the slight decrease (although non-significant) in BMI, and based on personal observation and training histories, it is likely that the trained group had greater lower limb muscle mass and thus were

activating a similar percentage of a larger muscle group resulting in similar CAR values but greater strength than the untrained group. This rationale is limited by the fact that body composition was not assessed but can only be inferred by the reasons given previously (training history, BMI, etc).

Finally, we expected the trained participants to be the most effected by type of encouragement. Strength trained undergraduate men significantly increased bench press performance with verbal encouragement (14,31). Thus, we expected to see similar improvements with encouragement in trained undergraduate women. Trained women did exhibit the greatest absolute force under the verbal and visual encouragement condition. However, as stated earlier, we found no interaction between training status and improvements in force output due to type of encouragement. Trained and untrained women responded similarly to the types of encouragement.

Previous studies suggest that trained individuals have most likely adapted to the overload stimulus and maximized the contributions of the nervous system to muscle contraction (30). Thus, strength trained individuals may be less likely to see changes in muscle performance related to motivation or self-efficacy (8,30). Our data suggests that trained individuals are just as influenced by encouragement, particularly verbal and visual encouragement, as untrained individuals. The discrepancies in the literature suggesting a training effect may be due to the different muscles studied, various types of movements, and varying definitions of "trained" (reviewed in 30). Since verbal encouragement is thought to increase muscle performance

through influences on the neural drive to activate a muscle (18), it would appear that both the trained and untrained individuals responded similarly to the types of encouragement despite any adaptation that may have occurred in the neural systems of the trained individuals.

The results of this study imply that participants who received verbal and visual feedback produced the greatest amount of muscular force. However, this study was not without its limitations. Due to time constraints and access to the testing equipment, a familiarization session was not possible until the day of testing. It is possible that the results may be different if the familiarization session was offered in the day(s) prior to the actual data collection. The lack of a familiarization session may have especially influenced the results of the untrained subjects considering most of them were unfamiliar with weight training or electrical stimulation. The order of the type of feedback trial was randomized in order to attempt to account for this limitation.

The findings from this study can potentially influence exercise prescription. As both trained and untrained individuals responded to the verbal and visual encouragements trials, both populations would benefit when attempting to determine peak muscle performance. In novice weightlifters, the inclusion of the V+V encouragement would give fitness professionals more valid assessments that would be used in determining the appropriate overloads for exercise prescription. This application would also be appropriate for experienced lifters to ensure peak performance particularly during novel movements outside of their normal training

protocols. Verbal and visual feedback may also be appropriate for rehabilitation protocols to more fully activate muscle and possibly reduce time to recovery.

As this is the first known study to focus on how these types of encouragement influence muscle strength in the quadriceps muscles, it is important that further research be done on this topic. Specifically, the ability to generalize these effects needs to be more fully examined by the inclusion of strength-trained and untrained older women as well as strength-trained and untrained younger and older men. Additionally, these effects should also be explored in individuals with chronic pain as a possible factor for improving performance and prescribing appropriate exercise therapies.

#### Conclusion

The primary finding of this investigation is that all participants, regardless of training status, produced the greatest amount of force during the verbal and visual encouragement trial. Findings from this study could prompt future research into the influence of various stimuli on older strength-trained and untrained women as well as younger and older strength-trained and untrained males. The results from this study can be used to more accurately assess strength and apply appropriate overloads to strength-training programs especially for college-age women. Although this study focused on an isometric knee extension, further investigations should also examine isotonic and isokinetic movements as well.

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