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Is Low Level Laser Therapy Effective for the Treatment of Delayed Onset Muscle Soreness

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Is Low Level Laser Therapy Effective for the Treatment of Delayed Onset Muscle Soreness

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Overview:

Delayed Onset Muscle Soreness (DOMS) is a phenomenon that is experienced frequently in the active population. As the name implies, the onset of muscle soreness occurs at a point in time long after the bout of exercise was performed. DOMS may hinder athletic performance through decreases in strength and range of motion (ROM) and may cause considerable pain upon movement. The goal of this paper is to investigate different therapeutic modalities as treatment for DOMS and determine which intervention produces the most desirable results by way of treating the signs and symptoms associated with delayed onset muscle soreness.

Introduction:

Delayed onset muscle soreness (DOMS) is a sensation that is experienced among the active population following performance of physical activity of a greater than usual intensity and/or duration or unaccustomed physical activity.[1,2] Of these unfamiliar types of exercise, eccentric muscle contractions (the lengthening phase of muscle contraction) have been found to be the leading culprit in the induction of DOMS.[1,3] Fewer muscle fibers are recruited during eccentric muscle contractions; therefore, there is a higher potential for muscle fiber damage to occur during eccentric movements.[1] Although bouts of eccentric exercises have been found to create the highest occurrence of DOMS, other theories have been suggested by researchers. These theories include: mechanical disruption of contractile or connective tissue[1,2,3], leakage of muscle protein into circulation[2], build up of lactic acid[2], and muscle spasm.[2,3]

Patients experiencing delayed onset muscle soreness have reported a variety of signs and symptoms. DOMS is typically characterized by feelings of muscle soreness

upon movement or palpation[1,3], decreased range of motion[1], decreased muscle strength[1,3], pain[1,4], stiffness[1,4], swelling[1], and loss of muscle function.[1] DOMS typically begins to become apparent in the overworked muscle tissue 24 hours post exercise and peaks in intensity between 24 and 72 hours post exercise.[1,2,3,4] After DOMS peaks in intensity it generally takes another five to seven days for the signs and symptoms to dissipate.[1]

Although the active population commonly experiences delayed onset muscle soreness there is not a clearly established therapeutic intervention to treat the signs and symptoms accompanying DOMS. Numerous treatments have been investigated in the past and few, if any, were found effective. The goal of this research paper is to investigate the effectiveness of electrical muscle stimulation and low-level laser therapy in treating the side effects of DOMS.

Therapeutic Interventions:

Both electrical muscle stimulation and low-level laser therapy have been used in some capacity in an attempt to alleviate the signs and symptoms of delayed onset muscle soreness in the past. Weber et al.[3] used a microcurrent electrical muscle stimulation technique to relieve the soreness accompanying DOMS, but failed to find any significant data. Hashmi et al.[4] used a pulsed laser parameter in an effort to eliminate the soreness experienced along with DOMS, but also found pulsed laser to be an ineffective treatment protocol. This research paper will explore the effectiveness of other types of muscle stimulation and laser therapy techniques to determine their effectiveness in treating DOMS. By exploring these different therapeutic modalities, an answer can be provided for the research question: is low-level laser therapy effective for the treatment of delayed onset muscle soreness?

Electrical Muscle Stimulation:

Electrical Muscle Stimulation (EMS) produces its primary effects on the body through the depolarization of sensory, motor, or nociceptive (pain) nerves. The electrical impulses that are produced by the generator mimic action potentials that arise from the central nervous system. These action potentials will depolarize the nerves in a specific order: sensory, motor, then pain depending upon intensity of stimulation.[5] In the clinical setting EMS can be used for a variety of therapeutic purposes. The most common applications of EMS currents include: controlling acute and chronic pain[5,6], reducing edema[5], reducing muscle spasm[5,6], reducing joint contractures[5], inhibiting muscle spasm[5], facilitating tissue healing[5,6], and strengthening muscle.[5,6]

For the purpose of this study a premodulated electrical stimulation current was used. Premodulated stimulation currents are created within the electrical generator before they are introduced to the tissue. The integration of the electrical current occurs outside of the body, therefore, the amplitude of the current is directly applied to the target tissue when it leaves the machine.[6] These currents are created by the mixing of alternating "carrier" currents of differing frequencies. When the alternating currents come into contact as their phases are in sync, constructive interference is formed which builds a larger amplitude wave. The mixing of currents minimizes skin impedance (skin resistance to current flow) and causes a beating effect within the tissue, which causes the current amplitude to change constantly. The two factors mentioned above allow the patient to receive the highest amount of stimulation while experiencing the least discomfort during treatment. Premodulated currents are delivered via two electrodes

placed on the patient's skin by way of a single electrical channel. This set up is indicated as the use of four electrodes is impractical for the size of the body area being treated.[5,6]

Low-Level Laser Therapy:

Low-Level Laser Therapy (LLLT) creates its effect on the body by producing highly organized beams of light (photons) which stimulate changes at the molecular, cellular, and tissue levels. The two most commonly observed effects of the laser are its ability to act on the mitochondria of cells and its specific action on immune cells. The photons produced by the laser enhance the mitochondrion's ability to produce adenosine triphosphate (ATP); which in turn creates changes at the molecular level.[5,7] These changes include: "stimulation of the electron transport chain, stimulation of the mitochondrial respiratory chain…and a reduction in intracellular pH."[5] Lasers affect immune cells specifically by influencing lymphocytes. This allows the lymphocyte to activate and divide more rapidly and move more efficiently throughout the body, in turn causing an increased rate of healing.[7] Other less documented effects include: altered nerve conduction velocity, vessel vasodilation and increased circulation, increased collagen production, and decreased muscle spasm.[5]

Clinically the laser can be used for a wide array of therapeutic purposes. These reasons include: would healing[4,5,7], tissue regeneration[4,5,7], relief of acute and chronic pain[4,5,7], relief of inflammation[4,5,7], prevention of tissue death[4,7], possible inhibition of neurological degeneration[4], fracture healing[5], treatment of multiple forms of arthritis[5], and edema reduction.[7] As more research is being conducted on the use of laser therapy in the clinical setting a variety of other indications for LLLT are certain to be discovered.

Exposing body tissue to electromagnetic energy generates the photochemical events associated with low-level laser therapy. These light forms are referred to as low-level because it uses "light at energy densities that are low compared to other forms of laser therapy,"[7] and for this reason LLLT is also considered a "cold laser."[5,7] In this study a continuous waveform laser was used to treat the signs and symptoms of DOMS. In a continuous waveform application the light will constantly be emitted from the laser apparatus. This light wave will be released from the applicator with a relatively stable intensity and a coherent, collimated light beam.[4,5] A continuous waveform is the gold standard for LLLT application[4], hence it was chosen for the output parameter in this study.

Research Objectives:

The research for this paper was conducted in an effort to meet three objectives:

1. To determine the effectiveness of low-level laser therapy in the treatment of Delayed Onset Muscle Soreness
2. To compare low-level laser therapy to other traditional treatment methods for DOMS
3. To add to the body of research investigating the uses for low-level laser therapy

Research Methods:

The purpose of this research was to measure the effects of premodulated electrical stimulation currents and continuous low-level laser therapy on the elbow flexors of a group of patients after inducing delayed onset muscle soreness. The dependent variables assessed following each treatment included: elbow flexion, elbow extension, and perceived pain. The independent variable was the therapeutic intervention that each participant received in an attempt to treat the signs and symptoms of delayed onset muscle soreness.

Subjects:

Ten male and 20 female college aged students (ages 18-30) from The College at Brockport were recruited for participation in this research project. Those considered for participation in the project were deemed healthy and free of any upper extremity pathology or contraindications to electrical muscle stimulation or laser therapy techniques. Subjects were also required to refrain from any upper extremity resistance training exercises or strenuous upper body dominant physical activity for three days prior to the start of the investigation and for five days following the initial induction of DOMS. The subjects were made aware of the possible side effects associated with each therapeutic modality as well as the risks and benefits associated with their voluntary participation at an informed consent meeting. The meeting was followed by a question and answer session where subjects could express any concerns they had in regards to their participation before signing the official informed consent documents. The informed consent paperwork was screened and approved by the Institutional Review Board at The College at Brockport.

As the 30 subjects were being selected for participation they were given a patient number that was attached to their data to maintain confidentiality. Each number was then input into a computer system that randomly determined which treatment group the participant would be a part of for the duration of the study. The computer generated three groups of ten. The three treatment groups included: premodulated electrical stimulation, continuous low-level laser therapy, and a placebo laser treatment.

Outcome Measures:

Measurements of patient outcomes (elbow flexion and extension and pain) were recorded on six different occasions throughout the duration of the study. Baseline measurements were recorded before the patient underwent the DOMS induction protocol. The five other outcome measurements took place after each treatment session was completed.

The first outcome measure was elbow range of motion (ROM). These measurements were taken with a standard, plastic, universal goniometer[8], and recorded in degrees of movement at each collection period throughout the study. Research conducted by Gajdosik and Bohannon[8] demonstrated that the universal goniometer is a valid and reliable instrument for assessing ROM. Goniometry is a valid assessment of ROM because the only outcome that a goniometer will measure is ROM.[8] Goniometry is deemed most reliable when the same practitioner takes the measurements.[8] In an effort to produce the most reliable ROM results, the same practitioner took elbow flexion and extension measurements at each successive treatment time. The measurements were taken with the patient standing in anatomical position with the center of the goniometer aligned with the lateral epicondyle of the humerus. The stationary arm was in line with the length of the humerus pointing to the acromion process, while the moving arm was aligned with the radius pointing to the styloid process. Standardizing the ROM testing procedures used, "improve[d] reliability, and goniometric measurements must be reliable to be valid.[8]"

Patient pain outcomes were recorded on the Numeric Rating Scale for Pain (NRS), which determines the average intensity of pain that the patient has been

experiencing. Researchers have shown the NRS to be both a valid and reliable assessment of pain. The NRS is an easy to use, eleven-point scale where pain is rated in intensity from zero to ten. Zero represents "no pain" whereas ten represents the "worst possible pain."[9] Pain intensity measurements were recorded following ROM measurements after each treatment session was completed.

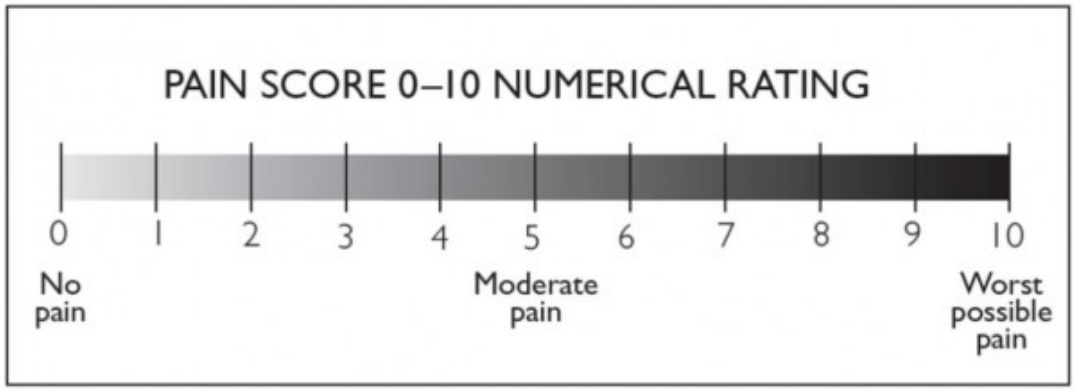

Figure 1: The Numeric Rating Scale for Pain

DOMS Induction Procedure:

To induce delayed onset muscle soreness in the musculature responsible for elbow flexion, a modified protocol adopted from Kuligowski et al.[1] was used. Patients were first instructed to determine their one repetition maximum (1-RM) for a bicep curl. Starting with a five-pound weight the participant was instructed to lift the weight twice. If the participant successfully completed the lift twice he/she was instructed to increase the weight of the dumbbell by five pounds. Patients continued to lift the dumbbells in five-pound increments until they could only complete one repetition with the selected weight.[1] The 1-RM for each patient was recorded and the patient then performed the DOMS induction protocol with that weight.

The patients assumed the starting position with their arm in full elbow flexion and complete supination of the forearm. The exercise was performed on an incline bench to

prevent hyperextension of the elbow during each repetition. The weight was placed in the subject's hand by the researcher as they held the aforementioned position. Once the weight was placed in the patient's hand, they were instructed to lower the weight on a five-second count. After each repetition the researcher returned the patient's arm, with the dumbbell in hand, to the starting position. The patient completed the eccentric lowering of the weight until ten repetitions were completed or until the bicep muscle fatigued (fatigue was classified as the inability to lower the weight for the full five-second count). After the successful completion of ten repetitions, or patient fatigue, a one-minute rest period was given to the subjects. The patient repeated this eccentric exercise cycle five times, performing a maximum of 50 total repetitions throughout the duration of the protocol.[1]

Treatments and Post-treatment Retests:

Immediately following the delayed onset muscle soreness induction protocol the patients received their first treatment. As mentioned above, the patients were either assigned to a premodulated electrical stimulation group, low-level laser therapy group, or a placebo laser treatment group. Immediately following their treatments, the outcome measures of elbow flexion, elbow extension, and perceived pain were recorded. The following sections detail the specific parameters used to treat the signs and symptoms of DOMS.

Group one received the premodulated electrical stimulation treatment for a 15-minute period of time. This treatment was delivered by way of two electrodes placed on the biceps brachii muscle. The pads were placed at the proximal and distal belly of the biceps muscle, which allowed the current to spread throughout the length of the muscle.

The premodulated current was delivered at a strong sensory level, which is reached by increasing the current output to a level where a slight muscle contraction is felt and then decreasing the intensity by roughly five percent.[5] Research has shown that electrical stimulation at a sub-motor (sensory) level has, "positive effects on postexercise muscle soreness and thus exercise recovery."[10] These findings support the rationale to use a premodulated current at a strong sensory level in an attempt to reduce the signs and symptoms of DOMS.

Group two was administered low-level laser therapy. This treatment was given at four locations along the length of the biceps brachii muscle. These locations included: the origin of the muscle, the insertion of the muscle, and two equidistant points in the belly of the biceps muscle. Each location was treated for a duration of 23 seconds with a continuous wave light being applied to the participant's tissue. Continuous wave laser is the gold standard for laser therapy and has been shown to promote quicker nerve and muscle recovery than its pulsed wave counterpart.[4] Therefore, a continuous light application was selected for the purpose of this research paper to treat delayed onset muscle soreness.

Group three received a placebo treatment as the control group. A sham laser treatment was given to each participant in this group. Like the authentic laser treatment, the duration of time spent at each location was 23 seconds. The applicator head was placed along the same four locations as that of the true laser group (origin of the muscle, insertion of the muscle, and two equidistant sites in the belly of the muscle), but no light waves were emitted from the generator.

Five total treatments were administered to the patients throughout the length of the study. Directly following the conclusion of each treatment the participants were instructed to have their outcomes measures of elbow flexion and extension and pain reassessed. These reassessment periods were conducted at zero (immediately after the first treatment), 24, 48, 72, and 96 hours post-exercise.

Statistical Analysis:

The data was statistically analyzed using SPSS version 22. Before any true statistical analysis was performed, the data was tested for normality. T-tests, with a significance level of $\alpha = 0.05$, were completed for each group (premodulated stimulation, LLLT, and placebo LLLT) and each parameter measured (flexion, extension, and pain) as well as for the combined data set for all three groups. The T-tests were designed to determine if there was any significance from baseline measures to measurements taken at hour 96. A six-factor repeated measure ANOVA, with a significance level of $\alpha = 0.05$, was performed to analyze the variance among groups. The assumption of sphericity was violated based upon calculations with Mauchly's test for sphericity; therefore, the degrees of freedom were modified based upon the Greenhouse-Geisser epsilon correction factor.

Results:

The normality testing showed that there were no significant outliers or missing data points and based upon the Q-Q plots the data sets were normally distributed. T-testing for the placebo laser treatment group revealed that there was significance for the outcome of pain, a value of (0.045). The outcome measures of flexion (0.406) and extension (0.696) for this group did not produce significant T-test results. Premodulated electrical stimulation produced no significant results in the treatment of the signs and

symptoms of delayed onset muscle soreness. The results for each outcome are as follows: pain (0.052), flexion (0.096), and extension (0.162). Low-level laser therapy exhibited no significant results through T-testing each variable. The results showed values of (0.143) for pain, (0.624) for flexion, and (0.776) for extension. The results of the combined T-test indicated a significant value for the outcome of pain (0.001), but no statistical significance for flexion (0.327) or extension (0.395) range of motion measurements. The repeated measures ANOVA tested the within subjects effects of each therapeutic modality on the signs and symptoms of delayed onset muscle soreness. The results revealed that over a 96-hour time period no significance existed between any of the three treatment conditions; (0.756) for pain, (0.485) for flexion, and (0.538) on the behalf of extension measurements.

The charts below display the average value for each patient outcome throughout the duration of the study. Each therapeutic modality is shown on its own line in an effort to visually compare and contrast the effectiveness of each treatment for the signs and symptoms of delayed onset muscle soreness.

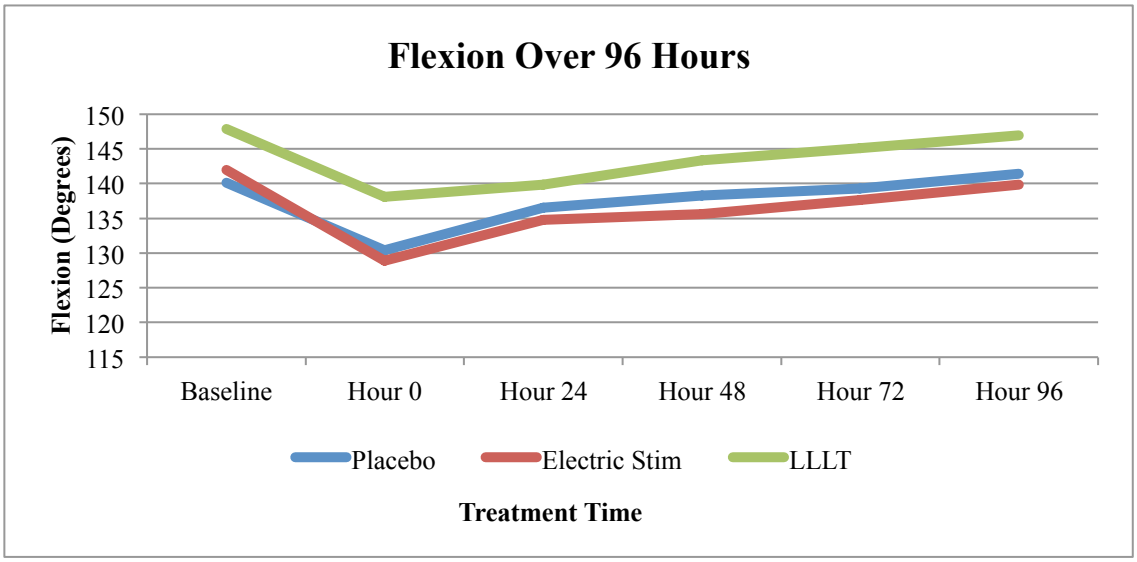

Figure 2: Average flexion measurements for each group at each treatment session

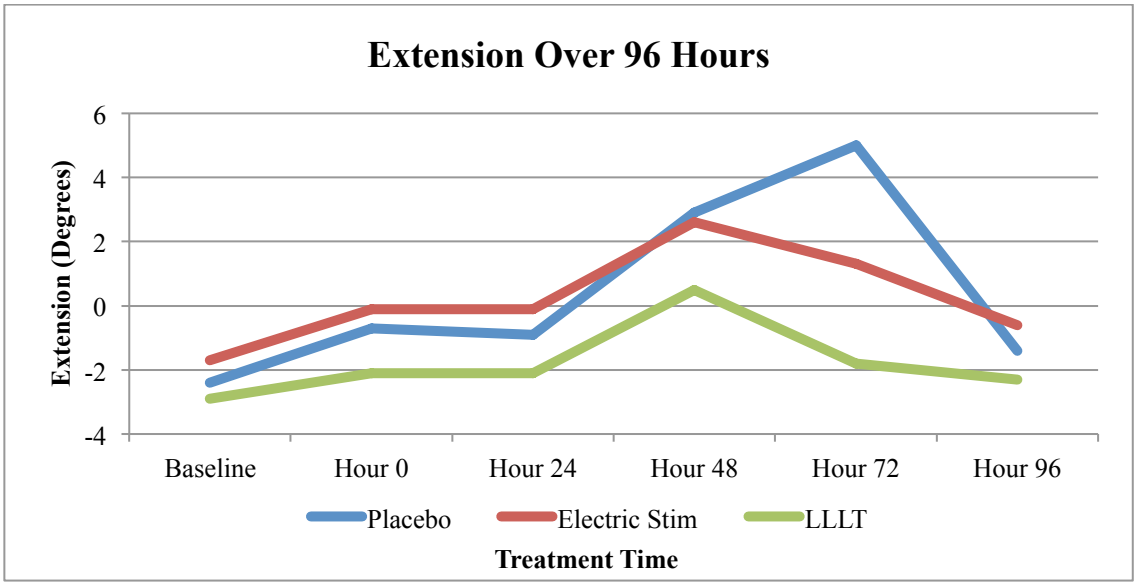

Figure 3: Average extension measurements for each group at each treatment session

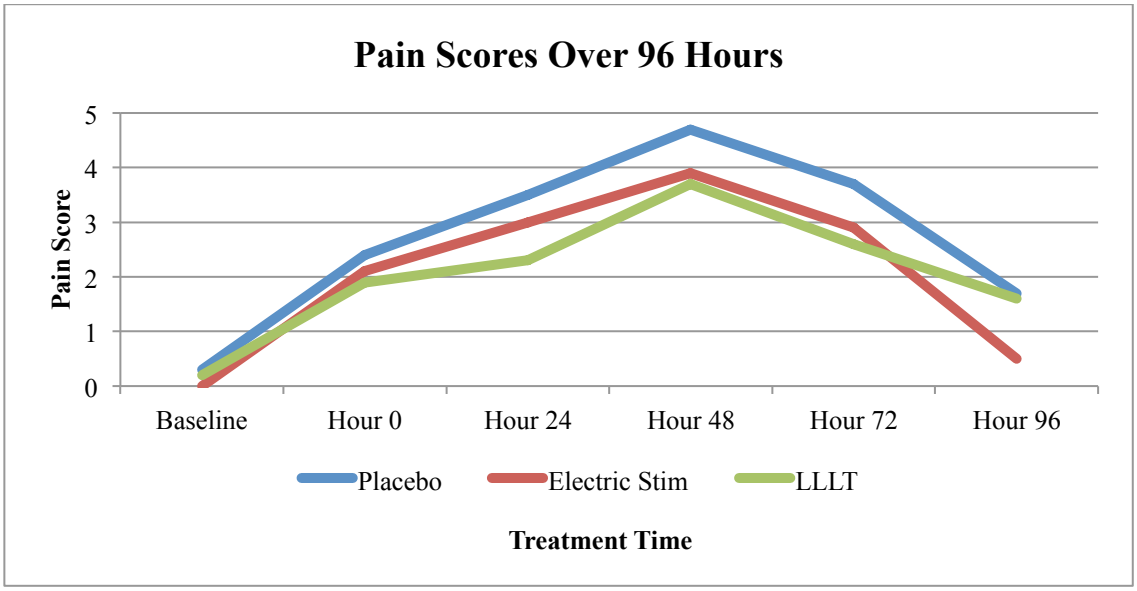

Figure 4: Average pain scores for each group at each treatment session

Discussion:

Upon analysis of the data produced by each individual a substantial increase in perceived pain near hour 48 was noticeable. This suggests that the protocol used to induce delayed onset muscle soreness was effective. The patients in the placebo group reported an average of 4.7 out of 10 for pain scores at hour 48. Those in the electric stimulation group reported 3.9 out of 10 and the LLLT group described pain as an average of 3.7 out of 10 on the numeric rating scale for pain at hour 48.

Statistical analysis demonstrated that neither premodulated stimulation or low-level laser therapy were effective treatments for reducing the signs and symptoms related to DOMS. T-tests showed that after a series of treatments, over a duration of 96 hours, patients did not return to their baseline measurements for perceived soreness or elbow flexion and extension. The ANOVA's also displayed no significant results, which means that there were not any significant differences among the treatment groups over the given time period. According to the results neither treatment was effective; however, if given a choice between premodulated stimulation and LLLT to treat DOMS it would be more beneficial to choose a premodulated current. The electrical current proved to relieve the patients' signs and symptoms more quickly than LLLT.

Based upon the data produced throughout the course of the study, many hypotheses have been formulated as to why particular results were achieved for each treatment group and each variable. In regards to flexion measurements, the muscle stimulation group encountered the largest drop in elbow flexion at hour zero. This is most likely attributed to the electrical current continually stressing the muscle fibers immediately after the treatment. This factor increased the initial fatigue of the muscle

due to the additional stress, and thereby decreased ROM into flexion. This initial drop in flexion meant that the premodulated stimulation group had a larger ROM deficit to overcome to achieve baseline levels after 96 hours. The LLLT group was the closest to achieving baseline flexion measurements after 96 hours. This can be credited to the photochemical events responsible for reducing inflammation and muscle spasm, thus increasing ROM.

The outcome measure of extension suffered for each group because the patients carried their arms in a slightly flexed position, as if they were in a sling. By holding the arm in that position, the muscle remained in a constantly shortened state. The combination of pain, stiffness, and muscle spasm associated with DOMS prevented the subjects from moving their arms into extension comfortably, therefore many patients refused to move their arms at all. The premodulated stimulation group showed slightly better measures of extension at hour 96. The hypothesis for this phenomenon is that the subjects who were treated with muscle stimulation were treated in an extended position whereas those treated with LLLT were in a flexed position. By allowing the muscle to stretch for the duration of treatment those in the stimulation group recovered their baseline ROM more quickly than those who were treated in a flexed position.

In regards to pain measures, premodulated stimulation and LLLT were comparable in reducing the pain and soreness associated with DOMS. Although neither treatment was deemed truly effective, patients in both groups expressed subjective relief either during or after the treatment was administered. Those who received LLLT reported a steady decline in pain after the peak of DOMS, but not immediately after the treatment was given. Members of the premodulated stimulation group reported pain

relief during treatment while the arm was at rest but claimed that pain levels increased upon performance of daily activities after the treatment had concluded.

The placebo laser treatment group had no effects on the healing process and the results showed the most unfavorable outcomes for all three dependent variables. These findings can be credited to the circumstance that no therapeutic intervention was introduced to the body in an attempt promote an atmosphere for healing or to slow the rate of cell death. When comparing the results of the body's natural timeframe for healing to the use of a treatment such as LLLT or premodulated stimulation, results show that it is better to use some form of treatment rather than no treatment at all. The placebo group did present a unique finding though. T-testing showed that the placebo group was significant in controlling pain in the subjects who participated in the experiment. This phenomenon may be directly related to the placebo effect.

The placebo effect is a description of "pain reduction obtained through mechanisms other than those related to the physiological effects of the treatment."[5] In other words, the placebo effect is related to the cognitive and psychological aspects of pain, rather than the physical healing mechanisms within the body. If the patient believes that the treatment will work, there will be a degree of pain reduction although there are no physical changes occurring to the injured tissue. Although the control group, which received placebo laser treatment, did not have any medium introduced to the tissue, they experienced the most significant value of pain reduction. This can be directly related to the placebo effect. Since the patient was told how the modality would work and they believed that it would make them feel better, they actually experienced pain relief with the use of a sham treatment.[5]

The placebo effect has been researched on a wide variety of therapeutic modalities and it has been demonstrated that all modalities produce some degree of a placebo effect. This might also explain the fact that although the premodulated stimulation and the low-level laser therapy groups did not produce significant data, the participants still expressed pain relief upon treatment. As is the case with many other experiments, the patients believed that the treatment was working for them despite hard evidence to prove that they were experiencing pain relief.[5]

Objective and subjective patient data must be explored to answer the question: Is low-level laser therapy effective for the treatment of delayed onset muscle soreness? Objectively, the results of the statistical analysis did not display a quantitative significance for LLLT as a treatment for the signs and symptoms of DOMS. However, subjectively patients reported decreases in the pain and stiffness associated with DOMS, which could be directly related to the placebo effect of the LLLT treatment itself.

Conclusion:

As mentioned previously, DOMS is frequently experienced in the athletic population after an unaccustomed bout of strenuous exercise. The signs and symptoms of DOMS generally peak between 24 and 72 hours after the completion of the bout of exercise. Despite the fact that DOMS is commonly experienced in the active population, there is no treatment protocol deemed significantly effective at treating the signs and symptoms of delayed onset muscle soreness. The goal of this research was to determine if low-level laser therapy was an effective treatment for the signs and symptoms of DOMS. The statistical analysis revealed that LLLT was not effective in restoring range of motion or pain scores to baseline levels after the completion of five treatments.

Physiological healing must not be the only factor taken into consideration though. Clinicians must take into effect the presence of the placebo effect and how it influences psychological healing. If the patient believes in the effects of the treatment they will experience pain relief to a certain extent. There is no "gold standard" for the treatment of DOMS and therefore additional research should be conducted exploring other therapeutic modalities as a treatment for its signs and symptoms.

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