EFFECTS OF TWO THERAPEUTIC MODALITIES ON ACUTE MUSCLE SORENESS

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EFFECTS OF TWO THERAPEUTIC MODALITIES ON ACUTE MUSCLE SORENESS

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Thesis

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ABSTRACT

College athletics is constantly striving to improve athlete health and recovery from injury. This study compared two therapeutic modalities and no treatment for the reduction of delayed onset muscle soreness (DOMS) symptoms. The goal of this research is to advance the treatment of injuries with electrotherapy. Twelve college students aged 20-26 years volunteered for this study. They were instructed to perform eccentric bicep curls with a set amount of weight (thirty pounds for males, twenty-five for females) and to keep rhythm with a three second timer, going through the entire range of motion (ROM) in one direction every three seconds using their non-dominant arm. When subjects were unable to maintain timing the respective dumbbell was replaced by a weight that was five pounds less than the previous. This continued until they used a five pound dumbbell. Subjects were then measured for ROM, and completed a graphic rating scale (GRS-IM). Each subject performed three trials and randomly received one of each treatment: (1) the InterX Sport Flexible Array® (InterX); (2) microcurrent electrical nerve stimulation (MENS); or (3) no treatment. Each subject received each treatment only once. The results show no statistically significant difference, though MENS and InterX were both more effective than no treatment in DOMS reduction, with InterX yielding the best results. Future research should expand the subject population and apply the therapeutic modalities to actual injuries.
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CHAPTER I
INTRODUCTION

College athletics is a growing business. More and more people seem to be drawn into the pageantry and tradition of college athletics. Universities across the country are pouring millions of dollars into their athletic departments to gain an edge on the competition and take the next step towards athletic success. Student-athletes in elementary and high school learn that they too can be college athletes through hard work and dedication.

On par with the growing public interest in college athletics is the demand for coaching and support staffs. Athletic trainers are an integral part of this support staff. Their major responsibilities involve the recognition, prevention, evaluation, treatment, and rehabilitation of injuries.  

Just as the popularity for college athletics grows so too do the demands upon the student-athletes. Student-athletes are expected to be able to perform at their highest level at all times. Unfortunately tribulations such as injuries may prevent a student-athlete from full-participation.

Injury has been described as damage to the body which limits activity or causes disability to such a degree that one may not be able to be as physically active relative to their prior level. Injuries vary in severity and therefore vary in recovery time. Athletic
trainers are usually the first responders to collegiate student-athletes and they work
diligently to return the student-athletes to their previous level of performance. Athletic
trainers utilize anything at their disposal to achieve this goal, from stretching techniques
to therapeutic modalities. Therapeutic modalities are instruments which apply a certain
form of energy to the body that elicit an involuntary response which has healing
properties. The purpose of therapeutic modalities is to place the body into the best
possible environment for healing to occur. \(^7\)

Student-athletes have high demands on them to return to competition following an
injury. In order to expedite this process, athletic trainers require evidence based medicine
(EBM) to validate therapeutic modalities. EBM requires clinicians to create research
proposals which aim to validate the claims made by the many therapeutic modalities.

Evaluating athletic injuries in a natural setting can be a lengthy process due to the
amount of time spent waiting for the specific injury needed for the study. Researchers
would rather design studies in which they may manipulate the initiation of injury.
Research studying therapeutic modalities favors a naturally occurring body response
named delayed onset muscle soreness (DOMS) to emulate athletic injury. Starkey
defines DOMS as "residual muscle soreness, caused secondary to damage of the muscle
cells."\(^{12}\) DOMS usually peaks within twenty-four to forty-eight hours of exertion. Effects
of DOMS are similar to those experienced with musculoskeletal injuries and therefore are
reliable alternatives to instigating actual injury for research purposes.

Therapeutic modalities such as microcurrent electrical nerve stimulation (MENS)
aim to increase adenosine triphosphate (ATP) and therefore protein synthesis at the injury
site to promote healing.\(^{12}\) In a pressure filled setting such as college athletics, any
decrease in recovery time is significant. So if MENS can increase protein synthesis at the injury site and expedite tissue healing then it can be an incredibly valuable tool to the athletic training profession.

The NRG Company recently released a therapeutic modality they called InterX. Clinical trials validate InterX as an effective means to reduce pain associated with musculoskeletal injuries, yet there are not many published articles to support this new product. Though they claim that the mechanism by which this modality operates may not be understood, there are many similarities between both InterX and MENS. InterX claims to have a neuropeptide release, which acts as a long lasting pain reliever. Neuropeptides such as cannabinol give the body a feeling of euphoria. This relates strongly to the noxious nerve stimulation that MENS may elicit. NRG encourages research to gain a better understanding of the mechanism by which InterX operates.

The purpose of this study was to evaluate the claims made by manufacturers and supporters of MENS. The specific purpose of this study was to evaluate the effect of MENS on DOMS symptoms. A secondary purpose of this study was to establish a relationship between MENS and InterX. The hypothesis for this study was that neither MENS nor InterX would be more effective in reducing perceived DOMS pain than no-treatment across three different bouts of induced DOMS after twenty-four hours.
Prentice defines injury as damage that impairs one's ability to compete at the same capacity as they did previously. This impairment plainly contradicts an athlete's livelihood. Athletes are used to competing at a high level of competition. Disrupting this ability may cost the athlete the chance to participate in practice, games, or other sport-specific events.

**General Healing Process**

The human body tries to heal itself when it undergoes an injury. Initial steps the body takes include muscle guarding (contraction), edema (accumulation of blood), and pain with moving the involved body part. These adaptations are natural processes the body takes to protect the involved structures.

Muscle guarding is an automatic attempt to theoretically splint the area to reduce movement which in effect limits pain. This splinting protects the area from further damage. Muscle guarding can be differentiated from muscle spasm by the length of time associated with each response. Houglum describes muscle spasm as a prolonged reflex muscle contraction.

Edema can more easily be recognized as swelling. This response occurs because of the blood sent to the injury to aid in healing the damaged tissues. Initially this reaction
seems sensible because blood carries nutrients vital to tissue healing. However, this vasodilation results in decreased venous compliance which leads to increased capillary permeability, ultimately resulting in blood pooling at the injury site. Because of the inability of the venous system to extract the blood at the injury site no new blood can be transported to distribute new nutrients. This buildup of fluids and blockage of nutrients leads to cellular death. It stands to reason that edema retards the healing process.\textsuperscript{11}

Pain logically follows this sequence of events. If the muscles are tight then moving that body part will be painful. Further if the tissues have increased pressure underneath the skin due to swelling then initiating movement eludes a pain response. Edema begins to push upon the local nerves which causes irritation and can lead to further immobility, keeping the injured individual in the pain-spasm-pain cycle.\textsuperscript{12}

\textbf{Acute Inflammatory Process}

In response to any type of injury, no matter how seemingly insignificant, the body follows a process which tries to promote healing. It must be recognized that this inflammatory process is necessary for healing to occur.\textsuperscript{7, 12} The three stages of the acute inflammatory process are inflammation, proliferation, and remodeling.\textsuperscript{7, 11, 12}

Inflammation begins with immediate local vasoconstriction following any type of trauma (from ankle sprains to paper cuts). Within seconds vasodilation takes over, though, which leads to the release of blood platelets.\textsuperscript{7} However uncontrolled vasodilation leads to increased localized swelling and edema.\textsuperscript{11} In response to vasodilation phospholipids accumulate in order to begin the clotting mechanism. Platelets further release fibronectin, growth factors and fibrogen. Fibronectin and fibrin begin forming a lattice-like complex (which works to clot the wound).\textsuperscript{7} Although fairly fragile, this lattice
is effective in clotting the area, which localizes the injury. Later on this lattice is replaced with type III collagen.

An enormous drawback to this course of action is the obstruction of the lymphatic system.\textsuperscript{7} This can account for the persistence of localized swelling in some cases.

Eventually the body will release an enzyme called fibrolysin to collapse the lattice for absorption. Specific neutrophils called polymorphonuclear leukocytes (PMNs) accumulate within hours of injury as they are the most plentiful leukocytes in normal blood flow. These particular leukocytes are short lived, though, and are replaced with monocytes and macrophages within twenty-four to forty-eight hours.\textsuperscript{7}

Significant amounts of exudate will have likely formed at and around the injury site. This exudate is composed of fluid that has leaked from the blood vessels, dead cells from the actual injury, and dying PMN cells. It is crucial that the area be cleansed of the exudate for the next phases of healing to occur.\textsuperscript{7}

Chemotaxis occurs simultaneously with the aforementioned responses and is a process in which chemicals are attracted to the injury site.\textsuperscript{7} Histamine is one the first chemicals which is attracted. According to Houglum et. al. histamine helps to increase capillary blood flow and vascular permeability.\textsuperscript{6} Early histamine release causes redness and swelling at the injury site caused by this increase in capillary permeability. Because of histamine’s short lived nature the body further releases serotonin and kinins to maintain vascular permeability.\textsuperscript{7}

Kinins are important in the healing process because they are needed to promote prostaglandin (PG) stimulation. Prostaglandins produce PGE\textsubscript{1} and PGE\textsubscript{2}. PGE\textsubscript{1} is used to maintain vascular permeability, whereas PGE\textsubscript{2} is used to attract leukocytes to the site.\textsuperscript{7}
Histamine, PGE$_1$, PGE$_2$ and bradykinin (a noxious stimulating chemical) all trigger local vasodilation which leads to increased capillary permeability.$^6$ The increase in extracellular compounds irritates the nerve endings and cause hypersensitivity. All of these events lead to a decrease in function of the injured area. Muscle spasms become more rigid as the functionality diminishes, which makes moving the injured site more painful.$^7$ This perpetuates the pain-spasm-pain cycle.$^{12}$

The proliferation phase begins with the debridement of the exudate.$^{12}$ There is an overlap, however, of the stages of healing. Each step has events that are specific to it, yet they may begin in the midst of the previous phase.

Once the area has been removed of the exudate the body begins the process of angiogenesis and new granulation tissue formation. Fibroblasts aggregation further aids in the development of new capillaries and the extracellular matrix. The extracellular matrix is composed of collagen, proteoglycans, and elastin. The extracellular matrix will form into scar tissue.$^7$

Granulation tissue is the combination of the new extracellular matrix and capillary buds. The richly vascular capillary buds give the granulation tissue a red hue. Increased numbers of local capillaries as well as the additional water volume produce swelling at the injury site.$^7$ The continuing effort of fibroblasts form ground substances as they lay down collagen. Epithelial fibroblasts release collagenase to prevent an overstimulation of collagen which may eventually lead to excessive amounts of scar tissue formation.

The collagen that is initially sent to this area is type III and is relatively weak and thin. Type III is replaced by type I collagen (which is much stronger and durable) around day twelve of the acute inflammatory process.$^{12}$ Type I collagen lay in parallel relative to
the randomized orientation of type III collagen. Parallel composition results in a great
number of cross-links which in turn exponentially increase strength.\textsuperscript{7}

Although wound contraction begins in the proliferation phase it culminates in the
remodeling/maturation phase. In this final phase fibroblasts begin converting
myofibroblasts in order to contract the wound. Collagen also transcends phases as type I
is synthesized and type III is destroyed. Once fibroblasts and myofibroblasts contract the
wound and type I collagen is formed fibroblasts and myofibroblasts are transported away
from the site.\textsuperscript{7}

Visible changes at the dermal level include the progression of red skin to white
skin and finally to the natural skin tone. Swelling and sensitivity are diminished with the
loss of the extracellular matrix substances.

Prentice notes many various impedances along the acute inflammatory process
which can slow the progression through the phases. The biggest deterrent along this
process is the severity of the injury. Perceptibly the worse the initial damage to the
involved structures the longer it will take them to completely heal.\textsuperscript{11}

Early control of edema is vital to completion of the inflammatory phase. In this
sense hemorrhage and edema are identical. Compression to the site may alleviate some
of the swelling and edema.\textsuperscript{11, 12, 13} Atrophy occurs immediately following the initial injury
and may be perpetuated by edema.\textsuperscript{11} Loss of limb function retains the exudate and
continues the pain-spasm-pain cycle.\textsuperscript{12}

Poor vascular supply also negatively influences healing. Leukocytes, for
example, are critical to clotting and exudate phagocytosis.\textsuperscript{7} Therefore if leukocytes are
absent from the injury site then swelling cannot be controlled or reduced.
Purpose of Therapeutic Modalities

Therapeutic modalities are mainly used to treat both acute and chronic pain.\textsuperscript{9} They are most useful in injury rehabilitation, especially when adjunct to therapeutic exercises. They may also greatly enhance the athletes' chances for a safe and rapid return to prior athletic competition.\textsuperscript{11} Therapeutic modalities may be used to reduce symptoms of musculoskeletal injuries such as pain, swelling and muscle spasm.\textsuperscript{1}

Electrotherapy is one type of therapeutic modality. It utilizes a mild form of electrically induced nerve stimulation to block the body's ability to perceive pain. Gorodetskyi et al. describe electrotherapy as a manner of facilitating recovery and managing pain.\textsuperscript{5} Electrotherapy has been proven to aid in wound healing and soft tissue injury.\textsuperscript{8} Low intensity electrical currents produce increased endorphin release which will generate long-lasting pain relief.\textsuperscript{3} Endorphins (from "endogenous morphine") literally occupy pain receptor sites inhibiting the body to perceive pain.\textsuperscript{6} Endorphins are released when noxious nerve fibers are stimulated.

The gate control theory is the presumption that A\textsubscript{β} nerves are the quickest pathway to the brain, and so will block any pain sensations that may occur to the body. As long as the sensory nerves are stimulated the gate for noxious nerves will be closed. If stimulation of the sensory fibers ceases then the gate will be open and the perception of pain allowed. Increased phase duration and high pulse frequency are the ideal parameters to activate gate control.\textsuperscript{11}

Therapeutic modalities which operate at phase duration of ten to one hundred microseconds (interferential current, pre-modulated current) stimulate only A\textsubscript{β} nerve fibers. A\textsubscript{β} nerve fibers are the thickest and the most myelinated nerves and so have the
fastest pathway to the brain. They are also sensory nerves, meaning that they are excited when the body senses mechanical force. Aβ nerves block other nerve sensations if they are aroused.\textsuperscript{12}

\textit{Aδ} nerves are motor nerve fibers and are affected when phase duration is between two hundred and four hundred microseconds. These nerves are less myelinated and not as thick as Aβ which means that they are not as quick to send stimulation to the brain.\textsuperscript{12} Examples of this electrotherapy include High-Volt and Russian currents.

Noxious nerves fibers are called C-fibers and they stimulate pain. Though seemingly negative, these nerves initiate a release of endogenous opiates which act as long-term pain relief. Unlike Aβ nerve stimulation which is only effective when the nerve is being stimulating, these endogenous opiates work for hours and have a long lasting life span.\textsuperscript{12} The downside to noxious nerves, beyond exciting pain sensations, is that they are very thin and do not have much myelin surrounding them which leads to very slow signals to the brain. Slow signals mean that treatment times must be increased to allow for opiate release. Microcurrent electrical nerve stimulation is an example of a therapeutic modality which may innervate noxious nerve fibers.

Microcurrent Electrical Nerve Stimulation and Tissue Healing

Microcurrent electric nerve stimulation (MENS) is an example of a low intensity electrotherapy.\textsuperscript{3} Mercola et. al. reports that MENS could increase ATP generation by almost 500\%.\textsuperscript{9} MENS has further been proven to be successful to enhance soft tissue healing through previous research.\textsuperscript{2,4,10} This mechanism may be due to its ability to affect the altered electrical potential of the injury site.\textsuperscript{9} When injured the electrical resistance increases at the wound site relative to the surrounding, uninjured areas. The
body struggles to properly maintain electrical conductance which further impairs the progression of the healing process.\textsuperscript{9} MENS application, therefore, may be able to correct the electrical imbalance which may reduce muscle spasm and pain.\textsuperscript{1, 3, 8, 9}

InterX is a state of the art therapeutic modality. One published article supports the use of InterX to promote healing following trochlear fracture surgery.\textsuperscript{5} Gorodetskyi et. al. report that the InterX is capable of automatically adjusting its strength in accordance with the impedance of the underlying tissue which results in a highly sensitive and variable voltage in order to maintain a constant peak current of near seventeen volts.\textsuperscript{5} InterX may initiate opiate release, which is similar to the mechanism by which MENS functions.\textsuperscript{14}

Another similarity between these two therapeutic modalities is that they each assert that they affect areas of low electrical impedence.\textsuperscript{9, 14} Low impedance areas are identified as those areas responding to injury.\textsuperscript{14} Mercola et. al. support MENS as an electrotherapy which positively alters the electric potential of nerves at a site of cell damage.\textsuperscript{9}

Studies with the InterX showed elevated levels of endogenous opiates circulating near the injury site.\textsuperscript{5} These findings, along with anecdotal reports and testimonials from the InterX website, demonstrates a correlation between MENS and InterX.\textsuperscript{9, 11, 12, 14}

Current research cannot support the effectiveness of MENS in the reduction of DOMS.\textsuperscript{1, 3, 8, 9, 12} There are mostly anecdotal reports of the effectiveness of InterX.\textsuperscript{14} While there is very limited research supporting InterX, their claims are very similar to those made by MENS. Therefore it can be assumed InterX utilizes a similar electric
current as MENS and thus will only be as effective as MENS. Research directed to this purpose is needed to validate this alleged correlation.
CHAPTER III

METHODS

The study design was a randomized controlled-trial. Five males and seven females volunteered for this research study. The age range was 20 to 26 years (mean age 23). Willing participants were excluded if they had a history of previous injury to the non-dominant arm. Furthermore subjects were not considered if they were currently participating in an advanced weight lifting program. In compliance with The University of Akron’s Institutional Review Board (IRB) all subjects agreed to and signed an informed consent.

Clinicians began the data collection by identifying the subjects’ non-dominant arms. After subjects identifying which arm was their non-dominant arm range of motion (ROM) measurements were taken using a standard goniometer. ROM measurements were compared before and after exercise to justify the onset of DOMS, as a restricted ROM is one of the indicators of DOMS. Subjects flexed and extended their elbows and the ROM measurements were recorded at the terminal end of each respective motion. Subjects then began the process of initiating DOMS by eccentrically contracting their biceps brachii muscles. Symptoms of DOMS replicate those experienced with a musculoskeletal injury and so DOMS is an appropriate model for emulating musculoskeletal injuries.\textsuperscript{1, 3, 8}
Males began the protocol with a thirty pound dumbbell and females a twenty-five pound dumbbell. The clinician then instructed each subject to lower the weight into a flexed elbow position with a three second count. Then they used their dominant arm to raise the weight to full elbow flexion with another three second count. It was vital that the flexion be completely passive and so the protocol was demonstrated by the clinian. The extension and passive flexion process was repeated until the subject could no longer control the weight in the three second period, or if they felt that the weight was too much for their tolerance. At this point the weight of the dumbell was reduced by five pounds and the protocol repeated until they reached a five-pound dumbbell. Once they reached the five pound weight subjects performed ten repetitions with the same protocol or they stopped if they were too fatigued to continue.1,3,8

Following the conclusion of the exercises, ROM measurements were again recorded. These numbers were used to evaluate whether or not DOMS was present. A graphic rating scale (GRS)1 was used to establish a subjective record of their level of discomfort. Then each subject was randomly assigned to a treatment following exercise. There were three possible treatments: (1) the InterX Sport Flexible Array ® for a ten minute treatment; (2) MENS with a bipolar pad setup with the dispersment pad placed over the distal end of the biceps brachii tendon and the active pad placed over the distal end of the triceps tendon with a treatment time of twenty minutes;1 or (3) no treatment. The InterX Sport had a preset treatment duration (time) of ten minutes yet the intensity was increased according to each subject's tolerance. The duration of treatment for InterX could not be manipulated. MENS used parameters of 0.3 Hz with a continuous pulse for twenty minutes.3 These parameters have been validated as the standard for MENS
application with a therapeutic goal of DOMS reduction. Subjects were then instructed to complete another GRS twenty-four hours following their exercise session.

Each treatment was randomly assigned, and each subject was to receive each of the three treatments over three separate exercise trials. There was a mandatory six-day grace period between trials to allow the body to completely heal from induced DOMS.
CHAPTER IV

RESULTS

This chapter has two sections. The first section is descriptive statistics where the mean for each trial is disaggregated by treatment for both GRS-IM and GRS-24. The second section analyzes the two research hypotheses. The two research hypotheses were analyzed utilizing Hierarchical Linear Modeling (HLM). This analysis was the most appropriate because it allows one to conduct repeated measures research without losing subjects who did not complete every trial.

Average mean differences for treatments across trials for GRS-IM were slightly different. The group that received no-treatment (TX 3) scored the highest immediately following DOMS initiation (See Table 1). However GRS-IM scores were independent of treatment since treatment was not administered until after GRS-IM scores were collected.

<table>
<thead>
<tr>
<th>TX</th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>InterX</td>
<td>3.650</td>
<td>5.350</td>
<td>7.925</td>
</tr>
<tr>
<td>MENS</td>
<td>5.517</td>
<td>2.700</td>
<td>1.750</td>
</tr>
<tr>
<td>No Treatment</td>
<td>7.150</td>
<td>5.375</td>
<td>3.400</td>
</tr>
</tbody>
</table>
MENS and no treatment improved over the three trials. InterX showed an increase in scores yet these results do not show a linear pattern and do not seem to correlate to the findings.

The first research hypothesis was neither MENS nor InterX will be more effective in reducing DOMS pain than no-treatment across the three trials for GRS-IM. This hypothesis revealed no statistical significance. There was no significant differences in the initial pain scores (p=.347) nor was there any significant difference in the slope of the trials due to treatment (p=.523) (See Table 2 & Figure 1).

Table 2: HLM for GRS-IM

<table>
<thead>
<tr>
<th>Fixed Effect</th>
<th>Coefficient</th>
<th>Error</th>
<th>T-ratio</th>
<th>d.f.</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>For INTRCPT1, P0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INTRCPT2, B00</td>
<td>1.004</td>
<td>3.433</td>
<td>0.293</td>
<td>10</td>
<td>0.776</td>
</tr>
<tr>
<td>TX, B01</td>
<td>2.282</td>
<td>2.313</td>
<td>0.987</td>
<td>10</td>
<td>0.347</td>
</tr>
<tr>
<td>For TRIAL slope, P1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INTRCPT2, B10</td>
<td>1.017</td>
<td>1.725</td>
<td>0.589</td>
<td>10</td>
<td>0.568</td>
</tr>
<tr>
<td>TX, B11</td>
<td>-0.688</td>
<td>1.038</td>
<td>-0.662</td>
<td>10</td>
<td>0.523</td>
</tr>
</tbody>
</table>

Figure 1: Initial pain scores following DOMS induction
Average mean differences for treatments across trials for GRS-24 also showed a slight difference. The group receiving MENS (TX 2) as treatment had the highest GRS-24 scores following DOMS inductions (See Table 3). Subjects receiving MENS also showed an increase from Trial 2 to Trial 3. These findings did not follow a linear pattern and do not correlate to the findings.

Table 3: Pain scores twenty-four hours after DOMS induction and treatment

<table>
<thead>
<tr>
<th>GRS-24</th>
<th>TX</th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>InterX</td>
<td>11.625</td>
<td>5.600</td>
<td>4.425</td>
</tr>
<tr>
<td></td>
<td>MENS</td>
<td>12.700</td>
<td>3.333</td>
<td>9.850</td>
</tr>
<tr>
<td></td>
<td>No Treatment</td>
<td>10.800</td>
<td>9.825</td>
<td>7.733</td>
</tr>
</tbody>
</table>

The second hypothesis was neither MENS nor InterX will be any more effective in reducing DOMS pain than no-treatment across the three trials for GRS-24. This hypothesis was not statistically significant. There was no significant differences in the initial pain scores (p=.885) nor was there any significant different in the slope of the trials due to treatment (p=.623) (See Table 4 & Figure 2).

Table 4: HLM for GRS-24

<table>
<thead>
<tr>
<th>Fixed Effect</th>
<th>Coefficient</th>
<th>Error</th>
<th>T-ratio</th>
<th>d.f.</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>For INTRCPT1, P0</td>
<td></td>
<td></td>
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<tr>
<td>INTRCPT2, B00</td>
<td>13.428</td>
<td>5.602</td>
<td>2.397</td>
<td>10</td>
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</tr>
<tr>
<td>TX, B01</td>
<td>0.422</td>
<td>2.847</td>
<td>0.148</td>
<td>10</td>
<td>0.885</td>
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<tr>
<td>For TRIAL slope, P1</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>INTRCPT2, B10</td>
<td>-1.717</td>
<td>2.274</td>
<td>-0.755</td>
<td>10</td>
<td>0.468</td>
</tr>
<tr>
<td>TX, B11</td>
<td>-0.577</td>
<td>1.139</td>
<td>-0.506</td>
<td>10</td>
<td>0.623</td>
</tr>
</tbody>
</table>
Table 5 and Figure 3 illustrate the direct comparison of InterX to MENS. The average scores from both the GRS-IM and GRS-24 were evaluated to see which electrotherapy was more effective in reducing DOMS. As these demonstrate, InterX was the most effective treatment regarding DOMS pain perception.

Table 5: Average GRS-IM without treatment and GRS-24 scores with treatment

<table>
<thead>
<tr>
<th></th>
<th>GRS-IM</th>
<th>GRS-24</th>
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</thead>
<tbody>
<tr>
<td>InterX</td>
<td>5.69</td>
<td>7.22</td>
</tr>
<tr>
<td>MENS</td>
<td>3.32</td>
<td>8.63</td>
</tr>
<tr>
<td>No Treatment</td>
<td>5.31</td>
<td>9.45</td>
</tr>
</tbody>
</table>
Figure 3: Average pain scores following treatment
CHAPTER V
DISCUSSION

This study was aimed to investigate the use of standard MENS protocol and InterX to improve recovery from injury. MENS and InterX were both applied to the distal biceps brachii tendon following separate initiations of acute muscle soreness. When compared to no-treatment each modality showed a decline in pain scores, yet yielded no statistical significance. However Figure 1 reveals that InterX was the most effective treatment intervention evaluated in this study.

These results may be attributable to the proposition that MENS and InterX utilize similar electric currents. Each therapeutic modality attempts to correct damaged nerve endings at the site of injury, establishing a correlation between their mechanisms.

It is also possible that neither MENS nor InterX are effective modalities for reducing the symptoms of DOMS. Previous studies have reviewed standard MENS protocol as it relates to DOMS reduction.\textsuperscript{1,2,3,8} These studies did not find significance among MENS treatments of DOMS, though Mercola et. al. found MENS to be a credible therapeutic modality for DOMS reduction.\textsuperscript{1,2,3,8,9}

MENS claims to stimulate noxious c-fibers to initiate local endogenous opiate release.\textsuperscript{5,9} These claims directly contradict research reporting that MENS utilizes a subsensory current.\textsuperscript{9,11,12} In order to stimulate the release of endorphins these noxious c-
fibers must be excited. If an electric current stimulates c-fibers then the subject will experience pain, which no longer conflicts with the subsensory theory backing MENS. This may explain some of the variability in research evaluating MENS.

InterX and MENS each claim to have the ability to correct the electric imbalances at the wound site following injury.9, 14 Conversely, electric potentials at the injury site have not routinely been evaluated while studying the effectiveness of various therapeutic modalities. Future research should focus on measuring the electrical potentials of injury sites before and after the application of MENS and InterX. Once these values have been established then the effectiveness of the electrotherapies will be more apparent.

In this study each subject was in the inflammatory stage when MENS and InterX were respectively applied to the biceps brachii tendon. Future research should take into account the stage of the acute inflammatory process when evaluating the effectiveness of electrotherapies. The ideal stage of the acute inflammatory process for MENS would be the proliferation stage, as MENS increases protein synthesis at the injury site.5, 9 The proliferation stage is ideal for MENS application because during this stage the body is regenerating capillary buds. If MENS can indeed increase protein synthesis at the injury site, then it may exponentially increase recovery rate from injury and may enhance tensile strength of the newly formed scar tissue.

In order to fully validate the results the treatments should be applied to actual musculoskeletal injuries. Future research may benefit from applying the therapeutic modalities to actual injuries. The greatest delimitation was that this study population did not include student-athletes.
The results for each hypothesis were not statistically significant, yet the small difference showed that each modality positively affected perceived pain following the onset of DOMS. The extent of their success cannot be totally understood, though, due to the relatively small sample size.

The chief limitation in this study was not having all of the subjects complete all three trials. At the beginning there were twelve volunteer subjects, which formulated to thirty-six total trials. Three subjects only completed the first trial, which weakened the results because then only thirty total trials were recorded. A larger sample size may reveal a statistically significance difference between the two electrotherapy modalities. Future research should focus on larger sample sizes so that there may be definitive results concerning the effectiveness of reducing DOMS with InterX and MENS therapeutic modalities.

Emulating an injury in a controlled environment is a safe way to test the healing process. However it must be acknowledged that treating an actual injury may vary the results as severity of injury and the mechanism of injury cannot be controlled. More over electrotherapy is most often accompanied with other forms of therapeutic modalities, particularly cryotherapy and pharmaceutical medicines. Coupling these treatments may significantly affect the outcome of injury recovery. This study did not allow the subjects to partake in these (or other) forms of treatment. Since actual injury treatment usually includes the use of electrotherapy, cryotherapy, and pharmaceutical medicines more research should concentrate on the synergy of these three aspects.
REFERENCES


APPENDIX A

HUMAN SUBJECTS APPROVAL

NOTICE OF APPROVAL

Date: January 30, 2009
To: Thomas Kopec
2200 High St. Apt. 471
Cuyahoga Falls, Ohio 44221

From: Sharon McWhorter, IRB Administrator

Re: IRB Number 20090115 “Effects of Two Therapeutic Modalities on Acute Muscle Soreness”

Thank you for submitting an IRB Application for Review of Research Involving Human Subjects for the referenced project. Your protocol represents minimal risk to subjects and has been approved under Expedited Category #4.

Approval Date: January 29, 2009
Expiration Date: January 29, 2010
Continuation Application Due: January 15, 2010

In addition, the following is/are approved:

☐ Waiver of documentation of consent
☐ Waiver or alteration of consent
☐ Research involving children
☐ Research involving prisoners

Please adhere to the following IRB policies:

• IRB approval is given for not more than 12 months. If your project will be active for longer than one year, it is your responsibility to submit a continuation application prior to the expiration date. We request submission two weeks prior to expiration to insure sufficient time for review.
• A copy of the approved consent form must be submitted with any continuation application.
• If you plan to make any changes to the approved protocol you must submit a continuation application for change and it must be approved by the IRB before being implemented.
• Any adverse reactions/incidents must be reported immediately to the IRB.
• If this research is being conducted for a master’s thesis or doctoral dissertation, you must file a copy of this letter with the thesis or dissertation.
• When your project terminates you must submit a Final Report Form in order to close your IRB file.

Additional information and all IRB forms can be accessed on the IRB web site at:
http://www.uakron.edu/research/orsp/compliance/IRBHome.php

CC: Ronald Otterstetter - Advisor
CC: Stephanie Woods - IRB Chair

☒ Approved consent form/s enclosed

Office of Research Services and Sponsored Programs
Akron, OH 44325-0106
330-972-7666 • 330-972-8281 Fax
The University of Akron is an Equal Educator and Employment Institution
APPENDIX B

INFORMED CONSENT

EFFECTS OF TWO THERAPEUTIC MODALITIES ON ACUTE MUSCLE SORENESS

You are invited to participate in a research project conducted by Thomas Kopec, a graduate assistant athletic trainer in the physiology of exercise program at The University of Akron, as well as Ronald Otterstetter, a faculty member at The University of Akron. We designed a study that will test the effectiveness of certain therapeutic modalities on delayed onset of muscle soreness (DOMS). Both of these therapeutic modalities claim to reduce the symptoms of DOMS, though past there is conflicting research regarding these claims. I am evaluating the claims made by the InterX for DOMS symptom reduction.

You will be required to perform eccentric biceps contractions until your arm is fatigued, at which point your range of motion will be measured. Next, you will complete a graphic rating scale (GRS) which will indicate your level of discomfort. Finally you will receive one of the three forms of treatment. One of the treatments is InterX with the Flexible Array®. This involves strapping the Flexible Array® to the elbow over the tendon of the biceps brachii muscle for ten minutes. At this point a small electrical current will pass through the injury site in an attempt to heal the tendon from soreness. Another treatment is microcurrent and is a twenty-minute treatment where pads will again be placed over the biceps brachii tendon and an electric current will pass through the sore tendon in order to heal it. The third treatment is no treatment and is the control. You will be excused for that particular day’s participation once you finish the GRS. A twenty-four hour follow-up appointment must be scheduled after each treatment so that you can complete another GRS. You will be required for a total of six (6) visits over three weeks.

It is likely that you will experience discomfort due to the induced DOMS. The discomfort should not be any more that anything you have experienced previously. DOMS is a natural occurring response to exercise in the body so there is no foreseeable harm besides a few days of soreness. It is possible that the discomfort last for longer than the expected few days. The total amount of time your participation will be required is three weeks. This allows you to receive all three forms of treatment.
You are asked NOT to use any type of treatment for the soreness (including, but not limited to, pharmaceutical medication, ice, compression, stretching). Please tell the researchers if you DO feel the need for alternative treatments (anything besides what the researchers provide). If you seek external treatments you forfeit your involvement in this research and neither The University of Akron nor the research group members are required to provide care for the discomfort experienced due to the research. By agreeing to participate in this study you do not waive any of your legal rights.

There are no direct benefits to you for your participation in this study. Your participation will help the allied healthcare profession by providing more decisive evidence as to whether microcurrent and InterX are effective in reducing the effects of DOMS when compared to no treatment. Participation in the research is completely voluntary and you may refuse to participate or withdraw consent and discontinue participation in the study at any time without any consequence to you.

Any data collected with identifying information will be kept confidential and will be available only to Thomas Kopec and Ronald Otterstetter. Each participant will randomly be assigned a numerical code to protect their identity on all documented paperwork. All information in this study will be subjected to the confidentiality and privacy regulations of The University of Akron. The research advisor will keep the code key connecting your name to your number in a secure location. At the completion of the study the raw data will all be destroyed.

If you have question at any time please feel free to contact either of the researchers. If you feel you need to speak with someone not directly involved in the study about your participation you may contact the research advisor Dr. Ronald Otterstetter at (330) 972-7738. This project has been reviewed and approved by The University of Akron Institutional Review Board (IRB). If you have any questions about your rights as a research participant you may call the IRB at (330) 972-7666 or 1-888-232-8790.

Thank you for your willingness to participate in this study.

Thomas Kopec, ATC, LAT
Primary Researcher

Ronald Otterstetter, PhD
Research Advisor

I have read the information provided above and all of my questions have been answered. I voluntarily agree to participate in this study. I will receive a copy of this consent form for my information.

Participant signature: ________________________________ Date: ________________________________

Signature of witness: ________________________________ Date: ________________________________
APPENDIX C
SUMMARY OF PROJECT

This research proposal intends to investigate the effectiveness of two therapeutic modalities on induced delayed onset muscle soreness (DOMS). We will record baseline flexion and extension range of motion (ROM) at the elbow of the non-dominant arm, then initiating eccentric biceps curls to induce DOMS. Males will begin with a thirty pound dumbbell and females with a twenty-five pound dumbbell. These values are validated by previous research. The subjects will begin with the non-dominant arm and appropriate dumbbell in full elbow flexion and then lower the weight through full elbow extension within a three second time period. Once they reach full extension they will use their opposite arm to lift the arm with the weight back to the flexed-start position within three seconds. This process is repeated until they cannot keep up with the three second time frame. At that point the researcher will reduce the weight by five pounds and will repeat the procedures until the subject reaches a five pound dumbbell. The subject will then continue eccentric biceps curls until they 1.) become too fatigued to continue or 2.) successfully complete ten repetitions.

Once they have completed the exercise portion they will again be measured for flexion and extension ROM. Next subjects will complete a graphic scale rating (GRS), which is a horizontal line with different phrases to describe their discomfort. The
participants must actively extend their elbow and then place a vertical line through the horizontal line nearest the phrase that best describes their discomfort. The distance from the start of the line on the left to the subject’s marking will be measured in centimeters to quantify the data.

Then the subjects will receive one of the three forms of treatment available in this study. Treatment 1 (T1) is the InterX with Flexible Array ®. The Flexible Array ® is a pad that is strapped around the target tissue and held in place with a Velcro strap. The researcher then gradually increases the intensity of the InterX until the intensity is as high as the subject can comfortably tolerate. The preset parameters of the machine have treatments with the Flexible Array ® lasting ten minutes.

Treatment 2 (T2) is microcurrent electric nerve stimulation (MENS). This modality utilizes a bipolar pad setup. The positive electrode is placed directly over the biceps brachii tendon and the negative electrode is placed over the triceps tendon on the posterior surface of the arm. Then the machine is programmed to 0.3 Hz for twenty minutes. Research justifies both the pad placement and the parameters for this modality.

The third treatment (T3) is the control treatment, so it is . These subjects will be excused once they complete the GRS following exercise. All three of the treatment groups are required to make a twenty-four hour follow-up appointment to complete a second GRS. Each participant is required to complete two graphic rating scales per treatment, totalling their participation to six visits.

With this data I will be able to determine if the two modalities are valid in claiming they increase protein synthesis at the injury site (hence expediting the healing process). I chose DOMS because it most closely replicates an acute injury to
musculoskeletal tissue, though in a very safe manner. As a practicing certified and licensed athletic trainer it is vital for me to know which therapeutic modalities work best in healing injuries so that I can expand that information to athletic populations.
APPENDIX D

DEMOGRAPHIC QUESTIONNAIRE

1. Age:

2. Gender:

3. Have you ever been diagnosed with an upper body injury? Y/N
   a. If yes, please state the condition.

4. Are you currently taking any medications? Y/N
   a. If yes, please state which medication(s).

________________________________________________________________________
APPENDIX E
GRAPHIC RATING SCALE

Please place a vertical line through the most accurate description of your pain.

APPENDIX F

SCRIPTED VERBAL INSTRUCTION

1. The tester must begin by establishing which arm is the subject’s dominant arm and measuring and documenting the flexion and extension range of motion (ROM) at the elbow of the non-dominant arm by using a goniometer.

2. The tester will place the appropriate dumbbell in the subject’s non-dominant hand.
   a. Males - Thirty (30) pounds
   b. Females - Twenty-five (25) pounds

3. The tester will instruct the subject that once the stopwatch has started they will count, “Down, two, three,” at which time the subject will move their arm into full elbow extension. At this point the stopwatch will be started again and the tester will count, “Up, two, three,” at which time the subject will use their dominant arm to pull the weight up into full elbow flexion/starting position.
   a. The arm with the weight should only be working while subjects lower the weight.

4. If they are unable to keep up with the time demands the weight will be reduced by five (5) pounds and previous steps will be repeated.
5. Once the weight is reduced to five (5) pounds the subject will be required to perform ten (10) repetitions using the same format, or until they are too fatigued to continue.

6. Once the procedures have been completed then the tester must measure and document flexion and extension ROM of the involved elbow.

7. The subjects must then complete a graphic rating scale to assess their pain level.

8. According to which group the subject has been assigned one of the following treatments must be applied: InterX with the Flexible Array for ten minutes (T1), microcurrent at 0.3 Hz and 995 watts for twenty minutes using bipolar pad placement (T2), or no treatment (T3).

9. At the conclusion of treatment the subject must make an appointment with the tester to complete another graphic rating scale in twenty-four (24) hours.
APPENDIX G

RECRUITMENT FLYER

Research Subjects Needed

Sport Science & Wellness Department is conducting a research project and needs subjects. Participants will be required to lift weights and then receive one of three types of treatment for soreness. Participants will be tested three (3) times, and have a twenty-four (24) hour follow-up after each test for a total of six (6) visits for this research, each lasting no longer than sixty (60) minutes. Subjects will only be required to make these visits for three weeks.

If you are interested or have questions please contact the primary investigator at the e-mail address listed below.

Thank you for your time,

Thomas Kopec, ATC, LAT
Primary Investigator

Contact information:
Tjk26@uakron.edu or (251) 490-2738