Effects of Microcurrent Electrical Stimulation on Delayed Onset Muscle Soreness and Torque Values

A THESIS

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THESIS APPROVAL

Athletic Training

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INTRODUCTION

People often experience pain related to training and competition. For as long as people have experienced soreness, someone has attempted to relieve it through various means. Some methods have been shrouded in doubt and mystery while others have actually increased pain. This process continues today. Pain and soreness are a major limiting factor in athletes returning to practice and competition. Athletic trainers continue to seek pain relief methods that will allow athletes to return to competition sooner.

The types and the degree of pain vary from individual to individual. The body responds in a variety of ways to trauma and injury including muscle spasm, reduced blood flow, reduced oxygen supply, reduced food required for energy, increased waste build up and delayed onset (DOMS) muscle soreness leading to pain. [1]

DOMS is different from other acute injuries to the muscle. It usually gets worse 2-3 days following an activity and can last as long as 7 days. The damage and pain seems to be caused by microscopic tears to the muscle tissue. These tears may lead to sub lethal and lethal damage to the muscle tissue that occurs most often at the beginning stages of a weight lifting program, especially those using eccentric contraction. The amount of damage is related to the intensity and duration of the activity. Soreness is caused by activation of free nerve endings around the muscle fiber. [2]

Many methods have been used to reduce pain and soreness so as to allow the athlete to return to competition and peak performance. These methods have included: ice, heat, massage, stretching, whirlpool, prescription and nonprescription drugs, acupuncture, acupressure and electrical stimulation. These treatments work either by blocking brain sensation, reducing the pain source by reducing swelling or by blocking afferent input.[3] Three primary nerve fibers exist which respond to different levels of stimuli. Sensory nerves, large in diameter, respond to the lowest levels of electrical stimulation followed by motor fibers and finally the smallest nerve fibers, pain fibers.

There are a variety of ways to use each of the treatment methods. One can treat with ice for example using an ice bath, ice cup, ice bag or cold compress system. Heat can be applied in the form of hydrocollator packs, whirlpools, ultrasound, or analgesia (counter irritant).[4] Electrical stimulation is no exception, using a wide variety of protocols used to treat pain and injury. It has many different forms and treatment protocols. One can use interferential, premodulated or in some cases biphasic current. However, it must be remembered that pain is due most often to tissue damage. Even if we mask the pain there may not be an improvement in performance since performance can also be affected by tissue damage.

Electrical stimulation

Electrical stimulation has been used in many different ways to treat pain. Interferential, transcutaneous electrical nerve stimulation (TENS), and biphasic stimulation within the pain curve are a few of the different types of treatment with electrical stimulation that are available. These types of electrical stimulation attempt to

relieve pain by blocking the transmission of the pain impulse and by releasing the body's natural opiate response.[3] The two most common ways to increase the input to the nerve fibers is either by increasing the intensity or duration of the current.[4] Although these techniques relieve pain they may not promote healing. According to the Arndt-Schulz law, the current of electricity associated with these forms of treatment may be too high to promote body tissue healing.[5,6] Nerves can respond to electrical stimuli. Traditionally, the stimulus has been at a level to reach the nerve threshold; the minimal level needed to elicit depolarization of the nerve. These stimuli cause the nerve to depolarize but do not necessarily cause healing of the nerve or surrounding tissue.[1]

Microcurrent Electrical Stimulation

This Arndt-Schulz theory has given rise to a resurgence of interest in the use of microcurrent electrical stimulation for the treatment of injury. Microcurrent neuromuscular electrical stimulation (MENS) is the new electrifying treatment of the future. MENS stimulates the body at a threshold level below sensation.[1] The levels of stimulation range between 50-1,000 microamps (uA) as opposed to the more traditional levels.[5,6] The levels of electrical stimulation for alternate methods such as Russian can reach levels as high as 2,500 Hz.[7]

MENS has been reported to increase tissue healing and relieve pain at a quicker rate when compared to a placebo group.[8] These benefits coupled by the lack of discomfort associated with traditional electrical stimulation would make this a great asset to the person treating an athlete. If MENS can do what it is reported to do, it would also be of great benefit to the athlete by relieving pain and promoting tissue healing. The

theory behind MENS is really not all that new. In 1792, Galvini observed that injured tissue produces an electrical current different from healthy tissue. Nerves innervate muscle and both of these tissues are regulated by ions.[1] During injury the body's electrical current is altered causing a disruption of tissue function. As this happens the muscle reaches threshold causing the muscle to go into spasm. This spasm uses energy, which depletes the ATP stores in the cell. It also causes an accumulation of waste, decrease of blood flow and a decrease of oxygen.[1] If the disruption of energy could be controlled it would be advantageous to the athlete. However, we must take into account that the body's electrical current is very low and that we should work within these limits. As early as the 1800's it was reported, "weak stimuli increase physiologic activity and very strong stimuli inhibit or abolish activity" this is called the Arndt-Shulz law.[5] Cheng et al. has also demonstrated favorable results in increased ATP production and protein synthesis using low volt stimulation as opposed to electrical stimulation over 1,000 microamps. Through traditional uses of pain relief using electrical stimulation we may have not been giving them the best possible treatment.[8] Therefore, it may be theorized that by using microcurrent electrical stimulation, we may be able to not only provide pain relief but also promote tissue healing.

Delayed Onset Muscle Soreness

Delayed onset muscle soreness is caused by damaged muscle fibers most commonly caused by unaccustomed eccentric muscle contraction. It has been described as the sublethal and lethal damage to a small group of recruited muscle fibers usually intensifying over the 2 to 3 days following activity. The greatest soreness is caused by

eccentric exercise. The perception of soreness is caused by the activation of free nerve endings. The pain usually subsides within 7 days but the muscle fiber may need as much as 12 weeks to repair.[2] Traditional methods have attempted to relieve pain by fatiguing the nerve endings or by stimulating the release of enkenphalins, opiate like substances.[4] However, this does not promote healing. Therefore, the individual may be relieved of pain but the muscle tissue cannot function any better. This study will attempt to determine if MENS is effective in relieving exercise induced DOMS on the quadriceps musculature of healthy volunteers.

The questions that this study hope to answer:

1) Is microcurrent electrical stimulation effective in returning the quadriceps to peak output following DOMS?
2) Is microcurrent electrical stimulation effective in returning the quadriceps to average peak output?
3) Is microcurrent electrical stimulation effective in treating pain caused by DOMS?
4) How effective is the treatment with microcurrent electrical stimulation compared to a control group?

METHODS

The primary purpose of this study was to determine if microcurrent stimulation at 200 microamps was effective in treating the quadriceps for DOMS and returning it to pre-injury peak torque output. The second purpose of this study was to determine if MENS is effective in reducing pain associated with DOMS. The methods in this section include: Research Design, Subjects, Preliminary Research, Instrumentation, Procedures, Hypotheses, and Data Analysis.

Research Design

This study was used to determine the effectiveness of microcurrent electrical stimulation treatment on return to function after delayed onset muscle soreness. Untrained individuals frequently experience DOMS and it can significantly interfere with performance for 3-5 days following onset.

Specifically, the purpose of this study was to investigate the effectiveness of Microcurrent Electrical Stimulation (MENs) as a treatment for Delayed Onset Muscle Soreness (DOMS) of the quadriceps muscles. This was done by using a positive current at a level of 200 microamps, DC current, at 3 Hz delivered through the affected quadriceps muscles for 20 minutes. Pad placement was determined through motor points that correspond to meridians in the muscle.

This study used a single blind experimental design to study the effects of microcurrent electrical stimulation for the treatment of delayed onset muscle soreness. The independent variable for this study was the microcurrent treatment administered by the Dynatron 950+ muscle stimulator. The dependent variables for this study were perceived pain levels measured using the Visual Analog Pain Scale; and peak torque and average torque values for three repetitions of knee extensions using the Kin-Com 500H isokinetic dynamometer. Each of the volunteer subjects who met the criteria for the study was randomly assigned to one of two groups. Both groups performed concentric and eccentric contractions of the quadriceps muscle for 10 sets of 10 repetitions.[9-11] The first set was a submaximal effort to familiarize the subject with the machine. The first 3 repetitions of the second set were used to determine peak and average torque. Each effort following the first set was a maximal effort and enhanced through visual feedback of the Kin-Com 500H isokinetic dynamometer. These next 8 sets were used to produce DOMS. Group one received treatment with microcurrent electrical stimulation using a direct current at 200 microamps, positive current polarities, at 3 Hz at 24, 48, 72, and 96 hours post DOMS inducement. Group two served as a placebo group and was treated with electrodes that were connected to the Dynatron 950+ but the output was not turned on. The output display was covered during the treatment time for both groups. Therefore, none of the subjects knew if they were receiving treatment since it was sub sensory. All subjects rated their pain on the Visual Analog Pain Scale prior to and following treatment with microcurrent stimulation. All subjects were also tested at 48 and 96 hours post DOMS inducement for maximal and average peak output effort on the Kin-Com 500H isokinetic dynamometer after treatment. Each subject performed a warm-up set of 3

repetitions at sub maximal effort. They then performed 3 repetitions at maximal effort. The peak and average torque was compared to the baseline results obtained the first day.

Subjects

Prior to collecting any data, approval was obtained from the Institutional Review Board for the Protection of Human Subjects (Appendix C-1). The subjects (N=14) in this study were volunteer males and females from California, PA; 7 in the control group and 7 in the experimental group, from the population of associates in the Department of Health Science and Sports Study at California University of Pennsylvania during the 2003-2004 academic school year. Subjects were not currently engaged in a leg-strengthening program within the previous two weeks, and were not currently taking anti-inflammatory or pain relief medication. All subjects were given a letter regarding informed consent (Appendix C-2) and a personal data demographic profile information questionnaire (Appendix C-3). The consent form explained the rights of the participants. After review of the questionnaire participants were given a code number to protect their anonymity.

Preliminary Research

The pilot study was conducted using the stated procedures and methodology to determine if any changes were needed to the design. Three subjects were recruited to participate in the pilot study. They completed the necessary informed consent and

personal profile questionnaire. Each participant was explained the expectations of participating in the study. The Visual Analog Pain Scale was then shown and explained to each subject. All subjects indicated that they had no current pain in their quadriceps. Each subject was then fitted on the Kin-Com 500H isokinetic dynamometer, and the settings were then recorded. The subject then performed a warm up set of 10 repetitions at a submaximal level to allow them to become familiar with the machine. They then performed 10 repetitions at maximal effort. The first 3 repetitions of the second set were used to determine peak and average torque efforts. The next four to six sets of 10 repetitions were used to produce DOMS. Subject one performed 4 sets of 10, subject two 5 sets of 10 and subject three performed 6 sets of 10 of maximal effort or to failure. Concentric and eccentric contractions were performed at ninety degrees per second concentric and sixty degrees per second eccentric, with one minute rest between sets.[9-11] It was necessary to determine if the protocol used for the administration of DOMS would be appropriate. Each subject then reported to the athletic training room the following day to begin treatment with micro current electrical stimulation using the Dynatron 950+ plus. Each subject rated his or her pain on the Visual Analog Pain scale. Next the motor end point for the quadriceps was determined using stated meridians over the proximal end of the quadriceps muscle of the effected leg. This area was marked and the proximal pad was placed over this location. The distal pad was then placed at the distal end of the quadriceps muscle four inches above the joint line in a direct line between the ASIS and the tibial tuberosity. The subjects then received 20 minutes of microcurrent electrical stimulation using a positive current at 200 microamps positive current polarity, at 3 Hz. Following treatment the subject was again asked to rate their pain on the Visual Analog

Pain Scale. The subject was then set up on the Kin Com 500H isokinetic dynamometer for testing for peak and average torque. Each subject performed a warm-up set of 3 repetitions at a sub maximal effort for a warm up. They then performed a three repetition maximal effort to be used for comparison to base levels. This was done to determine the length of time needed for treatment and testing of each subject. From the pilot study it was determined that for the study additional repetitions on the Kin-Com 500H isokinetic dynamometer would be needed to induce DOMS. Ten sets of 10 repetitions were needed to produce DOMS on all of the subjects. The first set was a warm up set. The first 3 repetitions of the second set were used to collect data. The remaining repetitions were used to produce DOMS.

Instrumentation

The instruments used in this study included: an informed consent form, a demographic data questionnaire, the Kin-Com 500-H isokinetic dynamometer machine, the Dynatron 950+ micro current electrical stimulator, and the Visual Analog Pain Scale (Appendix C-4). The information from the demographic data questionnaire was used primarily to give a profile of the subjects and to identify subjects that treatment is contraindicated. Demographic data included: height, weight, age, and gender. The demographic data questionnaire was used to determine dominant leg. Contraindications to treatment with electrical stimulation are: pregnancy, heart patients with pacemakers or those with a malignant tumor.[1]

Kin-Com 500-H Isokinetic Dynamometer Machine

The Kin-Com 500-H isokinetic dynamometer was used to induce DOMS, and to measure quadriceps concentric and eccentric strength. The Kin-Com 500-H isokinetic dynamometer has been used successfully in other studies to test peak and average torque, and to induce DOMs to the quadriceps muscle.[11] Each subject was fitted to the Kin-Com 500-H isokinetic dynamometer and the settings were recorded to assure consistency for testing. The range of motion was set at 90 degrees to 25 degrees.

Dynatron 950+ Electrical Stimulator

The Dynatron 950+ plus electrical stimulation machine was used to treat the subjects using the microcurrent setting with the following parameters: 3 Hz, positive current at 200 microamps.[12] To ensure that the subjects did not know the output used during their treatment a piece of paper was taped over the output reading on the Dynatron 950+ display panel.

Visual Analog Pain Scale

The Visual Analog Pain Scale (Appendix C-4) was used to determine the amount of perceived pain in the quadriceps before and after treatment with microcurrent electrical stimulation. The scale or similar scales have been used in other studies to rate perceived pain associated with DOMS.[9,11,13,14] The Visual Analog Pain Scale consisted of a 10-centimeter line. At the end of the line on the left hand side was a perpendicular line

indicating no pain and on the right had side was a perpendicular line representing the worst pain imaginable.

Procedures

After gaining approval from the Institutional Review Board for the Protection of Human Subjects (Appendix C-1), a pilot study was conducted. After the pilot study, subjects were obtained by recruiting from people at California University of Pennsylvania. All volunteers were given an informed consent form explaining the purpose of the study, what to expect during testing, what would be expected of them, and their rights (Appendix C-2). Each participant was then given a personal demographic data profile questionnaire (Appendix C-3). Following filling out the forms the key points were highlighted for the participants and they were given the opportunity to ask questions. The participants were then randomly assigned to one of two groups. After assignment to a group the participants were scheduled for a time to report for testing and treatment. Each participant performed their warm up set on the Kin Com 500-H isokinetic dynamometer. Average and peak torque was determined from the first three repetitions of the second set. The results from the Kin-Com 500-H isokinetic dynamometer were recorded and saved. Each participant then continued with the 8 sets of 10 repetitions to induce DOMS. Each participant was encouraged to perform maximal effort and received visual feedback from the Kin-Com 500-H isokinetic dynamometer screen. Participants were reminded not to partake in any other form of pain relief such as

ice, anti-inflammatory or other pain medication. They were then instructed to return in 24 hours to begin treatment.

The following day subjects rated their pain using the Visual Analog Pain Scale. They then either received a 20-minute treatment with microcurrent electrical stimulation with a direct current of 200 microamps, positive polarity current, at 3 Hz or a placebo. The placebo was administered by attaching electrodes to the subject but without the output being turned on. Subjects were prevented from seeing the screen on the Dynatron 950+. Subjects then again rated their pain levels. On the second day participants rated their pain using the Visual Pain Analog scale, received the appropriate treatment, subjects again rated their pain using the Visual Pain Analog Scale, they then performed a warm up set of 3 repetitions and then a set of 3 repetitions on the Kin-Com 500H isokinetic dynamometer to determine average and peak torque output. Participants returned on days 3, 4, and 5 post exercise and repeated the procedures stated above. Treatments with microcurrent occurred every day and testing on the Kin-Com 500 isokinetic dynamometer occurred again on day four.

Research Hypotheses

This study investigated the following hypotheses:

1. Subjects receiving microcurrent electrical stimulation will have peak torque values significantly higher than the control group following treatment during concentric and eccentric contractions.

2. Subjects receiving microcurrent electrical stimulation will have higher average peak levels compared to the control group during concentric and eccentric contractions.
3. There will be a significant difference in the mean pain score between those receiving microcurrent electrical stimulation and a control group.
4. There will be a significant difference in the mean pain score between pre and post treatment.

Data Analysis

For all tests of statistical significance performed on the data, the alpha level was set at .05. The following summarizes the statistical tests used for each hypothesis.

Hypothesis 1: The independent t-test was used to determine if the application of microcurrent electrical stimulation significantly improved concentric and eccentric torque values.

Hypothesis 2: The independent t-test was used to determine if the application of microcurrent electrical stimulation significantly improved average peak levels for concentric and eccentric contractions.

Hypothesis 3: The dependent t- test was used to determine the daily pre and post treatment visual analog results.

Hypothesis 4: The dependent t-test was used to determine if there was a significance difference in perceived pre-treatment and post-treatment mean pain levels between the treatment and control groups.

RESULTS

The purpose of this study was to determine if microcurrent electrical stimulation significantly improved daily peak and average values of the quadriceps muscle following delayed onset muscle soreness. It also attempted to determine if microcurrent electrical stimulation relieved pain values following delayed onset muscle soreness. The study used the Kin-Com 500-H isokinetic dynamometer to determine the peak and daily peak values. The Visual Analog Scale was used to record pain level changes.

Demographic Data

The 14 subjects in this study were volunteer males and females from the population of associates in the Department of Health Science and Sports Study at California University of Pennsylvania during the 2003-2004 academic school year. The age of the subjects ranged from 19 to 42. The mean age was 23.9 years of age. The group consisted of 8 females and 6 males. The subjects denied having preexisting knee or heart pathologies.

Hypotheses Testing

The following hypotheses were tested for the study. All of the hypotheses were tested at the .05 alpha level.

Hypothesis 1: Subjects receiving microcurrent electrical stimulation would have a) peak torque values significantly higher than the control group during concentric contraction of the quadriceps following treatment, b) peak torque values significantly higher than the control group during eccentric contraction of the quadriceps following treatment.

An independent T-test was used to compare the mean scores of the concentric peak torque values of the treatment group to the mean scores of the placebo group on days three and five. It was also used to compare the mean scores of the eccentric peak torque values of the treatment group to the mean scores of the placebo group on days three and five.

Conclusion: The independent T-test was used to compare the peak torque values of the group receiving microcurrent electrical stimulation to a placebo group. The effect of microcurrent electrical stimulation causing a change in the quadriceps peak torque value during a concentric on day three was not significant ($t(10) = .34$, $P < .05$) nor was it significant on day five ($t(11) = .38$, $P < .05$).

Table 1. Comparison of peak torque values during concentric contraction on day 3

Groups	N	Mean	St. Dev.	SE Mean	t	*P*
Treatment	7	80.4	44.1	17	0.34	0.36
Control	7	73.4	31.2	12		

Table 2. Comparison of peak torque values during concentric contraction on day 5

Groups	N	Mean	St. Dev.	SE Mean	t	*P*
Treatment	7	75.0	40.5	15	0.31	0.38
Control	7	68.9	32.8	12		

The effect of microcurrent electrical stimulation returning the quadriceps to peak torque value during an eccentric contraction on day three ($t(9) = .91$, $P < .05$) and day five ($t(9) = 1.5$, $P < .05$) was also not significant. Although the peak values for eccentric contraction improved from Day 3 to Day 5 for the treatment group they were not significantly different from the placebo group. The peak values for the eccentric contraction showed greater difference than the concentric contraction but again the treatment group was not significantly different than the placebo group at the .05 level.

Table 3. Comparison of peak torque values during eccentric contraction on day 3

Groups	N	Mean	St. Dev.	SE Mean	t	*P*
Treatment	7	64.4	32.9	12	0.91	0.19
Control	7	51.6	18.1	6.9		

Table 4. Comparison of peak torque values during eccentric contraction on day 5

Groups	N	Mean	St. Dev.	SE Mean	t	*P*
Treatment	7	62.9	29.4	11	1.5	0.078
Control	7	43.1	16.5	6.2		

Hypothesis 2: Subjects receiving microcurrent electrical stimulation will have higher average peak levels during: a) a concentric contraction of the quadriceps muscle compared to the control group; b) an eccentric contraction of the quadriceps muscle when compared to a control group.

An independent t-test was used to compare the mean scores of the concentric average torque values of the treatment group to the mean scores of the concentric average torque values of the placebo group on days three and five. It was also used to compare the mean scores of the eccentric average torque values of the treatment group to the mean scores of the placebo group on days three and five.

Conclusion: The independent t-test was used to compare the average torque values of the group receiving microcurrent electrical stimulation to a placebo group. The effect of microcurrent electrical stimulation on the quadriceps average torque value during a concentric on day three was not significant when compared to the control group. ($t(10) = .25$; $P < .05$) nor was day five ($t(11) = .26$; $P < .05$).

Table 5. Comparison of average peak torque values during concentric contraction on day 3

Groups	N	Mean	St. Dev.	SE Mean	t	*P*
Treatment	7	53.4	32.9	12	0.25	0.404
Control	7	49.7	21.7	8.2		

Table 6. Comparison of average peak torque values during concentric contraction on day 5

Groups	N	Mean	St. Dev.	SE Mean	t	*P*
Treatment	7	51.1	30.3	11	0.26	0.399
Control	7	47.4	22.3	8.4		

The effect of microcurrent electrical stimulation on the quadriceps average torque value during an eccentric contraction on day three when compared to the control group was also not significant at the .05 level ($t(9) = 1.09$; $P < .05$). Although the average values for eccentric contraction improved from Day 3 to Day 5 for the

treatment group they were not significantly different from the placebo group (t(7) = .98; $P < .05$). The average values for the eccentric contraction showed greater difference than the concentric contraction but again the treatment group was not significantly different than the placebo group.

Table 7. Comparison of average peak torque values during eccentric contraction on day 3

Groups	N	Mean	St. Dev.	SE Mean	t	*P*
Treatment	7	47.0	22.7	8.6	1.09	0.152
Control	7	36.4	12.1	4.6		

Table 8. Comparison of average peak torque values during eccentric contraction on day 5

Groups	N	Mean	St. Dev.	SE Mean	t	*P*
Treatment	7	41.6	24.8	9.4	0.98	0.181
Control	7	31.71	9.96	3.8		

Hypothesis 3: There will be a significant difference in the mean pain score between pre and post treatment.

A dependent t-test was used to calculate the difference between the mean pain scores from pre-treatment to the mean pain scores from post treatment for the group receiving microcurrent electrical stimulation. Results are located in Table 9.

For the first day of treatment, the mean of the pre-treatment score was 1.2 (SD = .936) and the mean post-treatment score was 1.057 (SD = .757). No significant difference was found from pre-treatment to post-treatment. For the second day of treatment, the mean pre-treatment score was 1.2 (SD = 1.53) and the mean post-treatment score was .829 (SD = .991). Day two showed the greatest difference but no significant difference was found from the pre-treatment to post-treatment at the .05 level. The third day mean pre-treatment score was .386 (SD = .273) and the mean post-treatment score was .357 (SD = .282). No significant difference was found from pre-treatment to post treatment. For the fourth day of treatment, the mean of the pre-treatment score was .429 (SD = 1.04) and the mean post-treatment score was .314 (SD = .747). Again no significant difference was found from the pre-treatment to the post-treatment. Finally on day five of treatment, the mean pre-treatment pain score was .05 (SD = .122) and the mean post-treatment score was .05 (SD = .122). No significant difference was found from the pre-treatment to the post-treatment and since all values were the same, only one person reported pain that remained the same, the T-Test mean difference was 0.

Conclusion: there was not difference between the treatment group for pre and post-treatment mean pain score.

Table 9. Daily mean pain scores comparing pre-treatment vs. post treatment in treatment group

Groups	N	Mean	St. Dev.	SE Mean	t	*P*
Day 1 pre	7	1.20	0.936	0.354	1.01	0.351
Day 1 post	7	1.057	0.757	0.286		
Day 2 pre	7	1.20	1.539	0.0582	1.70	0.141
Day 2 post	7	0.829	0.991	0.375		
Day 3 pre	7	0.386	0.273	0.103	0.60	0.569
Day 3 post	7	0.357	0.282	0.107		
Day 4 pre	7	0.429	1.048	0.0396	1.00	0.356
Day 4 post	7	0.314	0.747	0.282		
Day 5 pre	6	0.050	0.1225	0.050	*	*
Day 5 post	6	0.050	0.1225	0.050		

*all values in columns were identical

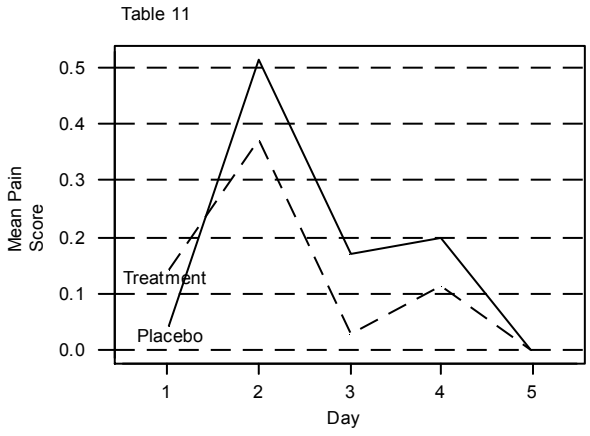
Hypothesis 4: There will be a significant difference in the mean pain score between those receiving micro current electrical stimulation and a control group. A dependent t-test was calculated to compare the mean pain scores for the treatment and control groups. Results are located in Table 10 and comparisons are located in figure 1. None of the days showed a significant difference in pain levels between the treatment group and the placebo.

Table 10. Daily mean pain scores comparing treatment group vs. control group

Groups	N	Mean	St. Dev.	SE Mean	t	*P*	df
Day 1 tre	7	0.143	0.373	0.14	0.53	0.304	11
Day 1 pl	7	0.043	0.336	0.13			
Day 2 pre	7	0.371	0.579	0.22	-0.44	0.667	11
Day 2 pl	7	0.514	0.623	0.24			
Day 3 tr	7	0.029	0.125	0.047	-1.35	0.893	8
Day 3 pl	7	0.171	0.250	0.094			
Day 4 tr	7	0.114	0.302	0.11	-.035	0.632	9
Day 4 pl	7	0.020	0.580	0.22			

*Day 5 data resulted in 0 and therefore no data available

Conclusion: There were no differences in mean pain scores between the treatment group and the placebo group.



DISCUSSION

The following section is divided into three parts: discussion of the results, conclusions and recommendations.

Discussion of Results

The purpose of this study was to determine if a treatment method of using microcurrent electrical stimulation would be an effective means of treating delayed onset muscle soreness. A protocol was developed that tested the use of microcurrent electrical stimulation at a level of 200 microamps, positive polarity at 3 Hz for 20 minutes against a placebo group. The subjects would be compared not only on their perceived pain levels as determined by a visual analog scale but also on their strength performance. The strength performance was measured on a Kin-Com 500-H isokinetic dynamometer and it measured peak and average torque. Each subject performed concentric and eccentric contractions on the Kin-Com 500-H isokinetic dynamometer for 10 sets of 10 repetitions to produce delayed onset muscle soreness.

The first and second hypotheses tested stated there would be a significant difference in the subjects' strength in peak and average torque on days 3 and 5. The statistical analysis showed that there was no significant difference between the treatment group and the placebo group in peak and average torque.

Hypothesis three stated there would be a significant difference in the daily pre-treatment and post-treatment perceived pain scores for those receiving treatment with micorcurrent electrical stimulation. There was no significant difference in the daily pre-treatment and post-treatment pain scores on days one through five. However, day two did show values nearing a level of significance but not at a level to show true significance.

Hypothesis four stated that there would be a difference mean pain scores between the treatment group and the placebo group. The results did not show a significant difference in mean pain scores between the treatment group and the control group. It is also worthy to note that both groups, placebo and treatment, returned to pain free levels by day five

The original design of this study was changed due to the availability of subjects and the effects of DOMS. Only 14 subjects were used as opposed to the desired 18-24 due to the lack of available subjects. To induce DOMS using the Kin-Com 500-H dynamometer it was necessary to increase the number of sets and repetitions. It was found during the pilot study that an increase to 10 sets and 10 repetitions was necessary to obtain the desired results of DOMS. The study was also shortened to five days from the scheduled six days since all subjects but one returned to zero pain by day five. The one subject that had pain rated it a .5 out of a scale of 10 with no change in pain levels following treatment. The *t* and *p* values were zero due to the data results on day five. The pain associated with DOMS is consistent with the anticipated effect reported in *Rehabilitation Techniques in Sports Medicine*.[4] The results related to the treatment of

pain with microcurrent electrical stimulation are also consistent with other research treating with electrical stimulation.[9,11] Other studies have shown that microcurrent electrical stimulation has not significantly improved ROM, but have not compared muscle strength testing.[9] The results of this study did not compare ROM but did examine eccentric and concentric muscle contraction. Although the results did not show a significant difference in the treatment and placebo group, a larger group may reveal different results. Also a test studying the effects of microcurrent on chronic pain may reveal different results. Studies have shown that ATP production increase with microcurrent electrical stimulation over time.[5] Other studies have also shown that microcurrent electrical stimulation has improved healing time with conditions that last a longer time to heal.[14] The short healing time related to DOMS, 5-7 days, may not be long enough to see the benefits of treatment with microcurrent. Most of the original information for the treatment with microcurrent did not examine pain relief. However, studies conducted more recently have looked at the reduction of pain levels following treatment with microcurrent electrical stimulation.[11,13] The original studies showed an increase in the ATP production.[14] This study did not look specifically at ATP changes at the cellular level. It did attempt to determine if muscle strength would be significantly improved through the treatment with microcurrent electrical stimulation due to the possible increase of ATP. The short duration of the need for treatment related to DOMS may have an affect on the possible benefits of microcurrent electrical stimulation. The studies that showed the greatest benefit from microcurrent electrical stimulation were on chronic injuries such as bone and ulcer healing. [1,5,7]

Conclusions

Based on the results of this study, the exact importance and parameters of the use of microcurrent electrical stimulation have yet to be determined. The information from this study indicates that the stated protocols of treatment with MENs are not effective for pain relief or function of the quadriceps muscle following DOMS. Specifically:

1. Peak concentric contractions of the quadriceps for those receiving microcurrent electrical stimulation for the treatment of DOMS over five days were not significantly different from those receiving a placebo.
2. Peak eccentric contractions of the quadriceps for those receiving microcurrent electrical stimulation for the treatment of DOMS over five days were not significantly different from those receiving a placebo.
3. Microcurrent electrical stimulation did not significantly improve average peak torque concentric contractions of the quadriceps for subjects receiving microcurrent electrical stimulation to those receiving a placebo.
4. Microcurrent electrical stimulation did not significantly improve average peak torque concentric contractions of the quadriceps for subjects receiving microcurrent electrical stimulation to those receiving a placebo.
5. There was no significant difference in the pre-post treatment scores in those subjects that received microcurrent electrical stimulation over a five day period.
6. There was no significant difference in the daily mean pain scores for those receiving microcurrent electrical stimulation to those receiving a placebo.

Recommendations for Future Research

While this study did attempt to examine the effect of microcurrent electrical stimulation on an acute injury such as delayed onset muscle soreness further research is still need to determine if there are any practical uses for MENS. The specific following recommendations are suggested for future research in this area.

1. Future research studies should investigate altering the type of current used with the treatment of microcurrent electrical stimulation.
2. Additional studies should be performed on injuries requiring a longer healing time than five days.
3. Future studies should be done on healthy individuals to compare muscle strength during eccentric and concentric contractions following treatment with microcurrent electrical stimulation.
4. Additional studies should be conducted to investigate the impact of microcurrent electrical stimulation following DOMS.
5. Further studies should be conducted using longer treatment times with microcurrent electrical stimulation on the treatment of DOMS.

References

1. Weiss D, D'more G, Rothrock RW. Microelectrical Nueromuscular Stimulation: Theory and Techniques *Osteopathic Medical News.* 1984-1991: 34-35.

2. Arnheim D; Prentice W. *Principles of Athletic Training*. 8th ed. St. Louis, MO: Mosby-Year Book, Inc. 1993; 155-156.

3. Weider D. Microucurrent Therapy: "Wave" of the Future? *Rehab Management.* February/March 1991.

4. Prentice W. *Rehabilitation Techniques in Sports Medicine.* St. Louis, MO: Times Mirror/Mosby-College Publishing, Inc. 1990; 124-126.

5. Picker MD R. Current Low-Volt Pulsed Microamp Stimulation, Part 1 *Clinical Management.* 9,2:10-14.

6. Picker MD R. Current Low-Volt Pulsed Microamp Stimulation, Part 2 *Clinical Management*. 9,3:28-33.

7. McAuliffe K. I Sing the Body Electric *Omni Scientific.* 72-73,98-99.

8. Cheng N, Van Hoof H, Bockx E, et al. The Effects of Electrical Currents on ATP Generation, Protein Synthesis and Membrane Transport in Rat Skin *Clinical Orthopedics*. November/December 1982; 171:264-271

9. Anderson M. The Effects of Massage on Delayed Onset Muscle Soreness *Research Thesis California University of Pennsylvania.* 1996.

10. Hoagland S. The Effects of Ice, Heat, and Stretch on Delayed Onset Muscle Soreness *Research Thesis California University of Pennsylvania.* 1997.

11. Jenkins T. The Effectiveness of Treatment Times using Transcutaneous Electrical Nerve Stimulation in Treating Muscle Soreness *Research Thesis California University of Pennsylvania.* 1994.

12. Harrington D, Meyer Jr R. Effects of Small Amounts of Electric Current at the Cellular Level *Annals New York Academy of Science*. 1974; 238: 300-304

13. Schening P. Use of Acupressure Points and Electrical Stimulation for the Treatment of Delayed Onset Muscle Soreness *Research Thesis California University of Pennsylvania.* 1994.

14. Carley P, Wainapel S. Electrotherapy for Acceleration of Wound Healing: Low Intensity Direct Current *Archive Physical Medicine Rehabilitation.* July 1985; 66:443-445.

Appendix A

Selected Review of the Literature

Review of Literature

The purpose of this section is to review the literature pertaining to the use of microcurrent electrical stimulation as it relates to the treatment of delayed onset muscle soreness (DOMS). There seems to be contradicting information to the reported benefits of microcurrent electrical stimulation. This section will give a historical overview of electrical stimulation as well as evaluate some of the more recent studies using microcurrent for pain relief and tissue healing.

During the mid 1980's through the early 1990's there was a resurgence of interest in the healing properties of microcurrent electrical stimulation. This was supported by a number of testimonial findings such as those reported by Lynn Wallace.[1] However, more recently there have been contradictory findings regarding the treatment with micro current electrical stimulation such as the investigation by Jennifer Allen et al.[2] Microcurrent stimulation is an electrical current delivered to the body below nerve stimulation, at a level below 1,000 microamps (uA).[3]

The reported healing powers of electrical current are nothing new. As early as 2697-2597 BC, the Chinese reported an energy source responsible for healing powers. This energy power is called Qi or Chi which is composed of the Ying and Yang. In "The Yellow Emperor's Classic of Internal Medicine" they describe the ability to balance an inner energy as Qijong. Illness was the obstruction of the flow of energy in Meridians. When an obstruction occurred it caused an imbalance of the energy. The Meridians were

pathways that carried essential nutrients. These systems are closely related to blood vessels and nerve pathways.[4] Many of the Meridians are located at a motor end point.

Motor end points are areas where a muscle is easily excited with minimal electrical stimulation. They also found that by stimulating these points they were able to treat internal diseases.[4] The Chinese tried to open the channels or pathways by stimulating specific points through acupressure or acupuncture. Although these forms of treatment are controversial, there are studies that have shown favorable results using these methods. In a study using acupressure for the treatment of exercise-induced delayed onset muscle soreness, the researchers demonstrated a reduction of healing time for the group receiving treatment. The treatment was theorized to connect the flow of energy and therefore decrease healing time.[5] The use of acupressure and acupuncture attempt to correct the electrical flow of the body. It is believed that there are substances in the skin that can act as neurotransmitters.[4] Since the body works on currents of electricity supplied by ions it is possible that this type of stimulation may affect the energy flow. It is common knowledge that the nervous system and muscular system work through an electrical current supplied by ions. As a matter of fact all cells are affected by changing of electrical currents.[6] In the 18th century, a scientist named Galvani observed that injured tissue generated electrical currents different from healthy cells and he called it the "current of injury". Although he had no way of directly measuring the difference in current he was able to indirectly observe the current when observing the reaction of a frogs leg strung between two pieces of metal. This theory was reaffirmed in the Arndt-Schultz law during the late 1800's, which states; "Weak stimuli increase physiologic activity and very strong stimuli inhibit or abolish activity".[7]

During the Civil War, Dubois-Reymond reported on the observations of injury current. While working on injured soldiers he noted that injured tissue seemed to produce a different current than healthy tissue.[8] This current was later to be observed by Dr. Becker. This current was thought to be caused by the loss of intracellular ions and the disruption of the sodium pump.[9,10] Following World War II, Dr. Becker while working with veterans had access to electronic technology that allowed him to work and study electrical currents in the body. He noted that following an injury cells become "leaky". Ions pour out of a cell and cause a current of injury. If this flow of ions could be altered in a positive manner we can possibly decrease the amount of damage done to the tissue and reverse the effects. This would allow individuals to heal quicker. A colleague of Dr. Becker, who expanded on this theory, was able to produce tissue growth on frogs. Dr. Becker was again intrigued by the research and continued to work on his own research. Dr. Becker believed he found a second current carried through the peripheral nervous system. This current, while carried on the peripheral nervous system, is different from the traditional nerve transmission in that it is a constant flow rather than a burst of current. He claimed that a disruption of this field pattern caused current changes and could cause tissue to damage. If one could correct the field pattern they could theoretically cause healing. It also seemed that cells respond as well to artificial electrical currents as their own. If cells do respond to artificial stimuli from an external source such as acupuncture, acupressure or electrical stimulation it would be of great benefit for the healing process.[10,11] Most people were skeptical of Dr. Becker's claims. In 1982 further physiological benefits using microcurrent were reported, in a study by Cheng et al. at the University of Louvain, Belgium. He found a 500% increase in ATP

levels while using microcurrent stimulation. He also reported 30-50% increase in protein synthesis and membrane transport while using microcurrent electrical current. Interestingly, he also found a reverse of the effect in currents over 5,000 microamps.[6,7,9] Although this study in 1982 was done on rats, it caused a resurgence in the interest in the powers of microcurrent electrical stimulation. Health professionals started exploring and using microcurrent for the treatment of injuries. Microcurrent electrical stimulation was being used to treat injuries such as arthritis, nonunion fractures, neuropathies, joint dysfunction, and wound healing.[9]

From basic physiology it is understood that muscles and nerves work through electrical charges controlled by ions. When an injury occurs to muscle tissue the muscle tissue and nervous tissue are affected. The muscle goes into spasm. The spasm reduces blood flow to the area depriving tissue of needed elements for tissue healing. In addition, the trauma causes a decrease in ATP production, disruption of the sodium pump and an increase of metabolic waste.[9] One reported benefit of microcurrent electrical stimulation is an increase in ATP production.

Since one of the negative results of an injury is a decrease in ATP production, this increased response would be of great benefit to returning injured tissue to a healthy state. ATP is the primary source of energy used by the cell. This energy drives the metabolic reactions and production of proteins.[12] The most notable study on the increased production of ATP following treatment with microcurrent electrical stimulation was performed by Cheng et.al. They found that currents from 50 microamps up to 1,000 microamps had a favorable result in protein synthesis and ATP production. The increase in ATP production was threefold to fivefold. When currents exceeded 1,000 microamps

a reduction of protein synthesis by 50% was noted and ATP production leveled off. The treatment time was 2 hours in length. It is felt by some that this may be one of the bases for the reported benefits from microcurrent electrical stimulation.[6]

Health care professionals have attempted to treat patients using a variety of forms of electrical stimulation. High volt, biphasic, TENS, and interferential are a few of the more common forms used to treat pain. In order for the pain to be reduced one of three things must happen: it must block the brains ability to sense pain, reduce afferent input or restore tissue to a non-injury state.[11] The traditional forms of high frequency electrical stimulation have attempted to treat pain by affecting the afferent input to the CNS. There are three types of nerve categories in the peripheral nervous system: sensory, motor and pain (nocipceptors). Each of these has a different level of threshold; the minimal stimulus needed to cause a reaction. Nerves operate on the "all or none" theory. If threshold is reached the nerve fires and if it is a subthreshold stimulus no impulse is sent. Sensory nerves have the lowest threshold and pain fibers have the highest. Nocioceptive fibers are sensitive to tissue dysfunction. Deformation of nocioceptive fibers may cause pain sensation.[11] Basically, when a muscle fiber is injured it activates pain neurons. These traditional forms of electrical stimulation work through initiating either the gate theory or by causing the release of endorphins. These reactions cause an analgesic response in the body.[9,13,14] One of the biggest complaints of this type of electrical stimulation treatment is that it simply masks pain rather than causing healing.[15]

Microcurrent electrical stimulation in theory would be superior to these traditional forms of electrical stimulation because it would reduce pain because it would case tissue healing. Instead of masking the pain, microcurrent electrical stimulation would return the

tissue to its pre-injury state. Dr. Becker has shown that the body has an electro field that is reversed when tissue is injured. Microcurrent is compatible with the body's natural system and therefore it can reverse the damage done during an injury.[16] Initial testimonies using microcurrent electrical stimulation were very encouraging. Athletes such as Carl Lewis and Jackie Joyner were singing its praises.[17] Physical therapist Lynn Wallace reported a great amount of success in patients treated with microcurrent electrical simulation. Lynn Wallace measured the pain relief response in N=1531 patients. The patients suffered from a variety of injuries. The injuries ranged from acute, sub-acute to chronic in nature. His study revealed a reduction of pain in 94% of the patients after the first treatment. Ninety percent of the patients were virtually pain free in less than 10 treatments.[11,17,18] There were other health care professionals observing positive results using microcurrent electrical stimulation. In one report, microcurrent stimulation reportedly relieved TMJ pain in 76% of the cases.[13] Another observation of the benefits was made by other PT's for the treatment of painful neuropathies of lower extremities casued by AIDS.[19] These initial claims were not part of well controlled studies. The study by Lynn Wallace for example, although it used a 0-10 visual pain scale to rate pain, did not utilize a control group.[11,17] The other claims were also part of observations by the physical therapists that recognized the need for more controlled studies such as in the case of the treatment of neuropathies in patients with HIV.[19]

The challenge was to have well controlled studies to support the use of MENS for treatment of pain and to determine proper treatment parameters. Since the first observations of body current it was determined that the peripheral and central nervous system operated on different currents. The central nervous system seemed to respond

better to a cathodal (negative) current and the peripheral system responded in general to an anodal (positive) current. It was also observed that if the peripheral system was introduced to a cathodal (-) current negative results occurred.[17] The optimal current voltage also needed to be established since currents over 1,000 microamps reverse certain physiological effects.[6]

Some of the initial controlled studies continued to support some of the early observations. A double blind study comparing pain relief in chronic back patients was performed by Lerner and Kirsch. They showed that by treating subjects 3 times a week for two weeks chronic back pain was improved by 37% compared to a placebo group. The treatment group also reported a 75% pain relief compared to a 6% pain relief of the placebo group on a two month follow-up.[15] Other studies followed and showed a lot of promise for the potential of pain relief using microcurrent electrical stimulation. Dr. Morarity at Notre Dame University found a 78% positive effect in the treatment of ankle sprains in a double blind study using microcurrent electrical stimulation.[16]

Another study utilizing microcurrent to treat edema, range of motion and pain in lateral ankle sprains showed a significant difference in functional pain in the treatment group. The group in this study was small and consisted of 12 subjects.[17] Microcurrent was also found to be beneficial in the treatment of delayed onset muscle soreness (DOMS). A double blind study was conducted on 48 adults. Patients stimulated at 100 microamps showed favorable results when compared to subjects either treated at 40 microamps or a control group.[20] Treatment times in some of these studies lasted as long as two hours three times a day. Other studies showing positive results for the treatment

of knee pain and elbow pain used long treatment times ranging from 30 minutes to an average of nine hours.[3]

Unfortunately, not all studies have claimed similar results. A study on pain relief in epicondlyitis showed no significant difference in pain free ROM in the treatment group compared to a control group. The subjects were treated for 30 minutes 3 times a week for two weeks. It was determined that microcurrent was as insufficient in treating corocacromial pain when compared to a control group.[3] Even the treatment of DOMS has come into question following a number of double blind studies. The Journal of Athletic Training published a study by Jennifer et al. that reported that MENS was not effective in treating DOMS. Using a graphic rating pain scale, pain response of subjects showed no significant difference in their responses. In addition they did not find a significant difference in ROM scores following treatments. The subjects received a 20 minute treatment at 24, 48 and 72 hours. The treatment parameters ranged from 200 microamps to 100 microamps.[2] In a study done at California University of PA it was concluded that using microcurrent electrical stimulation over acupressure points showed no significant results for the reduction of pain for DOMS.[21] Other studies have also been referenced that do not support the use of microcurrent stimulation for the treatment of DOMS.[22]

It is obvious that the use of microcurrent for the relief of pain is still controversial and may need continued research. There have been other reported treatments from microcurrent electrical stimulation. Research has been done to determine the effectiveness of microcurrent electrical stimulation on wounds, and to help accelerate bone and tendon repair. Neil Speilholg at New York University medical center reported

that he observed greater tendon strength in those stimulated with lower currents of 40 microamps. A study conducted in 1985 demonstrated a 91% higher praline uptake in tendons over a control. They concluded that tendoblast repair was enhanced by microcurrent stimulation. A physician for the Canadian Olympic team claimed that he shortened the 18 month recovery period for ruptured tendons and ligaments down to six months.[7] Studies have confirmed better protein synthesis by as much as 255% when using microcurrent stimulation over a 7-day period.[6]

Others have found that fractures stubborn to healing responded to healing when a subject was fitted with a coil that carried a current around the bone. Dr. Bassett was one of the first to use electricity on bone fractures, hypothesizing that red blood cells stimulate new tissue. These red blood cells collect and special marrow cells provide the DNA to create new tissue. Cells around the peripheral nervous system that produce a low continuous current enhance this. Cells also respond to artificially induced currents as wells as the body's own. The treatment time was relativity long in duration. The patients were treated for 12 hours a day over a 4 to 6 month period.[10] The problem with the use of electrical stimulation for bone healing is that it requires a coil inserted into the bone.[10,23] This form of treatment is beyond the scope of the athletic trainer. Most often a negative current is used to treat non-union bone fractures. This is similar to the intrinsic current produced when mechanically stressing the bone.[24] Gault and Gatens also reported that the healing time for groups with fractures as well as other injuries responded in half the time when using microcurrent.[14]

The possible uses of microcurrent electrical stimulation in the medical field are numerous. One of its uses has been for the treatment of open wounds and ulcers.

Assimcopoulus used a negative current of 75 microamps to 100 microamps for the treatment of ulcers. He reported quicker healing time and stronger scar formation when using microcurrent electrical stimulation. Wolcott and associates also reported favorable results using a similar protocol. They treated wounds using a 200 microamps to 400 microamps negative current for two hours three times a day. They reported healing rates of 2 to 3.5 times faster than a control group. Patrick Carley and Wainapel again were successful in recreating similar results. Using negative currents of 300-500 microamps, they found that wounds healed 1.5 to 2.5 times faster than a control group treated with wet to dry gauze. Again the treatment time in this study was relatively long; two hours of stimulation twice a day. It is also important to note that the results did not occur until the third week of treatment since no significant difference was noted in the first two weeks.[25]

Not all studies have had as favorable results as the ones mentioned. Harrington and Meger studied the effects of Low-intensity direct current (200 microamps) on wounds in rats. They treated 1 cm long incisions on rats with a four hour 200 microamps current. Results showed that after 24 and 48 hours the rats receiving a negative current had a poorer result than the control group and those who received a positive current showed no significant difference.[26] It is important to note that there were a few differences in the studies. This study only performed one treatment time immediately following the incision and the results were taken at 24 and 48 hours. In another study on incision wounds, researches also found no significant difference in the healing rate of wounds on those treated with microcurrent compared to a control. The treatment time in this study was of longer duration. Wounds were treated for one hour for five days. The researches compared tensile strength, collagen density, and wound size.[27] Studies

showing positive results reported them up to two weeks following daily treatments with an average of four to six hours. Again there seems to be a lot of controversy and discrepancy between results. Some authors have noted favorable results with a positive current.[22,24] Others have shown negative results with a positive current and more favorable results with a negative current.[25]

Microcurrent electrical stimulation is still controversial at best. It has been reported to increase ATP production, accelerate wound and bone healing, increase tendon tensile strength and relieve pain. It has been used to treat all types of soft tissue injuries such as myofasciatis, tendonitis, bursitis, sprains, and synovits.[7,11] However, for every favorable observation there is one that contradicts its findings.[23] Continued controlled studies need to be performed to determine if there is a benefit from the use of microcurrent electrical stimulation. In addition consisted well developed protocols need to be established. Is it better to use a positive, negative or alternating current? What is the optimal treatment time: 15 minutes or 2 hours, 3 times a day? Only through continued research can it be determined whether microcurrent is a valuable treatment option.

The concept that the body has a current of electricity that regulates physiological functions and that damage to the body can disrupt this current. The Chinese have documentation of this as early as 2697 BC and it has been observed by physicians working with injured individuals at different times in history. It was also only a matter of time that individuals working with the injured would try to correct this disruption. In early times the use of acupuncture and acupressure were used to try and correct this electrical field. However, in more recent times researchers have tried to correct the

electrical current of healing by mimicking it with an external source. This led to the use of microcurrent electrical stimulation. Microcurrent is different from traditional forms of electrical current because it does try to mimic the body's natural current.

Microcurrent because of its similarities to the bodies own current levels has been used on a wide range of injuries. It has been used in an attempt to treat fractures, arthritis, joint dysfunction, chronic back pain, wound healing and delayed onset muscle soreness. It seems that the most favorable results have been observed when using microcurrent on chronic injuries when treating for a period of over two weeks. This is not favorable protocols for delayed onset muscle soreness since symptoms usually subside in five to seven days. The current research has not supported the use of microcurrent for the treatment of delayed onset muscle soreness. The other reported benefit of microcurrent would be to enhance ATP production. Although an increase in ATP production has been observed in those receiving microcurrent electrical stimulation, its practical application has not been realized. Continued research needs to be performed to determine the role of microcurrent in the treatment of injuries.

Appendix B

The Problem

The Problem

Statement of the Problem:

The primary purpose of this study was to determine the effectiveness of microcurrent electrical stimulation in the treatment of delayed onset muscle soreness. Specifically, this study investigated:

1) How the use of microcurrent electrical stimulation affected the perceived pain levels in subjects with DOMS over a 5-day period.
2) How the use of micro current electrical stimulation affected the strength output of the quadriceps muscle measure by the Kin-Com 500-H isokinetic dynamometer over a 4-day period.

Scope of the Problem:

The study was limited to volunteer graduate students at California University of PA. The 14 subjects consisted of 6 males and 8 females. The subjects had not participated in strength conditioning for the quadriceps in the last 2 weeks. Subjects were informed of their importance in the study and given an informed consent form to study. Base levels of peak torque strength and average torque strength were measured using the Kin-Com. DOMS was induced the same day following base level testing for the quadriceps muscle. Every subject was randomly assigned to one of two treatment groups. They then reported for treatments and testing over the next 5 days (Appendix C-5). Subjects also rated their perceived pain using the visual analog scale.

Definition of terms:

1) Delayed onset muscle soreness: Sublethal and lethal damage to a small group of recruited muscle fibers usually intensifying over the 2 to three days following activity. The greatest soreness caused by eccentric exercise. The perception of soreness is caused by the activation of free nerve endings. The pain usually subsides within 7 days but the muscle fiber may need as much as 12 weeks to repair.[28]
2) Microcurrent electrical stimulation: very low sensory or subsensory electrical current operating at less than 1000 microamps.[22]
3) Peak/average torque-The average output from three reps of maximal concentric effort on the Kin-Com isokinetic dynamometer.

Basic Assumptions:

1) The Kin-Com 500-H isokinetic dynamometer will produce DOMS in all subjects
2) Each subject will give a maximum effort during all tests
3) Each subject will be honest in their response to the Visual Analog Scale
4) Each subject will report for all 5 treatments at the scheduled times
5) Each subject will not participate in any other treatment for the relief of pain for DOMS.
6) Internal validity will be controlled by the research design.

Limitations of the Study:

The following factors may be possible limitations to this study:

1) Subjects were limited to volunteers from the graduate students at California University of PA.

2) Treatment groups were small due to the subject availability.
3) Conclusions of the study were limited to the factors addressed in the study. Other factors may have an impact on the strength outputs of the participants and their perceived pain levels.

Significance of the study:

It has been said that Thomas Edison failed over 200 times before developing the light bulb. He was asked how it felt to fail over 200 times. Thomas responded that he did not fail but learned 200 ways how not to make a light bulb. The knowledge of how to use microcurrent electrical stimulation is going through a similar process. The use of microcurrent electrical stimulation has been studied for chronic and acute pain. The reported benefits of microcurrent electrical stimulation are related to its ability to mimic the bodies natural current.[7,11] Studies have reported the benefits related to increased ATP production.[6] Other studies have examined its ability to decrease healing time of wounds.[26] This study developed data through experimental research how microcurrent electrical stimulation in the treatment of DOMS can improve the recovery of peak and average strength levels of the quadriceps muscle. It also determined the effectiveness of microcurrent electrical stimulation in the relief of pain associated with DOMS of the quadriceps muscle. The study specifically determined if microcurrent stimulation at a level of 200 microamps, positive polarity at 3 Hz for 20 minutes

The information from this study will help athletic trainers further determine what parameters are not acceptable uses of microcurrent electrical stimulation for the treatment

of DOMS. Other studies have determined ineffective treatments using microcurrent electrical stimulation on DOMS for improved range of motion or pain.[2]

Appendix C

Additional Methods

1. IRB form
2. Informed consent form
3. Demographic data form
4. Visual Analog scale
5. Daily schedule

Appendix C-1

IRB Form

Project Title: Use of Microcurrent Electrical Stimulation for the Treatment of Delayed Onset Muscle Soreness

Researcher/Project Director: Daniel R. Cowell

Phone #: (574) 842-8935 Email Address: cowelld@culver.org

Faculty Sponsor: Bruce Barnhart

Department: Health Science & Sport Sciences

Project Dates

Sponsoring Agent: N/A

Project to be Conducted at: California University of Pennsylvania

Purpose of the Project: Thesis

Required IRB Training: see attached document

Page 2

1. Give a brief overview of your project/proposal with research hypothesis: To Study the effects of microcurrent electrical stimulation for the treatment of Delayed Onset Muscle Soreness. I will determine if the treatment with microcurrent electrical stimulation improves peak and average torque output of the quadriceps muscle, and if it improves the perceived pain levels.
    a. Hypothesis 1: Subjects receiving microcurrent electrical stimulation would have significantly higher peak torque values compared to a control group over a six-day period
    b. Hypothesis 2: Subjects receiving microcurrent electrical stimulation would return quicker to base torque levels compared to a control group over a six-day period.
    c. Hypothesis 3: There would be a significant difference in the mean pain score following treatment between those receiving microcurrent electrical stimulation and those receiving a placebo as measured using the Visual Analog Pain Scale
    d. There would be a significant difference in the pre and post treatment pain levels for those receiving microcurrent electrical stimulation.

2. Give a brief description of the subjects you plan to use: Adult volunteers/California University Students

3. Is remuneration involved in your project? NO

4. How do you plan to select subjects? Did they Volunteer? Is participation required? Explain: Volunteers would be recruited from the students at California University of Pennsylvania. I would post a flyer and recruit volunteers in the Health Science and Sport Studies department.

5. Does your project involve use of a consent form? YES

6. What instruments or devices will be used to gather data? Provide a copy of documentation pertaining to the data collection, such as but not limited to : Demographic questionnaire, consent form, Kin Com 500 isokinetic machine, Visual Analog Pain Scale

7. Is this project part of a grant? NO

8. Does your project involve the debriefing of those who participated? NO

9. The Federal Regulations require that the protocol meet certain criteria before IRB approval can be obtained. Describe in detail how the following requirements will be satisfied:
    A. Insure that the risks of the subjects are minimized: demographic questionnaire to eliminate those subjects at risk of injury; informed consent to explain risks and allow subjects to drop out at any time; use previously tested protocols to produce Delayed Onset Muscle Soreness.
    B. Justify the degree of risk involved (if any) in relationship to the potential of the project to the subject matter: Delayed Onset Muscle Soreness is a common symptom experienced by those participating in sport and recreational activity, the methods used in reproducing this phenomena have been used in the past; micro current electrical stimulation is sub sensory and subjects should not experience any sensation when being treated. The information from this study will be valuable to determine if this treatment is effective for the treatment of Delayed Onset Muscle Soreness.
    C. Subjects will volunteer for the study and be randomly placed in either a treatment group or a control group.
    D. Each subject will be required to fill out an informed consent and informed of the study prior to participation.
    E. The subjects will be monitored daily during the course of the study and information will be locked up each day.
    F. All information collected will be locked up at the end of testing in a secure box in the Health Science and Sport Study office.
    G. There will not be any vulnerable subjects

Appendix C-2

Informed Consent Form

Code _____

Informed Consent

I, _____, (subject name) understand and give consent to the following:

1. Daniel Cowell, a Graduate Student at California University of Pennsylvania, has requested my participation in this study comparing microcurrent electrical stimulation therapy used in the treatment of Delayed Onset Muscle Soreness.

2. I have been informed of the purpose of this study that is to compare the effect of microcurrent electrical stimulation therapy to no treatment. Specifically, the study will compare the use of microcurrent electrical stimulation for the return of peak and average torque values of the quadriceps muscle compared to a placebo group.

3. My participation will involve up to five days of participation, approximately one hour per day.

4. I understand that there may be foreseeable risks or discomforts of study, specifically muscle soreness in my non-dominant leg, quadriceps muscle. However, there will be nothing that would prevent normal activities of daily living.

5. I understand that there are risks associated with the use of electrical stimulation. These risks are especially significant for those with heart conditions, tumors, or those taking certain medications. I assume responsibility for providing all medical information, as it is relevant to this study.

6. I understand the benefits of participation in this study. This study is to help find new and more effective ways of treating muscle pain and will increase the literature and research regarding uses of microcurrent electrical stimulation.

7. I understand that results may be published, but names will be held as confidential. The researcher will

keep all records in a safe place and replace names with a numerical value.

8. In case of injury, the researcher will treat to the best of his ability, or refer to appropriate care and all costs will be the responsibility of me. First aid can include but not limited to the application of ice, ace wrap and/or splint.

9. I have been informed that I will not be compensated for my participation.

10. I have been informed that any questions that I have will be directed to:
Daniel R. Cowell
(574) 842-8388
cowelld@culver.org

11. I understand that in case of injury, if I have questions about my rights as a subject/participant in this research, or if I feel that I have been placed at risk, I can contact the faculty sponsor, Bruce Barnhart.

12. I have read the above information. The nature, demands, risks, and benefits for the project have been explained to me. I knowingly assume the risks involved, and understand that I may withdraw my consent and discontinue participation at any time without penalty or loss of benefit to myself. In signing this consent form, I am not waiving any legal claims, rights, or remedies. A copy of this consent form will be given to me.

Subject's Signature Date

_____ _____

1. I certify that I have explained to the above individual the nature and purpose, the potential benefits and possible risks associated with participation in this research study, have answered any questions that have been raised and have witnessed the above signature.

2. These elements of informed consent conform to the Assurance given by the California University of Pennsylvania to the Department of Health and Human Services to protect the rights of human subjects.

3. I have provided the subject a copy of this signed consent form.

Investigator's signature Date

_____ _____

Daniel R. Cowell

Appendix C-3

Demographic Data Sheet

Demographic Data Sheet

Name: _____ Code: _____

Gender: ____ Age: ____ Height: ____ Weight: _____

1. Are you currently pregnant? Y/N NA
2. Do you have a pacemaker for a heart condition? Y/N
3. Do you have any heart conditions? Y/N
4. Do you have a malignant tumor? Y/N
5. Are you currently taking over the counter anti-inflammatory or pain medication (ie. Advil, aspirin, Ibuprofin…)? Y/N
6. Are you currently taking prescription anti-inflammatory or pain medication (ie. Celebrex, Vioxx)? Y/N
7. What leg do you kick a ball with?
8. Have you been involved in a leg-strengthening program in the last 6 weeks?
9. Have you ever had an injury to your non-dominant leg or knee?
10. If you answered yes to #9 please explain:

Appendix C-4

Visual Analog Scale

Visual Analog Pain Scale

Code: _____

Date: _____

Pre – Treatment Score: _____

Appendix C-5

Daily Schedule

Daily Schedule

Begin on day one:

- Perform the base line test and exercise program on Tuesday for the first 9 people (group A).
- Perform the base line test and exercise program on Wednesday for the second 5 people (group B) and treat group A.
- Treat and test group A on Thursday and treat group B
- Alternate the treatment only and treatment and testing for the groups.
- Repeat

The format for treating and testing took about ½ hour per person. Therefore, ran two people every ½ hour.

Tuesday:
Group A (test)
8:00 Participant 1
8:20 participant 2
8:40 Participant 3
9:00 Participant 4
9:20 Participant 5
9:40 Participant 6
10:00 Participant 7
10:20 Participant 8
10:40 Participant 9

Wednesday:
Group B (test)
8:00 Participant 1
8:20 participant 2
8:40 Participant 3
9:00 Participant 4
9:20 Participant 5
Group A (treat)
11:30 Participant 1
11:35 participant 2
12:05 Participant 3
12:10 Participant 4
12:40 Participant 5
12:45 Participant 6
1:15 Participant 7
1:20 Participant 8
2:50 Participant 9

References

1. Wallace, L. Electrotherapy's Diverse Capabilities *Rehab Management.* February/March 1991.

2. Allen J, Mattacola C, Perrin D. The Effect of Microcurrent Stimulation on Delayed-Onset Muscle Soreness: A Double-Blind Comparison *Journal of Athletic Training*. Vol. #34, Number 4, October/December 1999; 34:334-337.

3. Alon G PhD, Pt. Microcurrent Stimulation Progress Report *Athletic Therapy Today*. Nov. 1998:15-17.

4. Bukowski E. Dispelling the Voodoo of Traditional Chinese Medicine *Physical Therapy Forum.* May 1993:3-8.

5. Charles-Liscombe RS. The Effects of Acupressure Therapy on Exercise-Induced Delayed Onset Muscle Soreness and Muscle Function Following Eccentric Exercise (Master's thesis) Indian University; 1998.

6. Cheng N, Van Hoof H, Bockx E, et al. The Effects of Electrical Currents on ATP Generation, Protein Synthesis and Membrane Transport in Rat Skin *Clinical Orthopedics*. November/December 1982; 171:264-271

7. Picker MD R. Current Low-Volt Pulsed Microamp Stimulation, Part 1 *Clinical Management.* 9,2:10-14.

8. Picker MD R. Current Low-Volt Pulsed Microamp Stimulation, Part 2 *Clinical Management*. 9,3:28-33. .

9. Weiss D, D'more G, Rothrock RW. Microelectrical Nueromuscular Stimulation: Theory and Techniques *Osteopathic Medical News.* 1984-1991: 34-35.

10. McAuliffe K. I Sing the Body Electric *Omni Scientific.* 72-73,98-99.

11. Weider D. Microucurrent Therapy: "Wave" of the Future? *Rehab Management.* February/March 1991.

12. Davis V. A Review of the Biophysics of the Microcurrent Generation of ATP *Global Care MicroCurrent Reference Guide.* 2.

13. Picker R. Micro Electrical Neuromuscular Stimulation *Networx-Electrix.* March 1987: S71-S74.

14. Davis P. Microcurrent A Modern Healthcare Modality *Rehab and Therapy Products Review.* November/December 1992: 62-66.

15. Lerner F, Daniel K. A Double-Blind Comparative Study of Micro-Stimulation and Placebo Effect in Short Term Treatment of the Chronic Back Pain Patient *The ACA Journal or Chiropractic.* November 1981; 15:101-106.

16. Smith G. Micro-Current Influences on Pain Control and Healing *Physical Therapy Forum*. March 19, 1993:27-28.

17. Picker MD R. Microcurrent Revolution in Sports Therapy *Rehabilitation and Therapy Products and Review*. 1994:26-31.

18. Manley-Teahan L. Microcurrent Therapy *Cramer First-Aider*

19. Sinkus V. New Developments in Electrotherapy *Rehab Management*. April/May 1992:46-47.

20. Kulig K, Isles S, Rapaski D, Smith J. Comparison of Three Microcurrent Stimulation Protocols in Reducing Delayed Onset Muscle Soreness and Edema *American Physical Therapy Physical Therapy Association Physical Therapy Program.* 1990.

21. Schening P. Use of Acupressure Points and Electrical Stimulation for the Treatment of Delayed Onset Muscle Soreness *Research Thesis California University of Pennsylvania.* 1994

22. Denegar C. Sports Injuries-Treatment *Therapeutic Modalities for Athletic Injuries.* 2000:150-152.

23. Starkey C. Electrical Agents *Therapeutic Modalities for Athletic Trainers.* 1993:249-251.

24. Picker R. Microcurrent Therapy: "Jump-Starting" Healing with Bioelectricity *Physical Therapy Forum.* June 1989:5-6.

25. Carley P, Wainapel S. Electrotherapy for Acceleration of Wound Healing: Low Intensity Direct Current *Archive Physical Medicine Rehabilitation.* July 1985; 66:443-445.

26. Harrington D, Meyer Jr R. Effects of Small Amounts of Electric Current at the Cellular Level *Annals New York Academy of Science*. 1974; 238: 300-304.

27. McKenzie AL, West JM, Whitney JD, Hunt TK, Hopf HW, Scheuenstuhl H. Pulsed Microamperage Stimulation: A Controlled Study of Healing of Surgically Induced Wounds in Yucatan Pigs *Physical Therapy.* March 1994.

28. Arnheim D; Prentice W. *Principles of Athletic Training*. 8th ed. St. Louis, MO: Mosby-Year Book, Inc. 1993; 155-156.

29. Kahn PhD J. Electrotherapy *Rehab Management* February/March 1991:30-35.

30. Picker R, Nirenstein J, Wing T. The Revolution in Electrotherapy *Global Care MicroCurrent Reference Guide.* 1994:3-8.

Abstract

Title:	Effects of Microcurrent Electrical Stimulation on Delayed Onset Muscle Soreness and Torque Values
Researcher:	Daniel R. Cowell, ATC
Advisor:	Dr. Bruce Barnhart
Purpose:	The primary purpose of this study was to determine if microcurrent stimulation was effective in treating the quadriceps for DOMS and returning it to pre-injury peak torque output. The second purpose of this study was to determine if MENS is effective in reducing pain associated with DOMS.
Methods:	Fourteen participants from the graduate program participated in this experimental study. All were given a personal profile questionnaire and an informed consent form. They then had baseline measurements of eccentric and concentric torque values taken on the Kin-Com 500H isokinetic dynamometer and performed nine additional sets to induce delayed onset muscle soreness. They were then randomly assigned to the electrical stimulation group or the control group. Electrical stimulation consisted of two electrodes placed at the motor end point and 4" superior to the patella of the quadriceps muscle. Microcurrent stimulation was then applied at 200 microamps, 3 Hz for twenty minutes. Treatments were given at 24, 48, 72, 96 and 120 hours post exercise. Measurements for pain using the visual analog pain scale were taken before and after each treatment and torque values were taken at 48 and 96 hours post exercise.
Findings:	No significant differences were found between groups for either peak or average torque values during an eccentric or concentric contraction. Although the average values for a contraction improved from one test to the next such as during the eccentric contraction from Day 3 to Day 5 for the treatment group they were not significantly different from the placebo group ($t(7) = .98$; $P < .05$). There was also a decrease in overall pain across the board regardless of group. Pre and post-treatment analysis showed a trend of decreased pain for both groups with no significant difference by day 5 ($t(7) = 1.00$; $P < .356$).
Conclusions:	While the effectiveness of the microcurrent electrical stimulation treatment was not significant, a study utilizing longer treatment times may yield better results.