Journal of Exercise Physiologyonline

April 2013
Volume 16 Number 2

JEPonline

Official Research Journal of the American Society of Exercise Physiologists

ISSN 1097-9751

Effects of Electrical Stimulation Using the Marc Pro™ Device during the Recovery Period on Calf Muscle Strength and Fatigue in Adult Fitness Participants

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ABSTRACT

Westcott W, Han D, DiNubile N, Neric F, Loud RLR, Whitehead S, Blum K. Effects of Electrical Stimulation Using the Marc Pro™ Device during the Recovery Period on Calf Muscle Strength and Fatigue in Adult Fitness Participants. **JEPonline** 2013;16(2):40-49. The aim of this study was to determine the effects of electrical stimulation using the Marc Pro™ Device (MPD) during the recovery period on calf muscle strength and fatigue in two separate studies (n = 43, Mean age = 61.3 yrs; n = 62, Mean age = 61.7 yrs). The subjects performed the calf press exercise twice a week for 10 wks with or without electrical stimulation (M = 4 $hr \cdot wk^{-1}$) between training sessions. Subjects who received electrical stimulation (n = 54) in both studies attained a significant ($P<0.05$) increase in calf strength versus subjects who did not receive electrical stimulation (n = 51). Only the exercise plus electrical stimulation group in both studies showed a significant (P = 0.05) reduction in feelings of calf fatigue. The results indicate that using MPD electrical stimulation during recovery enhances the effects of resistance exercise by increasing muscle strength while decreasing the feelings of muscle fatigue.

Key Words: Exercise, Marc Pro™, Muscle Strength, Fatigue

INTRODUCTION

Progressive resistance exercise produces varying degrees of muscle micro-trauma that stimulate tissue remodeling processes during the post-training recovery period resulting in gradual strength gains. Although beginning exercisers appear to attain similar increases in muscle strength from 2 or 3 nonconsecutive strength training days a week (26), research indicates that the more demanding resistance workouts of advanced exercisers may require 3 recovery days for muscle remodeling processes to maximize subsequent strength development (14). These findings are consistent with studies that have reported significant increases in resting energy expenditure (REE) for 3 days following high-volume or high-intensity strength training sessions (9,10). Hackney et al. (9) found a mean REE increase of 8% for 72 hrs following a high-volume session of resistance exercise (8 sets x 8 exercises). Similarly, Heden et al. (10) observed a mean REE increase of 5% for 72 hrs following a high-intensity session of resistance exercise (1 set x 10 exercises). Based on the findings from these and other studies (3,11,15,20), it would appear that muscle micro-trauma caused by progressive resistance exercise requires a major metabolic response to facilitate muscle remodeling processes and resultant strength development.

One means for enhancing muscle remodeling and strength development during the recovery period appears to be post-training protein and carbohydrate consumption. Numerous studies have shown that ingesting supplemental protein and carbohydrate shortly after resistance exercise sessions significantly enhances muscle and strength development (1,5,7,12,18,19,25). Appropriately timed supplementation changes an otherwise negative post-exercise protein balance to a positive post-exercise protein balance that is a necessary condition for maximizing muscle hypertrophy and strength gain (19).

Another means for enhancing muscle remodeling and strength development between training sessions appears to be the appropriate application of electrical stimulation (6,8,13,17,23,24). In a 2011 study, the Marc Pro™ Device (MPD) was used to apply 1 hr of electrical stimulation to the right leg (only) after a challenging session of eccentric leg extension exercise (23). The following day, objective assessments of muscle strength and endurance demonstrated significantly more repetitions with the right leg (electrical stimulus) than the left leg (no electrical stimulus). Similarly, 24-hr post-workout subjective assessments of muscle soreness revealed significantly less discomfort in the right leg than in the left leg. In a second phase of this study, 1 hr of MPD electrical stimulation was applied to the right leg (only) following a challenging uphill/downhill hike. As in the first experiment, subjective assessments of post-activity muscle soreness revealed significantly less discomfort in the right leg than in the left leg.

A 2012 study (24) examined changes in low back fatigue in 80 subjects who completed 8 wks of total body resistance training with or without post-exercise MPD electrical stimulation (1 hr MPD following each training session). Although both groups attained significant improvements in low back fatigue, the results indicated a more favorable response in those participants who experienced electrical stimulation during the recovery period.

The findings from these studies indicate that 1 hr of MPD application following resistance training or stressful physical activity requiring forceful eccentric muscle actions may enhance recovery from exercise, thereby augmenting increases in muscle strength and decreases in muscle fatigue. As detailed in previous reports (6,23), MPD electrical stimulation may facilitate muscle recovery and performance through a nitric oxide (NO) dependent enhancement of microcirculation, mitochondrial biogenesis, angiogenesis, and fiber type transformation. This may be due to the unique waveform and electrical parameters of MPD electrical stimulation.

We recently conducted two similar studies to compare changes in calf muscle strength and calf muscle fatigue between participants who performed resistance exercise alone and participants who performed resistance exercise coupled with recovery period electrical stimulation. Based on the previous research, it was hypothesized that the subjects who received MPD electrical stimulation would experience a greater increase in calf muscle strength and a greater reduction in feelings of calf muscle fatigue.

METHODS

Subjects

Two studies were performed with essentially identical procedures, the first during the summer of 2011 and the second during the summer of 2012. Both studies were approved by the Quincy College Institutional Review Board (IRB), and both studies were conducted in strict adherence with the IRB requirements.

The first study (summer 2011) included 43 participants (M = 8; F = 35) with a mean age of 61.3 yrs. Twenty-two subjects performed the exercise program with electrical stimulation (MPD Group) during the recovery period. Twenty-one subjects performed the same exercise program without electrical stimulation during the recovery period (No MPD Group).

The second study (summer 2012) included 62 participants (M = 14; F = 48) with a mean age of 61.7 yrs. Thirty-two subjects performed the exercise program with electrical stimulation during the recovery period (MPD Group). Thirty subjects performed the same exercise program without electrical stimulation during the recovery period (No MPD Group). Characteristics for participants in the two study groups are presented in Table 1.

Table 1. Characteristics for Subjects in the Two Study Groups.

	Study 1	Study 2	All
Men	8	35	43
Women	14	48	62
Age (M ± SD)	61.3 ± 11.4	61.7 ± 11.8	61.5 ± 11.6

Procedures

All of the subjects in the two studies trained at the Quincy College Exercise Research Center, twice a week, approximately 60 min per session, for a period of 10 weeks. During each training session, the subjects performed 1 set of 13 Nautilus machine resistance exercises with a weight load that could be properly lifted between 8 to 12 repetitions. When 12 repetitions could be completed with correct technique, the resistance was increased by approximately 5%. Each repetition was performed with controlled movement speed (3 sec concentric muscle action and 3 sec eccentric muscle action) through a complete range of movement. The following exercise machines were incorporated in both studies:

- leg extension
- leg curl
- leg press
- hip abduction/adduction
- chest press
- seated row
- shoulder press
- lat pull down
- low back extension
- abdominal flexion
- torso rotation
- neck flexion/extension
- calf press

In addition to the standard strength workout, the subjects performed ~20 min of recumbent cycling at 70 to 80% of predicted maximum heart rate) and ~5 min of major muscle group stretching exercises. All the subjects trained in small classes of 6 to 10 subjects under close supervision of 2 or 3 nationally certified fitness instructors. In both studies, ~50% of the subjects (MPD groups) applied electrical stimulation to their calf muscles between training sessions. Thus, ~50% of the subjects (No MPD groups) did not receive electrical stimulation. All subjects in the MPD groups were given a personal Marc Pro™ Device (MPD). They were trained to self-administer 1-hr of electrical stimulation to the calf muscles of both legs 4 $d \cdot wk^{-1}$ throughout the 10-wk study periods.

Assessments

All assessments were conducted during the first week and last week of the 10-wk training sessions. Computerized ultrasound technology (SomaTech) was used to determine percent body fat, fat weight, and lean weight. Calf muscle strength was measured by the 3 repetition maximum (3 RM) weight load, which was the heaviest resistance that could be performed 3 times with correct technique on the Nautilus calf press machine. Calf muscle fatigue was assessed on a 9-point rating scale with anchors of 1 (never experience feelings of calf muscle fatigue) and 9 (always experience feelings of calf muscle fatigue).

Statistical Analyses

Data are presented as mean (M) ± standard deviation (SD). Statistical analyses included simple linear regressions as well as a one-way analysis of variance (ANOVA) or Welch's *t* test. When the test of multiple means was statistically significant at the 5% level, all pairs of means were compared using Tuckey-Kramer's HSD post-hoc method.

RESULTS

Data analyzed for changes in percent body fat, fat weight, and lean weight showed statistically significant improvement ($P<0.05$) in all of these parameters, with no significant differences between the MPD and the No MPD groups. Data analyzed for changes in calf muscle strength and feelings of calf muscle fatigue revealed significant differences between the MPD and the No MPD groups, as presented below.

Study 1

Means ± standard deviations for beginning and ending values of 3 RM calf muscle strength and calf muscle fatigue for the Study 1 MPD and No MPD groups are presented in Table 2. Both training groups experienced significant increases (P<0.05) in the 3 RM calf press. However, the mean 29.8-lb increase in calf muscle 3 RM strength by the MPD group was significantly greater (P<0.05) than the mean 18.1-lb increase by the No MPD group.

Table 2. Ten-Week (Study 1) Changes in 3 RM Calf Muscle Strength and Subjective Rating of Calf Muscle Fatigue for MPD and No MPD Groups (n = 43).

Assessment	MPD Group (n = 22)		No MPD Group (n = 21)	
	Pre (M ± SD)	Post	Pre (M ± SD)	Post
Muscle Strength	106.8 ± 29.7	136.6 ± 44.1	91.9 ± 33.5	110.0 ± 38.0
(3 RM - lbs)	+ 29.8 ± 21.4		+18.1 ± 15.4	
Muscle Fatigue	3.3 ± 0.4	1.8 ± 0.3	2.6 ± 0.5	1.8 ± 0.3
(Scale 1 - 9)	- 1.5 ± 1.8		- 0.8 ± 1.1	

Although both groups experienced a significant decrease (P<0.05) in calf muscle fatigue, the mean 1.5-point reduction in calf muscle fatigue by the MPD group was significantly greater (P<0.05) than the mean 0.8-point reduction by the No MPD group.

Study 2

Means ± standard deviations for beginning and ending values of 3 RM calf muscle strength and calf muscle fatigue for the Study 2 MPD and No MPD groups are presented in Table 3. Both training groups experienced a significant increase (P<0.05) in the 3 RM calf press. But, the mean 26.5-lb increase in calf muscle 3 RM strength by the MPD group was significantly greater (P<0.05) than the mean 14.7-lb increase by the No MPD group.

In this study, only the MPD group experienced a significant decrease (P<0.05) in calf muscle fatigue (-0.8 points). Although the No MPD group experienced a 0.6-point decrease in calf muscle fatigue, this reduction was not statistically significant at the 5% level.

Table 3. Ten-Week (Study 2) Changes in 3 RM Calf Muscle Strength and Subjective Rating of Calf Muscle Fatigue for MPD and No MPD Groups (n = 62).

Assessment	MPD Group (n = 32)		No MPD Group (n = 30)	
	Pre (M ± SD)	Post	Pre (M ± SD)	Post
Muscle Strength	104.4 ± 39.11	130.9 ± 42.09	96.3 ± 29.3	111.0 ± 27.2
(3 RM - lbs)	+ 26.5 ± 17.8		+14.7 ± 15.0	
Muscle Fatigue	2.4 ± 1.9	1.6 ± 1.1	3.0 ± 2.5	2.4 ± 1.6
(Scale 1 - 9)	- 0.8 ± 1.2		- 0.6 ± 1.6	

DISCUSSION

Findings from the first study indicate that applying MPD electrical stimulation to resistance trained muscles between exercise sessions is an effective method of increasing muscle strength. Specifically, the subjects who applied MPD electrical stimulation to their calf muscles during the post-training recovery periods experienced a significantly greater increase in the calf press 3 RM strength assessments than the subjects who did not receive electrical stimulation. Similarly, the subjects who received recovery period MPD electrical stimulation reported significantly greater reduction in feelings of calf muscle fatigue than those who did not apply electrical stimulation. Although there were subjects with no calf muscle fatigue, those who began the program with various levels of discomfort benefited from the MPD electrical stimulation. They improved by 1.5 points on the 9-point fatigue rating scale compared to 0.8 points for those who did not apply electrical stimulation.

The findings from the second study further supported the effectiveness of the electrical stimulation during recovery. As with the first study, subjects who applied MPD electrical stimulation to their calf muscles between training sessions attained significantly greater increases in calf press 3 RM strength assessments than subjects who did not receive electrical stimulation. However, there was no statistically significant difference in calf muscle fatigue reduction between the MPD and No MPD groups. Only the subjects who received electrical stimulation experienced a significant improvement in feelings of calf fatigue.

The consistent results from the two studies with a combined total of 105 subjects (n = 43 in Study 1 and n = 62 in Study 2) suggest that post-exercise MPD electrical stimulation enhanced recovery relative to the muscle tissue remodeling and strength development (6,8,13,17,23,24). While the exact mechanisms for facilitating the muscle recovery are not known, it has been postulated that MPD electrical stimulation causes positive cellular responses such as nitric oxide (NO) production, fluid shifts, protein clearance, and angiogenesis (6,23). It has also been suggested that MPD electrical stimulation has the potential to induce mRNA transcriptional proteins such as PPAR gamma co-activator (PGC)-1 alpha and VEGF (2,4,6,16).

We propose that the enhanced muscle recovery associated with MPD electrical stimulation may be due to increased microcirculation, muscle loading, and angiogenesis. Better muscle recovery provides the potential for larger and more frequent increases in the exercise resistance, thereby promoting greater strength gains over a given training period. Just as MPD electrical stimulation seems to enhance muscle strength development better than exercise alone, electrical stimulation also appears to decrease muscle fatigue better than exercise alone. Thus, it seems reasonable that there may be an inverse relationship between increased muscle strength and decreased muscle fatigue. The same cellular responses to MPD electrical stimulation that promote strength development (e.g., increased microcirculation, muscle loading, and angiogenesis) would likely result in reduced muscle fatigue.

Competitive athletes in essentially all sports have used electrical stimulation to reduce recovery time between training sessions, and this practice is particularly prevalent among professional sports teams. The primary reason elite athletes routinely apply electrical stimulation following strenuous workouts and stressful competitions is to expedite muscle remodeling and strength building for the purpose of improved sports performance. However, post-training electrical stimulation may also be beneficial for less fit individuals who experience prolonged periods of recovery or uncomfortable levels of muscle fatigue after exercising. With less than 5% of the American population physically active at the minimum recommendation of the American College of Sports Medicine (21), it is conceivable that an effective means for reducing training-related muscle fatigue could encourage more non-exercisers to pursue a fitness program. Therefore, it is suggested that post-exercise electrical stimulation to specific muscles may increase exercise adherence.

The MPD subjects in Study 1 and Study 2 self-administered during recovery ~4 hrs of electrical stimulation to their calf muscles each week for 10 wks (i.e., ~60 min·session^{-1}, 4 d·wk^{-1}). The amount of weekly electrical stimulation produced significantly greater increases in calf muscle strength and significantly greater decreases in calf muscle fatigue (MPD groups) than the exercise program alone (No MPD groups). However, it is not known whether a lesser amount of electrical stimulation (e.g., fewer min·session^{-1} and/or d·wk^{-1}) would elicit similar results, or if a greater amount of electrical stimulation (e.g., more min·session^{-1} and/or d·wk^{-1}) would be more effective than the protocol used in the present studies.

Additionally, the MPD subjects in our studies were advised to administer electrical stimulation at a moderate level of intensity (as perceived individually). It is not known whether lower levels of MPD intensity would elicit similar results, or if higher levels of MPD intensity would be more effective. Other Researchers may want to compare the effects of various electrical stimulation applications on muscle strength development and muscle fatigue reduction. They may also want to examine the effects of electrical stimulation on other exercise outcomes, such as muscle hypertrophy, muscle endurance, and selected physical performance factors.

CONCLUSIONS

Based on the findings from the two studies, performing standard resistance exercise, 2 $d \cdot wk^{-1}$, appears to be an effective means for increasing muscle strength and for decreasing feelings of muscle fatigue over a 10-wk training period. Performing the same exercise program with ~60 min of electrical stimulation to the exercised muscles during recovery 4 $d \cdot wk^{-1}$ appears to produce significantly greater gains in muscle strength and significantly greater reductions in feelings of muscle fatigue.

ACKNOWLEDGMENTS

The authors graciously acknowledge the following individuals for their assistance with the two research studies: Dean Sbragia, President of Med-Fit Systems for supplying the Nautilus Calf press machine; Ryan Heaney of Marc Pro™ for providing all the electrical stimulation devices; and Gary Reinl for teaching the subjects how to use the electrical stimulation device.

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