The Effects of High-Volt Pulsed Current Electrical Stimulation on Delayed-Onset Muscle Soreness

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Objective: We investigated three 30-minute high-volt pulsed current electrical stimulation (HVPC) treatments of 125 pps to reduce pain, restore range of motion (ROM), and recover strength loss associated with delayed-onset muscle soreness (DOMS).

Design and Setting: Randomized, masked comparison of three 30-minute treatment and sham HVPC regimens over a 48-hour period.

Subjects: Twenty-eight college students.

Measurements: Subjects performed concentric and eccentric knee extensions with the right leg to induce muscle soreness. Assessments were made before and after the exercise bout and each treatment at 24, 48, and 72 hours postexercise.

Results: Three separate 2 x 3 x 2 ANOVAs were used to determine significant differences (p < .05) between days, treatments, and pre-post treatment effects and significant interaction among these variables. Scheffe post hoc tests showed no significant reduction in pain perception or improvement in loss of function at 24, 48, and 72 hours postexercise. Mean pain perception assessments (0 = no pain, 10 = severe pain) for the HVPC group were 2.9, 4.5, and 3.5 and for the sham group 3.8, 4.8, and 3.5). Mean ROM losses for the HVPC group were 9.0°, 22.3°, and 26.2° and for the sham group were 9.5°, 23.1°, and 23.0°. Mean strength losses (1RM) for the HVPC group were 25.9, 25.7, and 20.8 lbs and for the sham group were 22.3, 22.3, and 13.8 lbs.

Conclusions: HVPC as we studied it was ineffective in providing lasting pain reduction and at reducing ROM and strength losses associated with DOMS.

Key words: muscle soreness; delayed-onset muscle soreness (DOMS); high-volt pulsed current

Delayed-onset muscle soreness (DOMS) is defined as “the sensation of discomfort or pain in skeletal muscles that occurs following unaccustomed muscular exertion.”1 The onset of symptoms associated with DOMS is generally 8 to 24 hours postexercise, peaking from 24 to 72 hours.2-5 DOMS is characterized by reduced mobility and increased tenderness, weakness, and pain.7-10 Armstrong observed that the tenderness resulting from DOMS is often localized in the distal third of the muscle and that the pain is generalized throughout most of the muscle belly.1,11,12

A considerable amount of research has been conducted investigating the etiology4,13,14 and treatment of DOMS. Some of the physical agents that have been used to treat DOMS include ice,15,16 ice massage,17,18 therapeutic massage,19,20 stretching exercises,20-23 superficial heat (hydrocollator packs),16 ultrasound,24,25 transcutaneous electrical neuromuscular stimulation (TENS),26,27 microcurrent electrical neuromuscular stimulation (MENS),12 iontophoresis,28 phonophoresis,24 and exercise (training).11,12,17,29,30 Pharmacologic and other therapeutic agents used to treat DOMS include anti-inflammatory drugs,31-33 ascorbic acid,34 ibuprofen,35 and counterirritants (topical analgesics).36,37 We found only one study that investigated the efficacy of high-volt pulsed current electrical stimulation (HVPC) in treating DOMS.18 That study compared the effects of 1) a subsensory HVPC treatment, 2) a submotor HVPC treatment, and 3) a microcurrent stimulation treatment for three indicators of DOMS: perception of soreness, hamstring flexibility, and plasma creatine kinase. The submotor HVPC treatment was the most effective of the three treatments in reducing DOMS.

Our study was designed to determine whether or not three 30-minute treatments of a twin-pulse HVPC set at 125 pulses per second (pps) would significantly reduce the soreness and loss of ROM and strength associated with DOMS.

METHODS

Subjects

Seventeen women and 11 men (age 21.8 ± 2.5 years, height 174.5 ± 11.4 cm, weight 69.9 ± 12.5 kg) volunteered to participate in the study. Each subject signed a consent form after being advised of the purposes of the study and the method of inducing DOMS. All subjects were instructed not to massage, apply ice, exercise, stretch, or take any pain medication for the duration of the study. The subjects had not been involved in conditioning or strength-training programs within one month of the study, reported no history of lower extremity...
injury, and were free from soreness in the right lower extremity.

**Instrumentation**

We used a visual analog scale (VAS) to assess pain. The scale consisted of a horizontal line 10 cm in length ranging from “no pain” at the far left to “severe pain” at the far right. Active knee flexion ROM was measured using a manual 12-inch full-circle plastic goniometer with the subject prone. We obtained strength measures using the Cybex leg extension machine (Eagle Fitness Systems, Owatonna, MN). This same leg extension machine was utilized to induce DOMS. The OmniStim 3020 medium frequency current generator with a high-volt pulsed current adapter (Physio Technology, Inc., Topeka, KS) provided the treatments. The amplitude was submotor, the frequency was 125 pps, and the pulse duration was 40 μsec with an interphase interval of 100 μsec.

**Procedures**

The 28 subjects were randomly assigned to one of two groups, HVPC or sham. Muscle soreness was induced in the right quadriceps using concentric and eccentric knee extensions on the Cybex leg extension machine. Subjects began the exercise protocol using 75% of their one-repetition maximum and performed up to 30 sets of 10 repetitions. Each set lasted approximately 20 to 30 seconds and was followed by a 15- to 20-second rest period. Following 8 sets of 10 repetitions of leg-extension exercises, the subjects were given a 2-minute rest period. The total exercise time took no longer than 50 minutes. When the subject was unable to fully extend the leg during the concentric phase, we lifted the weight and had the subject eccentrically load the quadriceps while lowering the weight. We continued this routine until the subject was unable to eccentrically resist a 30-pound load or refused to continue the exercise due to fatigue.

We administered 30-minute HVPC treatments once each day for three days. The first treatment was given at 24 hours postexercise, the second at 48 hours postexercise, and the final treatment at 72 hours postexercise. (Two of the subjects were excused from the study as a result of sickness and use of medication.)

Subjects in the HVPC treatment group were given a high-volt, twin-peak, pulsed electrical current delivered at a rate of 125 pps for 30 minutes. We cleansed the entire quadriceps with alcohol and placed one electrode directly over the site of greatest soreness. We then placed the other electrode over the furthest area to which the soreness extended, whether proximally or distally, to allow the electrical current to flow through as much of the painful area as possible. The intensity was increased to the point at which a muscle contraction was visible and then lowered to a comfortable sensation level, as determined by each subject. Reusable, self-adhering electrodes (Medical Specialists Company, Inc., Denver, CO) of equal size (4 1/2 inches by 2 1/2 inches) were used. A new pair of electrodes were assigned to each subject and were used for the duration of the study.

Subjects in the sham group received a mock treatment. We turned the machine on, and the dial, which was connected to a false channel, was manipulated, allowing the subjects to see what they perceived as an increase in the amplitude. No current, however, was actually being delivered. We told the subjects they were receiving a nonsensory treatment and should feel nothing.

**Assessments**

Assessments for perceived muscle soreness, loss of ROM, and strength loss were performed before and after each treatment. We used a visual analogue scale to evaluate muscle soreness. The subjects evaluated their own soreness by marking an “X” on the scale at their level of perceived pain. We assessed knee flexion ROM actively of each leg with the subject lying prone. The arms of a standard goniometer were aligned with the long axis directly over the lateral femoral condyle, using the greater trochanter and lateral malleolus as landmarks. We marked the placement of the goniometer on the skin of each subject with a permanent marker to ensure consistency and accuracy in the daily assessment of ROM. The point at which the subjects were unable to further actively flex their knee was considered the end point of their ROM.

We assessed strength as a one-repetition maximum (1RM) on the Cybex leg extension machine. We recorded the amount of weight lifted to full knee extension by the right leg (to the nearest 5 lbs) for each subject.

**Statistical Analysis**

We ran three separate $2 \times 3 \times 2$ ANOVAs to determine significant differences between days, treatments, and pre-post treatment effects, and significant interaction among these variables. We used Scheffe post hoc tests to determine which days, treatments, and/or pre-post treatment effects were significantly different. We set alpha at .05.

**RESULTS**

**Perceived Muscle Soreness**

Perceived pain peaked at 48 hours postexercise for both groups. A significant decrease in pre-post means for perceived pain for both groups was observed ($F(2,50) = 4.68, p = 0.01$) (Table 1), which indicated that the sham group experienced a placebo effect that reduced pain. However, Scheffe post hoc tests showed no significant differences in perceived pain between the two groups. Thus, neither group significantly reduced perceived pain from 24 to 72 hours postexercise ($F(2,50) = 0.41, p = 0.67$). The only significant pain reduction for both groups occurred during the 30-minute treatment, but this diminished shortly after the treatment concluded.

**Range of Motion**

There were no differences in range-of-motion loss between the treatment and sham groups ($F(2,48) = 0.99, p = 0.38$). An
improvement in ROM, however, at 72 hours postexercise was revealed for both groups (Table 2). As with muscle soreness, ROM loss was greatest at 48 hours postexercise.

**Strength**

There were no improvements in strength recovery in either the sham or HVPC group (F(2,46) = 1.41, p = 0.25), although improvements in strength were observed from 48 to 72 hours postexercise (Table 3). However, these improvements were similar for both groups, and strength loss remained low all 3 days post exercise. Peak strength loss occurred at 48 hours postexercise.

**Summary**

Maximum pain perception, loss of ROM, and strength loss occurred for both treatment and control groups at 48 hours postexercise. Furthermore, muscle soreness was diffuse, although the belly of the rectus femoris and the distal end of the vastus lateralis were the two common sites of most intense pain indicated by the subjects. The HVPC and sham treatments produced definite effects in pain perception during each 30-minute treatment but did not significantly decrease pain perception, improve ROM, or moderate strength losses at 24, 48, and 72 hours postexercise. It appeared that the sham treatment caused a decrease in pain perception due to a placebo effect.

**DISCUSSION**

Results from our study coincide with the results of other studies regarding the progression of DOMS. We found that muscle soreness associated with DOMS increases in intensity during the first 24 hours postexercise and peaks at 48 hours (Fig 1) postexercise.6,10,38 Results from our study are similar to other studies regarding the severity of DOMS. We observed that the tenderness resulting from DOMS induced in our study was most often localized to the distal third of the muscle,1 while the pain was generalized throughout most of the muscle belly, as has been reported by other researchers.11,12,39

In their study of the effects of intensity and duration of muscular exercise on DOMS, Tidus and Januzzo12 found that high-intensity (80% of 10RM), short-duration (170 contractions) exercise resulted in greater muscle soreness than long-duration (545 contractions), low-intensity exercise (30% of 10RM). Subjects in our study began their exercise protocol lifting 75% of their 1RM, which is a higher intensity than that used by other investigators.5,10,15,26,27 Thus, the possibility exists that our DOMS exercise protocol was too aggressive for conventional neuromuscular stimulation to reduce pain. We base this on the fact that the level of soreness induced in our subjects was so great that the majority of subjects were unable to walk without a limp. In some of the subjects we observed slight swelling in the distal third of the anterior portion of the thigh.

Some of the results from our study are not in accordance with those of Wolcot et al,18 who investigated the effects of a subsensory HVPC treatment, submotor HVPC treatment, and a microcurrent treatment on DOMS. They reported that the submotor HVPC treatment was the most effective in reducing pain. Other investigators have studied the effects of different electrical stimulation devices and treatment protocols, such as TENS (high- and low-frequency)15,26,27 and MENS.12 These studies found high- and low-frequency TENS to be effective in reducing pain and MENS to be ineffective. Compared with the

**Table 2. Table of Means and Standard Deviations For Range-of-Motion Losses Before and After Each Treatment at 24, 48, and 72 Hours Postexercise**

<table>
<thead>
<tr>
<th></th>
<th>24</th>
<th>48</th>
<th>72</th>
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<tbody>
<tr>
<td>HVPC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pre (deg)</td>
<td>−9.71 ± 9.90</td>
<td>−35.36 ± 39.83</td>
<td>−26.71 ± 33.69</td>
</tr>
<tr>
<td>post (deg)</td>
<td>−8.29 ± 10.12</td>
<td>−29.29 ± 32.75</td>
<td>−25.71 ± 30.81</td>
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<tr>
<td>Sham</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pre (deg)</td>
<td>−8.83 ± 13.72</td>
<td>−22.58 ± 32.80</td>
<td>−23.50 ± 33.91</td>
</tr>
<tr>
<td>post (deg)</td>
<td>−10.08 ± 10.65</td>
<td>−23.58 ± 31.79</td>
<td>−25.71 ± 30.81</td>
</tr>
<tr>
<td>Day mean</td>
<td>−9.21 ± 10.49</td>
<td>−28.06 ± 33.65*</td>
<td>−24.73 ± 32.01</td>
</tr>
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* Significant loss of ROM (p<.01) for both the HVPC and sham group from 24 to 48 hours postexercise (measured in active knee flexion in prone position)
findings of these studies, HVPC stimulation appears to be less effective than high- and low-frequency TENS and equally as ineffective as MENS in reducing pain. The differences in pain reduction among these three distinct electrotherapeutic modalities might be related to 1) the exercise protocol utilized for inducing muscle soreness, 2) the physiologic differences in the subjects, and/or 3) the treatment protocol administered.

While the exercise protocol we utilized did indeed induce DOMS, it may have been somewhat overstrenuous for some subjects. This was indicated by the pronounced decreases in ROM (Fig 2) and strength (Fig 3) immediately following the exercise protocol and at 24, 48, and 72 hours postexercise. Subjects at lower fitness levels will particularly be affected by such an exercise regimen. We recommend a thorough fitness assessment of each participant when selecting subjects to participate in a study of DOMS. This will control for variability between subjects by inducing approximately the same level of soreness, muscle damage, etc, in each person.

Another possible explanation for the differences in our findings and those of others might be related to the muscle group we chose for our study. We induced soreness in the knee extensors, a group of muscles used when weight bearing, whereas other researchers have induced soreness in the elbow flexors or extensors,5,6,15,17,24,26,27,31,32,38 which are non-weight-bearing muscles. By inducing soreness in non-weight-bearing muscles, complete rest is at least possible. When DOMS is induced in the musculature of the lower extremities, however, it is difficult to provide complete rest. Nevertheless, some researchers who have induced soreness in the lower extremity have found favorable results (ie, pain reduction and restoration of muscle function) with the use of electrical stimulation.18,25,28,35

The contradictory results of our study and the favorable results found in these studies involving the lower extremity might be explained by the differences in our treatments, the method of inducing soreness, and/or the assessment procedures utilized in each investigation. Each of these investigations involved different treatments and treatment methods, exercise protocols for inducing DOMS, and pain and function assessment procedures for evaluating soreness and loss of function.

In comparison with the treatment protocols used in those studies investigating the efficacy of MENS and high- and low-frequency TENS and the treatment protocol used in our study, there is also a distinction. For example, our intensity or pulse rate may have been too high, or the pulse duration may have been too low; the treatment duration may have been too short; our electrode sizes may have been too large or placed too far apart; and/or the frequency of our assessments may have been insufficient to discern change.

The treatment protocol used by Denegar et al27 delivered a pulse rate of 2 pps and pulse duration of 300 μsec, and the intensity was adjusted to maximal tolerance for a duration of 30 minutes. The high-frequency TENS protocol utilized in the investigation of Denegar and Huff26 delivered a pulse rate of 80 pps, pulse duration of 90 μsec, and a monophasic waveform for a duration of 30 minutes. Their low-frequency TENS protocol consisted of 2 pps, with a pulse duration of 200 μsec, and a biphasic waveform for 30 minutes. In addition, they

<table>
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<th>Table 3. Table of Means and Standard Deviations For Strength Losses Before and After Each Treatment at 24, 48, and 72 Hours Postexercise</th>
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<tr>
<td><strong>HVPC</strong></td>
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<tr>
<td><strong>Hours Postexercise</strong></td>
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<tr>
<td><strong>pre (lbs)</strong></td>
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<tr>
<td><strong>HVPC</strong></td>
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<td><strong>Sham</strong></td>
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<td><strong>Day mean</strong></td>
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<td><strong>Day mean</strong></td>
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<td><strong>Day mean</strong></td>
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* Significant decrease in strength loss (p<.05) for the HVPC and sham group (strength measured as 1RM)
performed assessments immediately, 1 hour, 2 hours, 3 hours, and 4 hours post-treatment.

Denegar and Perrin applied a 20-minute treatment, which delivered a pulse rate of 2 pps and pulse duration of 20 μsec. The intensity was adjusted to approximately 110 μA and the duty cycle set for an “off” time of 99 seconds and an “on” time of 1 second. Furthermore they used round, 50-mm diameter carbon electrodes treated with conductive gel. The parameters for MENS utilized by Weber et al were set at a duty cycle of 50% (with the electrodes alternating polarity every 2.5 seconds), an intensity of 30 μA, a frequency of 0.3 Hz, and a wave slope of 5 seconds.

All of the treatment protocols utilized in the TENS investigations cited above resulted in significant reductions of perceived pain following treatments at 48 hours postexercise. The treatment protocol used in our study was less effective than many in the literature; therefore, we recommend several changes for future studies. First, we suggest that assessments be taken at least twice each day at different times before and after each treatment. Second, if feasible, assessments should extend up to 96 or 120 hours postexercise. Third, when HVPC is used, we suggest a longer pulse duration (200 μsec) and lower pulse rate (1 to 5 pps), which may produce longer lasting analgesia. Fourth, more treatments, such as two or three each day, might be indicated. Fifth, treatments may need to be administered for longer periods, such as 45 minutes. Lastly, HVPC needs to be investigated in conjunction with other modalities such as ice, stretching, anti-inflammatories, and exercise.

In conclusion, our application of a high-volt, twin-peak pulsed electrical current delivered at 125 pps for a duration of 30 minutes was not effective in reducing the soreness, loss of ROM, and loss of strength associated with DOMS. However, HVPC did produce a reduction in pain perception throughout the duration of the treatment, possibly due to placebo effects.

ACKNOWLEDGMENTS

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REFERENCES


