

## **Research Digest**

### **Low Level laser Therapy (LLLT) / Photobiomodulation (PBM Therapy)**

for exercise, performance, fatigue and recovery

Prepared by James D Carroll

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# Photobiomodulation therapy (PBMT) improves performance and accelerates recovery of high-level Rugby players in field test: A randomized, crossover, double-blind, placebo-controlled clinical study.

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While growing evidence supports the use of photobiomodulation therapy (PBMT) for performance and recovery enhancement, there have only been laboratory-controlled studies. Therefore, the aim of this study was to analyze the effects of PBMT in performance and recovery of high-level rugby players during an anaerobic field test. Twelve male high-level rugby athletes were recruited in this randomized, crossover, double-blinded, placebo-controlled trial. No interventions were performed before the Bangsbo Sprint Test (BST) at familiarization phase (week 1), at weeks 2 and 3 pre-exercise PBMT or placebo were randomly applied to each athlete. PBMT irradiation was performed at 17 sites of each lower limb, employing a cluster with 12 diodes (4 laser diodes of 905nm, 4 LED diodes of 875nm, and 4 LED diodes of 640nm, 30J per site - manufactured by Multi Radiance Medical). Average time of sprints, best time of sprints, and fatigue index were obtained from BST. Blood lactate levels were assessed at baseline, and at 3, 10, 30 and 60 minutes after BST. Athletes' perceived fatigue was also assessed through a questionnaire. PBMT significantly ( $p < 0.05$ ) improved average time of sprints and fatigue index in BST. PBMT significantly decreased percentage of change in blood lactate levels ( $p < 0.05$ ) and perceived fatigue ( $p < 0.05$ ). Pre-exercise PBMT with the combination of super-pulsed laser (low-level laser), red and infrared LEDs can enhance performance and accelerate recovery of high-level rugby players in field test. This opens a new avenue for wide use of PBMT in real clinical practice in sports settings.

J Strength Cond Res 2016 Apr 2

<http://www.ncbi.nlm.nih.gov/pubmed/?term=27050245>

# Using Pre-Exercise Photobiomodulation Therapy Combining Super-Pulsed Lasers and Light-Emitting Diodes to Improve Performance in Progressive Cardiopulmonary Exercise Tests.

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**CONTEXT:** Skeletal muscle fatigue and exercise performance are novel areas of research and clinical application in the photobiomodulation field, and positive outcomes have been reported in several studies; however, the optimal measures have not been fully established. **OBJECTIVE:** To assess the acute effect of photobiomodulation therapy (PBMT) combining superpulsed lasers (low-level laser therapy) and light-emitting diodes (LEDs) on muscle performance during a progressive cardiopulmonary treadmill exercise test. **DESIGN:** Crossover study. **SETTING:** Laboratory. **PATIENTS OR OTHER PARTICIPANTS:** Twenty untrained male volunteers (age = 26.0 +/- 6.0 years, height = 175.0 +/- 10.0 cm, mass = 74.8 +/- 10.9 kg). **INTERVENTION(S):** Participants received PBMT with either combined superpulsed lasers and LED (active PBMT) or placebo at session 1 and the other treatment at session 2. All participants completed a cardiopulmonary test on a treadmill after each treatment. For active PBMT, we performed the irradiation at 17 sites on each lower limb (9 on the quadriceps, 6 on the hamstrings, and 2 on the gastrocnemius muscles), using a cluster with 12 diodes (four 905-nm superpulsed laser diodes with an average power of 0.3125 mW, peak power of 12.5 W for each diode, and frequency of 250 Hz; four 875-nm infrared LED diodes with an average power of 17.5 mW; and four 640-nm red LED diodes with an average power of 15 mW) and delivering a dose of 30 J per site. **MAIN OUTCOME MEASURE(S):** Distance covered, time until exhaustion, pulmonary ventilation, and dyspnea score. **RESULTS:** The distance covered (1.96 +/- 0.30 versus 1.84 +/- 0.40 km,  $t_{19} = 2.119$ ,  $P < .001$ ) and time until exhaustion of the cardiopulmonary test (780.2 +/- 91.0 versus 742.1 +/- 94.0 seconds,  $t_{19} = 3.028$ ,  $P < .001$ ) was greater after active PBMT than after placebo. Pulmonary ventilation was greater (76.4 +/- 21.9 versus 74.3 +/- 19.8 L/min,  $t_{19} = 0.180$ ,  $P = .004$ ) and the score for dyspnea was lower (3.0 [0.5-9.0] versus 4.0 [0.0-9.0],  $U = 184.000$ ,  $P < .001$ ) after active PBMT than after placebo. **CONCLUSIONS:** The combination of lasers and LEDs increased the time, distance, and pulmonary ventilation and decreased the score of dyspnea during a cardiopulmonary test.

# Role of low-level laser therapy on the cardiac remodeling after myocardial infarction: A systematic review of experimental studies.

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**AIMS:** We systematically reviewed the role of low-level laser therapy (LLLT) in cardiac remodeling after myocardial infarction. **MAIN METHODS:** Literatures were systematically searched in several electronic databases. We included only studies with a well-standardized coronary occlusion model in vivo LLLT application. **KEY FINDINGS:** After screening, 14 studies were eligible for review. The study heterogeneity was described in terms of rationality, gender, irradiation parameters, treatment numbers and moment of LLLT application. Three studies showed a null role of LLLT on infarct size, and only one study found positive LLLT effects on the cardiac performance. The cardioprotective role of LLLT was mediated by anti-inflammatory, pro-angiogenic and anti-oxidant actions. **SIGNIFICANCE:** The reduction in infarct size is a major finding. The LLLT cardioprotection may be mediated by several molecular and cellular mechanisms. Although these results are exciting, there are many limitations that must be resolved before LLLT clinical trials.

Life Sci 2016 Feb 27

<http://www.ncbi.nlm.nih.gov/pubmed/?term=26930372>

# The effect of low-level laser therapy on oxidative stress and functional fitness in aged rats subjected to swimming: an aerobic exercise.

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The aim of the present study was to determine whether low-level laser therapy (LLLT) in conjunction with aerobic training interferes with oxidative stress, thereby influencing the performance of old rats participating in swimming. Thirty Wistar rats (*Norvegicus albinus*) (24 aged and six young) were tested. The older animals were randomly divided into aged-control, aged-exercise, aged-LLLT, aged-LLLT/exercise, and young-control. Aerobic capacity ( $VO_{2max0.75}$ ) was analyzed before and after the training period. The exercise groups were trained for 6 weeks, and the LLLT was applied at 808 nm and 4 J energy. The rats were euthanized, and muscle tissue was collected to analyze the index of lipid peroxidation thiobarbituric acid reactive substances (TBARS), glutathione (GSH), superoxide dismutase (SOD), and catalase (CAT) activities.  $VO_{20.75max}$  values in the aged-LLLT/exercise group were significantly higher from those in the baseline older group ( $p < 0.01$ ) and the LLLT and exercise group ( $p < 0.05$ ). The results indicate that the activities of CAT, SOD, and GPx were higher and statistically significant ( $p < 0.05$ ) in the LLLT/exercise group than those in the LLLT and exercise groups. Young animals presented lesser and statistically significant activities of antioxidant enzymes compared to the aged group. The LLLT/exercise group and the LLLT and exercise group could also mitigate the concentration of TBARS ( $p > 0.05$ ). Laser therapy in conjunction with aerobic training may reduce oxidative stress, as well as increase  $VO_{20.75max}$ , indicating that an aerobic exercise such as swimming increases speed and improves performance in aged animals treated with LLLT.

Lasers Med Sci 2016 Feb 9

<http://www.ncbi.nlm.nih.gov/pubmed/?term=26861983>

# Effects of photobiomodulation on the fatigue level in elderly women: an isokinetic dynamometry evaluation.

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Aging is responsible by a series of morphological and functional modifications that lead to a decline of muscle function, particularly in females. Muscle tissue in elderly people is more susceptible to fatigue and, consequently, to an increased inability to maintain strength and motor control. In this context, therapeutic approaches able of attenuating muscle fatigue have been investigated. Among these, the photobiomodulation demonstrate positive results to interacts with biological tissues, promoting the increase in cell energy production. Thus, the aim of this study was to investigate the effects of photobiomodulation (808 nm, 250 J/cm<sup>2</sup>, 100 mW, 7 J each point) in the fatigue level and muscle performance in elderly women. Thirty subjects entered a crossover randomized double-blinded placebo-controlled trial. Photobiomodulation was delivered on the rectus femoris muscle of the dominant limb immediately before the fatigue protocol. In both sessions, peripheral muscle fatigue was analyzed by surface electromyography (EMG) and blood lactate analysis. Muscle performance was evaluated using an isokinetic dynamometer. The results showed that photobiomodulation was able of reducing muscle fatigue by a significant increase of electromyographic fatigue index (EFI) ( $p = 0.047$ ) and decreasing significantly lactate concentration 6 min after the performance of the fatigue protocol ( $p = 0.0006$ ) compared the placebo laser session. However, the photobiomodulation was not able of increasing muscle performance measured by the isokinetic dynamometer. Thus, it can be conclude that the photobiomodulation was effective in reducing fatigue levels. However, no effects of photobiomodulation on muscle performance was observed.

Lasers Med Sci 2015 Dec 29

<http://www.ncbi.nlm.nih.gov/pubmed/?term=26714981>

# Evaluation of the Proliferative Effects Induced by Low-Level Laser Therapy in Bone Marrow Stem Cell Culture.

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**OBJECTIVE:** The objective of this study was to evaluate the effect of laser irradiation on dog bone marrow stem cells. **BACKGROUND DATA:** Low doses of low-level red laser positively affect the viability of mesenchymal stem cells, and also increase proliferation. **METHODS:** Low-level laser (wavelength, 660 nm; power output, 50 mW), was applied to dog bone marrow stem cell cultures (DBMSC). The energy densities delivered varied from 1 to 12J/cm<sup>2</sup>. The effect of the laser irradiation was evaluated on cell proliferation measured with the MTT colorimetric test, cell cycle phase, and on lipidic peroxidation (free radical production). **RESULTS:** The results indicate that laser irradiation to DBMSC did not change the morphology of the cells, but significantly increased their viability and the number of cells at the G2/M phase with 6, 10, and 12 J/cm<sup>2</sup>. On the other hand, malonaldehyde production was significantly enhanced with 8 J/cm<sup>2</sup>. **CONCLUSIONS:** The parameters used to irradiate DBMSC increased significantly proliferation without producing high levels of reactive oxygen species (ROS).

Photomed Laser Surg 2015 Nov 18

<http://www.ncbi.nlm.nih.gov/pubmed/?term=26580583>

# Low Level Laser Therapy Reduces the Development of Lung Inflammation Induced by Formaldehyde Exposure.

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Lung diseases constitute an important public health problem and its growing level of concern has led to efforts for the development of new therapies, particularly for the control of lung inflammation. Low Level Laser Therapy (LLLT) has been highlighted as a non-invasive therapy with few side effects, but its mechanisms need to be better understood and explored. Considering that pollution causes several harmful effects on human health, including lung inflammation, in this study, we have used formaldehyde (FA), an environmental and occupational pollutant, for the induction of neutrophilic lung inflammation. Our objective was to investigate the local and systemic effects of LLLT after FA exposure. Male Wistar rats were exposed to FA (1%) or vehicle (distillated water) during 3 consecutive days and treated or not with LLLT (1 and 5 hours after each FA exposure). Non-manipulated rats were used as control. 24 h after the last FA exposure, we analyzed the local and systemic effects of LLLT. The treatment with LLLT reduced the development of neutrophilic lung inflammation induced by FA, as observed by the reduced number of leukocytes, mast cells degranulated, and a decreased myeloperoxidase activity in the lung. Moreover, LLLT also reduced the microvascular lung permeability in the parenchyma and the intrapulmonary bronchi. Alterations on the profile of inflammatory cytokines were evidenced by the reduced levels of IL-6 and TNF-alpha and the elevated levels of IL-10 in the lung. Together, our results showed that LLLT abolishes FA-induced neutrophilic lung inflammation by a reduction of the inflammatory cytokines and mast cell degranulation. This study may provide important information about the mechanisms of LLLT in lung inflammation induced by a pollutant.

PLoS One 2015 10(11) e0142816

<http://www.ncbi.nlm.nih.gov/pubmed/?term=26569396>



# Effect of low-level phototherapy on delayed onset muscle soreness: a systematic review and meta-analysis.

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To determine the effectiveness of low-level phototherapy (i.e. light-emitting diode therapy [LEDtherapy] or light amplification by stimulated emission of radiation therapy [LASERtherapy]) on pain, skeletal muscle injury (creatinase kinase [CK] levels and edema) and skeletal muscle function (range of movement and strength) in people undergoing an exercise protocol. (Cochrane Central Register of Controlled Trials, MEDLINE, EMBASE, PEDro, SciELO and LILACS up to May 2014), we included randomized controlled trials, quasi-randomized controlled trials and crossover studies in which study participants were allocated to receive either low-level phototherapy or placebo treatment. Phototherapy should have been applied in a single treatment session, either before or after an exercise protocol. We identified 15 studies involving 317 participants. Meta-analyses were limited by substantial heterogeneity. Compared to the placebo group, reduction in CK levels was only observed when LASERtherapy was applied before an exercise protocol (standardized mean difference = -0.66; 95 % CI = -1.30, -0.02). No between-group difference in edema, range of movement and strength were detected when phototherapy was applied before or after exercise. Evidence from this review suggests that low-level phototherapy may not have substantial effect in the treatment of skeletal muscle injury and pain caused by exercise. Definitive conclusions are limited due to the small number of included studies in each meta-analysis, disparities across the included studies and small sample sizes.

Lasers Med Sci 2016 Jan 31(1) 165-77

<http://www.ncbi.nlm.nih.gov/pubmed/?term=26563953>

# No Effect of Acupuncture in the Relief of Delayed-Onset Muscle Soreness: Results of a Randomized Controlled Trial.

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**BACKGROUND:** Delayed-onset muscle soreness (DOMS) is a common symptom in people participating in exercise, sport, or recreational physical activities. Several remedies have been proposed to prevent and alleviate DOMS. **DESIGN AND METHODS:** A five-arm randomized controlled study was conducted to examine the effects of acupuncture on eccentric exercise-induced DOMS of the biceps brachii muscle. Participants were recruited through convenience sampling of students and general public. Participants were randomly allocated to needle, laser, sham needle, sham laser acupuncture, and no intervention. Outcome measures included pressure pain threshold (PPT), pain intensity (visual analog scale), and maximum isometric voluntary force. **RESULTS:** Delayed-onset muscle soreness was induced in 60 participants (22 females, age 23.6 +/- 2.8 years, weight 66.1 +/- 9.6 kg, and height 171.6 +/- 7.9 cm). Neither verum nor sham interventions significantly improved outcomes within 72 hours when compared with no treatment control ( $P > 0.05$ ). **CONCLUSIONS:** Acupuncture was not effective in the treatment of DOMS. From a mechanistic point of view, these results have implications for further studies: (1) considering the high-threshold mechanosensitive nociceptors of the muscle, the cutoff for PPT (5 kg/cm) chosen to avoid bruising might have led to ceiling effects; (2) the traditional acupuncture regimen, targeting muscle pain, might have been inappropriate as the DOMS mechanisms seem limited to the muscular unit and its innervation. Therefore, a regionally based regimen including an intensified intramuscular needling (dry needling) should be tested in future studies, using a higher cutoff for PPT to avoid ceiling effects.

Clin J Sport Med 2015 Nov 4

<http://www.ncbi.nlm.nih.gov/pubmed/?term=26540600>

# Effects of low-intensity non-coherent light therapy on the inflammatory process in the calcaneal tendon of ovariectomized rats.

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The aim of this experimental study was to investigate the effects of low-intensity light-emitting diode (LED) phototherapy on the inflammatory process in the calcaneal tendon of ovariectomized rats (OVX) through the involvement of the inflammatory mediators interleukin (IL)-6, IL-10, and tumor necrosis factor-alpha (TNF-alpha). Thirty-five female Wistar rats were divided into 4 groups: 3 groups of OVX rats totaling 30 rats (untreated OVX rats [OVX injury group], treated OVX rats [OVX LED group], and control OVX rats; subgroups existed based on the sampling times, which were 3, 7, and 14 days) and 1 group of non-OVX rats (not OVX; n = 5). Tendon injury was induced by trauma using a 208-g mass placed at 20 cm from the right tendon of each animal with energy of 0.70 J. The animals were treated 12 h after tendonitis with LED therapy and every 48 h thereafter until euthanasia (at 3, 7, or 14 days). The tendons were dissected and stored in liquid nitrogen at -196 degrees C, thawed only at the time of immunoenzymatic testing (ELISA). Groups treated with LED showed a decrease in the number of pro-inflammatory cells, IL-6, and TNF-alpha ( $p < 0.05$ ), and an increase in IL-10 ( $p < 0.05$ ) when compared to the not OVX group ( $p < 0.05$ ). It was concluded that low-intensity LED treatment using the parameters and wavelength of 945 nm in the time periods studied reduced the release of IL-6 and TNF-alpha and increased the release of IL-10, thereby improving the inflammatory response in OVX rats.

Lasers Med Sci 2015 Oct 27

<http://www.ncbi.nlm.nih.gov/pubmed/?term=26507001>

# Dose-responses of Stem Cells from Human Exfoliated Teeth to Infrared LED Irradiation.

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Despite several reports regarding tissue regeneration, including pulp repair induced by different light sources, only limited data have been reported concerning the effects of light-emitting diodes (LED) on stem cells from human exfoliated deciduous teeth (SHEDs). The aim of this study was to evaluate the effects of different energy densities of infrared LED on the cell viability, number of cells and mineralized tissue production by SHEDs. SHEDs were obtained from near-exfoliation primary teeth (n=3), seeded in plain DMEM (104 cells/cm<sup>2</sup>), and irradiated by a LED prototype (LEDTable 850 nm, 40 mW/cm<sup>2</sup>) delivering 0 (control), 2, 4, 8, 15 or 30 J/cm<sup>2</sup> (n=9). Cell viability (MTT assay), cell proliferation (trypan blue assay), and mineralized nodule (MN) formation (alizarin red stain) were assessed 12 and 72 h post-irradiation. Data were subjected to Kruskal-Wallis and Mann-Whitney tests (alpha=0.05). Cells irradiated with 2 or 4 J/cm<sup>2</sup> exhibited higher metabolism at 72 h, and all energy densities provided increase in cell proliferation after 12 h. Regarding MN formation, the best results were observed at 72 h after SHED irradiation with 8 and 15 J/cm<sup>2</sup>. It was concluded that the cell viability, cell number and MN formation by pulp cells are enhanced after exposure to infrared LED irradiation. Overall, the greatest SHED biostimulation was obtained with 4 and 8 J/cm<sup>2</sup>.

Braz Dent J 2015 Jul-Aug 26(4) 409-15

<http://www.ncbi.nlm.nih.gov/pubmed/?term=26312982>

# Pre-exercise low-level laser therapy improves performance and levels of oxidative stress markers in mdx mice subjected to muscle fatigue by high-intensity exercise.

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This study was designed to determine if the levels of oxidative stress markers are influenced by low-level laser therapy (LLLT) in mdx mice subjected to high-intensity exercise training on an electric treadmill. We used 21 C57BL/10ScSn-Dmdmdx/J mice and 7 C57BL/10ScSn mice, all aged 4 weeks. The mice were divided into four groups: a positive control group of normal, wild-type mice (WT); a negative control group of untreated mdx mice; a group of mdx mice that underwent forced high-intensity exercise on a treadmill (mdx fatigue); and another group of mdx mice with the same characteristics that were treated with LLLT at a single point on the gastrocnemius muscle of the hind paw and underwent forced high-intensity exercise on a treadmill. The mdx mice treated with LLLT showed significantly lower levels of creatine kinase (CK) and oxidative stress than mdx mice that underwent forced high-intensity exercise on a treadmill. The activities of the antioxidant enzyme superoxide dismutase (SOD) were higher in control mdx mice than in WT mice. LLLT also significantly reduced the level of this marker. LLLT had a beneficial effect also on the skeletal muscle performance of mdx mice. However, the single application of LLLT and the dose parameters used in this study were not able to change the morphology of a dystrophic muscle.

Lasers Med Sci 2015 Jun 16

<http://www.ncbi.nlm.nih.gov/pubmed/?term=26076829>

# Effects of exercise training and photobiomodulation therapy (EXTRAPHOTO) on pain in women with fibromyalgia and temporomandibular disorder: study protocol for a randomized controlled trial.

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**BACKGROUND:** Fibromyalgia (FM) is a syndrome most prevalent in women, in whom it is characterized mainly by chronic pain. An important issue is that many patients with FM are reported to have temporomandibular dysfunction (TMD), and the coexistence of these pathologies generates a clinical outcome of high complexity. The literature is unclear regarding an effective therapy for reducing pain in patients with both comorbidities. Exercise training and phototherapy (low-level laser therapy with light-emitting diode) are two of the approaches used to treat pain. Thus, the aim of this study is to assess the potential role of exercise training plus phototherapy in reducing chronic pain in women with FM and TMD. A further aim is to determine whether the interventions can improve quality of life and modulate endogenous serotonin. **METHODS/DESIGN:** A randomized controlled clinical trial will be conducted. It will involve 60 women  $\geq$  35 years of age with a diagnosis of FM and TMD. After recruitment, patients will be randomly allocated to one of four groups: a control group (no intervention), a group that will receive a phototherapy intervention (PHO), a group that will be prescribed muscle-stretching, aerobic, and facial exercises (EXT), or a group that will receive phototherapy plus exercise interventions (PHO + EXT). The trial will last 10 weeks, and the following outcomes will be evaluated on two separate occasions (baseline and within 24 h after the last day of the protocol). Pain intensity will be analyzed using a visual analogue scale and the McGill Pain Questionnaire, and pain thresholds will be punctuated using a digital algometer. FM symptoms will be assessed using the Fibromyalgia Impact Questionnaire, and quality of life will be determined with the 36-item Short Form Health Survey. Serotonin levels will be evaluated in salivary samples using a competitive enzyme-linked immunosorbent assay. **DISCUSSION:** This is the first randomized controlled trial in which the role of phototherapy, exercise training, and a combination of these interventions will be evaluated for chronic pain in patients with FM and TMD. The results will offer valuable clinical evidence for objective assessment of the potential benefits and risks of procedures. **TRIAL REGISTRATION:** ClinicalTrials.gov Identifier: NCT02279225. Registered 27 October 2014.

# Influence of low-level laser therapy on vertical jump in sedentary individuals.

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**OBJECTIVE:** To investigate the effects of low intensity laser (660nm), on the surae triceps muscle fatigue and power, during vertical jump in sedentary individuals, in addition to delayed onset muscle soreness. **METHODS:** We included 22 sedentary volunteers in the study, who were divided into three groups: G1 (n=8) without performing low intensity laser (control); G2 (n=7) subjected to 6 days of low intensity laser applications; and G3 (n=7) subjected to 10 days of low intensity laser applications. All subjects were evaluated by means of six evaluations of vertical jumps lasting 60 seconds each. In G2 and G3, laser applications in eight points, uniformly distributed directly to the skin in the region of the triceps surae were performed. Another variable analyzed was the delayed onset muscle soreness using the Visual Analog Scale of Pain. **RESULTS:** There was no significant difference in fatigue and mechanical power. In the evaluation of delayed onset muscle soreness, there was significant difference, being the first evaluation higher than the others. **CONCLUSION:** The low intensity laser on the triceps surae, in sedentary individuals, had no significant effects on the variables evaluated.

Einstein (Sao Paulo) 2015 Jan-Mar 13(1) 41-6

<http://www.ncbi.nlm.nih.gov/pubmed/?term=25993067>

# The thermal impact of phototherapy with concurrent super-pulsed lasers and red and infrared LEDs on human skin.

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From the very first reports describing the method of action of phototherapy, the effects have been considered to be the result of photochemical and photophysical interactions between the absorbed photons and tissue and not related to secondary changes in tissue or skin temperature. However, thermal effects have been recently reported in dark pigmented skin when irradiated with single wavelengths of 810 and 904 nm of low-level laser therapy (LLLT) devices even with doses that do not exceed those recommended by the World Association of Laser Therapy (WALT). The aim of this study was to evaluate the thermal impact during the concurrent use of pulsed red and infrared LEDs and super-pulsed lasers when applied to light, medium, and dark pigmented human skin with doses typically seen in clinical practice. The study evaluated the skin temperature of 42 healthy volunteers (males and females 18 years or older, who presented different pigmentations, stratified according to Von Luschan's chromatic scale) via the use of a thermographic camera. Active irradiation was performed with using the multi-diode phototherapy cluster containing four 905-nm super-pulsed laser diodes (frequency set to 250 Hz), four 875-nm infrared-emitting diodes, and four 640-nm LEDs (manufactured by Multi Radiance Medical, Solon, OH, USA). Each of the four doses were tested on each subject: placebo, 0 J (60 s); 10 J (76 s); 30 J (228 s); and 50 J (380 s). Data were collected during the last 5 s of each dose of irradiation and continued for 1 min after the end of each irradiation. No significant skin temperature increases were observed among the different skin color groups ( $p > 0.05$ ), age groups ( $p > 0.05$ ), or gender groups ( $p > 0.05$ ). Our results indicate that the concurrent use of super-pulsed lasers and pulsed red and infrared LEDs can be utilized in patients with all types of skin pigmentation without concern over safety or excessive tissue heating. Additionally, the doses and device utilized in present study have demonstrated positive outcomes in prior clinical trials. Therefore, it can be concluded that the effects seen by the concurrent use of multiple wavelengths and light sources were the result of desirable photobiomodulation effect and not related to thermal influence.

*Lasers Med Sci* 2015 Jul 30(5) 1575-81

<http://www.ncbi.nlm.nih.gov/pubmed/?term=25987340>



# The effect of low-level laser irradiation on sperm motility, and integrity of the plasma membrane and acrosome in cryopreserved bovine sperm.

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**BACKGROUND AND OBJECTIVE:** Freezing changes sperm integrity remarkably. Cryopreservation involves cooling, freezing, and thawing and all these contribute to structural damage in sperm, resulting in reduced fertility potential. Low-level laser irradiation (LLLI) could increase energy supply to the cell and cause reactive oxygen species reduction (ROS), contributing to the restoration of oxygen consumption and adenosine triphosphate synthesis (ATP) in the mitochondria. Our goal was to analyze the effects of low-level laser irradiation on sperm motility and integrity of the plasma membrane and acrosome in cryopreserved bovine sperm. **STUDY DESIGN/MATERIALS AND METHODS:** We analyzed 09 samples of bull semen (*Bos taurus indicus*), divided into three groups: a control group without laser irradiation, a 4J group subjected to a laser irradiation dose of 4 joules, and a 6J group subjected to dose of 6 joules. Samples were divided for the analysis of cell viability and acrosomal membrane integrity using flow cytometry; another portion was used for motion analysis. Irradiation was performed in petri dishes of 30 mm containing 3 ml of semen by an aluminum gallium indium phosphide laser diode with a wavelength of 660 nm, 30 mW power, and energy of 4 and 6 joules for 80 and 120 seconds respectively. Subsequently, the irradiated and control semen samples were subjected to cryopreservation and analyzed by flow cytometry (7AAD and FITC-PSA) using the ISAS--Integrated Semen Analysis System. **RESULTS:** Flow cytometry showed an increase in the percentage of live sperm cells and acrosome integrity in relation to control cells when subjected to irradiation of low-power laser in two different doses of 4 and 6 joules ( $p < 0.05$ ). In the analysis of straightness, percentage of cell movement, and motility, a dose of 4 joules was more effective ( $p < 0.05$ ). **CONCLUSION:** We conclude that LLLI may exert beneficial effects in the preservation of live sperm. A dose of 4 joules prior to cryopreservation was more effective than a dose of 6 joules in preserving sperm motility.

PLoS One 2015 10(3) e0121487

<http://www.ncbi.nlm.nih.gov/pubmed/?term=25781016>

## Light-emitting diode therapy (LEDT) before matches prevents increase in creatine kinase with a light dose response in volleyball players.

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Low-level laser (light) therapy (LLLT) has been applied over skeletal muscles before intense exercise (muscular pre-conditioning) in order to reduce fatigue and muscle damage (measured by creatine kinase, CK) in clinical trials. However, previous exercise protocols do not exactly simulate the real muscle demand required in sports. For this reason, the aim of this randomized and double-blind placebo-controlled trial was to investigate whether light-emitting diode therapy (LEDT) applied over the quadriceps femoris muscles, hamstrings, and triceps surae of volleyball players before official matches could prevent muscle damage (CK) with a dose response, establishing a therapeutic window. A professional male volleyball team (12 athletes) was enrolled in this study, and LEDT was applied before 4 matches during a national championship. LEDT used an array of 200 light-emitting diodes (LEDs) arranged in 25 clusters of 4 infrared LEDs (850 +/- 20 nm; 130 mW) and 25 clusters of 4 red LEDs (630 +/- 10 nm; 80 mW). Athletes were randomized to receive one of four different total doses over each muscle group in a double-blind protocol: 105 J (20 s), 210 J (40 s), 315 J (60 s), and placebo (no light for 30 s). CK in blood was assessed 1 h before and 24 h after each match. LEDT at 210 J avoided significant increases in CK (+10 %;  $P = 0.993$ ) as well as 315 J (+31 %,  $P = 0.407$ ). Placebo (0 J) allowed a significant increase in CK (+53 %;  $P = 0.012$ ) as well as LEDT at 105 J (+59 %;  $P = 0.001$ ). LEDT prevented significant increases of CK in blood in athletes when applied before official matches with a light dose response of 210-315 J, suggesting athletes might consider applying LEDT before competition.

*Lasers Med Sci* 2015 May 30(4) 1281-7

<http://www.ncbi.nlm.nih.gov/pubmed/?term=25722067>

# Time response of increases in ATP and muscle resistance to fatigue after low-level laser (light) therapy (LLLT) in mice.

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Recently, low-level laser (light) therapy has been used to increase muscle performance in intense exercises. However, there is a lack of understanding of the time response of muscles to light therapy. The first purpose of this study was to determine the time response for light-emitting diode therapy (LEDT)-mediated increase in adenosine triphosphate (ATP) in the soleus and gastrocnemius muscles in mice. Second purpose was to test whether LEDT can increase the resistance of muscles to fatigue during intense exercise. Fifty male Balb/c mice were randomly allocated into two equal groups: LEDT-ATP and LEDT-fatigue. Both groups were subdivided into five equal subgroups: LEDT-sham, LEDT-5 min, LEDT-3 h, LEDT-6 h, and LEDT-24 h. Each subgroup was analyzed for muscle ATP content or fatigue at specified time after LEDT. The fatigue test was performed by mice repeatedly climbing an inclined ladder bearing a load of 150 % of body weight until exhaustion. LEDT used a cluster of LEDs with 20 red (630 +/- 10 nm, 25 mW) and 20 infrared (850 +/- 20 nm, 50 mW) delivering 80 mW/cm(2) for 90 s (7.2 J/cm(2)) applied to legs, gluteus, and lower back muscles. LEDT-6 h was the subgroup with the highest ATP content in soleus and gastrocnemius compared to all subgroups ( $P < 0.001$ ). In addition, mice in LEDT-6 h group performed more repetitions in the fatigue test ( $P < 0.001$ ) compared to all subgroups: LEDT-sham and LEDT-5 min (~600 %), LEDT-3 h (~200 %), and LEDT-24 h (~300 %). A high correlation between the fatigue test repetitions and the ATP content in soleus ( $r = 0.84$ ) and gastrocnemius ( $r = 0.94$ ) muscles was observed. LEDT increased ATP content in muscles and fatigue resistance in mice with a peak at 6 h. Although the time response in mice and humans is not the same, athletes might consider applying LEDT at 6 h before competition.

Lasers Med Sci 2015 May 30(4) 1259-67

<http://www.ncbi.nlm.nih.gov/pubmed/?term=25700769>

# Photobiomodulation therapy in skeletal muscle: from exercise performance to muscular dystrophies.

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Photomed Laser Surg 2015 Feb 33(2) 53-4

<http://www.ncbi.nlm.nih.gov/pubmed/?term=25654277>

# The action of pre-exercise low-level laser therapy (LLLT) on the expression of IL-6 and TNF-alpha proteins and on the functional fitness of elderly rats subjected to aerobic training.

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The aim of the present study was to determine whether low-level laser therapy (LLLT), when used in conjunction with aerobic training, interferes with the expression of inflammatory markers IL-6 and TNF-alpha, thereby influencing the performance of old rats participating in swimming. A total of 30 Wistar rats (*Rattus norvegicus albinus*) were used for this study: 24 aged rats, and 6 young rats. The older animals were randomly divided into four groups designated as follows: aged-control, aged-exercise, aged-LLLT, aged-LLLT/exercise group, and young-control animals. Aerobic capacity (VO<sub>2</sub>max) was analyzed before and after training period. The aged-exercise and aged-LLLT/exercise groups were trained for 6 weeks. LLLT laser was applied before each training session with 808 nm and 4 J of energy to the indicated groups throughout training. The rats were euthanized, and muscle tissue and serum were collected for muscle cross-sectional area and IL-6 and TNF-alpha protein analysis. In VO<sub>2</sub> showed statistical difference between young- and aged-control groups (used as baseline) ( $p < 0.05$ ). The same difference can be observed in the young control group compared with all intervention groups (exercise, LLLT and LLLT + exercise). In comparison with the aged-control group, a difference was observed only for comparison with the exercise group ( $p < 0.05$ ), and exercise associated with LLLT group ( $p < 0.001$ ). Levels of IL-6 and TNF-alpha for the aged-exercise and the aged-LLLT/exercise groups were significantly decreased compared to the aged-control group ( $p < 0.05$ ). Analysis of the transverse section of the gastrocnemius muscle showed a significant difference between the aged-exercise and aged-LLLT/exercise groups ( $p < 0.001$ ). These results suggest that laser therapy in conjunction with aerobic training may provide a therapeutic approach for reducing the inflammatory markers (IL-6 and TNF-alpha), however, LLLT without exercise was not able to improve physical performance of aged rats.

Lasers Med Sci 2015 Apr 30(3) 1127-34

<http://www.ncbi.nlm.nih.gov/pubmed/?term=25647393>

# Analysis of laser therapy and assessment methods in the rehabilitation of temporomandibular disorder: a systematic review of the literature.

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The aim of the present study was to perform a systematic review of the literature on the effects of low-level laser therapy in the treatment of TMD, and to analyze the use of different assessment tools. [Subjects and Methods] Searches were carried out of the BIREME, MEDLINE, PubMed and SciELO electronic databases by two independent researchers for papers published in English and Portuguese using the terms: "temporomandibular joint laser therapy" and "TMJ laser treatment". [Results] Following the application of the eligibility criteria, 11 papers were selected for in-depth analysis. The papers analyzed exhibited considerable methodological differences, especially with regard to the number of sessions, anatomic site and duration of low-level laser therapy irradiation, as well as irradiation parameters, diagnostic criteria and assessment tools. [Conclusion] Further studies are needed, especially randomized clinical trials, to establish the exact dose and ideal parameters for low-level laser therapy and define the best assessment tools in this promising field of research that may benefit individuals with signs and symptoms of TMD.

# Immediate effects of low-intensity laser (808 nm) on fatigue and strength of spastic muscle.

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The cerebrovascular accident (CVA), high-impact disease II, affects the basic functions of the limbs, leading to changes of sensory, language, and motor functions. The search for resources that minimize the damage caused by this disease grows every day. The clinical use of low-intensity laser therapy (LILT) has provided major breakthroughs in the treatment of muscular disorders and prevention of muscle fatigue. Thus, the objective of the present study is to analyze the answers and immediate adaptations of the rectus femoris and vastus medialis of spastic hemiparetic patients, facing the increase in peak torque and triggering muscle fatigue, after application of LILT. Double-blind clinical trials were conducted with 15 volunteers post-CVA with spasticity, of both genders, between 40 and 80 years old. To this end, the volunteers went through three consecutive stages of rating (control, placebo, and laser). All performed tests of isometric contraction on the patient's hemiparetic side. Significant differences were observed with regard to the increase in muscle performance ( $p = 0.0043$ ) and the reduction in blood lactate concentration ( $p < 0.0001$ ) of the post-LILT muscles. The LILT (diode laser, 1100 mW 808 nm, 4.77 J/cm<sup>2</sup>/point, 40 s/AP) can be employed during and after spastic muscle-strengthening exercises, contributing to the improvement of motor function of the patient. After application of LILT, we found increased torque as well as decreased in lactate level in patients with spasticity.

Lasers Med Sci 2015 Jan 23

<http://www.ncbi.nlm.nih.gov/pubmed/?term=25614133>

# Muscular pre-conditioning using light-emitting diode therapy (LEDT) for high-intensity exercise: a randomized double-blind placebo-controlled trial with a single elite runner.

Ferraresi C, Beltrame T, Fabrizzi F, Nascimento ES, Karsten M, Francisco CO, Borghi-Silva A, Catai AM, Cardoso DR, Ferreira AG, Hamblin MR, Bagnato VS, Parizotto NA

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**Abstract** Recently, low-level laser (light) therapy (LLLT) has been used to improve muscle performance. This study aimed to evaluate the effectiveness of near-infrared light-emitting diode therapy (LEDT) and its mechanisms of action to improve muscle performance in an elite athlete. The kinetics of oxygen uptake (VO<sub>2</sub>), blood and urine markers of muscle damage (creatine kinase - CK and alanine) and fatigue (lactate) were analyzed. Additionally, some metabolic parameters were assessed in urine using proton nuclear magnetic resonance spectroscopy (1H NMR). A LED cluster with 50 LEDs ( $\lambda = 850 \text{ nm}$ ; 50 mW 15 s; 37.5 J) was applied on legs, arms and trunk muscles of a single runner athlete 5 min before a high-intense constant workload running exercise on treadmill. The athlete received either Placebo-1-LEDT; Placebo-2-LEDT; or Effective-LEDT in a randomized double-blind placebo-controlled trial with washout period of 7 d between each test. LEDT improved the speed of the muscular VO<sub>2</sub> adaptation ( approximately -9 s), decreased O<sub>2</sub> deficit ( approximately -10 L), increased the VO<sub>2</sub> from the slow component phase ( approximately +348 ml min<sup>-1</sup>) and increased the time limit of exercise ( approximately +589 s). LEDT decreased blood and urine markers of muscle damage and fatigue (CK, alanine and lactate levels). The results suggest that a muscular pre-conditioning regimen using LEDT before intense exercises could modulate metabolic and renal function to achieve better performance.

Physiother Theory Pract 2015 Jan 14 1-8

<http://www.ncbi.nlm.nih.gov/pubmed/?term=25585514>



# Effect of low-level laser therapy on adolescents with temporomandibular disorder: a blind randomized controlled pilot study.

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**PURPOSE:** The aim of this pilot study was to evaluate the effect of low-level laser therapy on pain, mandibular movements, and occlusal contacts in adolescents and young adults with temporomandibular disorder. **MATERIALS AND METHODS:** Individuals aged 14 to 23 years were evaluated. The Research Diagnostic Criteria for Temporomandibular Disorders were used for the diagnosis of temporomandibular disorders. Pain was assessed with a visual analog scale. Occlusal contacts were recorded using the T-Scan III program (Tekscan, Boston, MA). The participants were randomly allocated to 2 groups: active or placebo laser treatment. The laser parameters were as follows: wavelength of 780 nm, energy density of 33.5 J/cm<sup>2</sup>, power of 50 mW, power density of 1.67 W/cm<sup>2</sup>, and 20-second exposure time. The Kolmogorov-Smirnov test was used to determine the normality of the data distribution. The paired t test was used for the comparisons of the pretreatment and post-treatment results. The SPSS program for Windows (version 15.0; SPSS, Chicago, IL) was used for all analyses, with the level of significance set at 5% ( $P < .05$ ). **RESULTS:** No statistically significant differences between groups were found for the right and left anterior temporal muscles ( $P = .3801$  and  $P = .5595$ , respectively), superior masseter muscles ( $P = .087$  and  $P = .1969$ , respectively), medial masseter muscles ( $P = .2241$  and  $P = .076$ , respectively), or inferior masseter muscles ( $P = .5589$  and  $P = .3268$ , respectively) after treatment. **CONCLUSIONS:** No statistically significant differences were found regarding pain, mandibular range of motion, or the distribution of occlusal contacts after treatment with low-level laser therapy. These preliminary results need to be verified in a larger sample of patients to confirm the lack of response to low-level laser therapy.

J Oral Maxillofac Surg 2015 Apr 73(4) 622-9

<http://www.ncbi.nlm.nih.gov/pubmed/?term=25542604>

# Effects of phototherapy on muscle activity and pain in individuals with temporomandibular disorder: a study protocol for a randomized controlled trial.

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**BACKGROUND:** According to the International Association for the Study of Pain (IASP), the term temporomandibular disorder (TMD) regards a subgroup of orofacial pain, the symptoms of which include pain or discomfort in the temporomandibular joint, ears, masticatory muscles and neck on one or both sides, as well as joint sounds, limited mandibular movements or mandibular deviation and difficulties chewing. Phototherapy, such as low-level laser therapy (LLLT) and light-emitting diode (LED) therapy, is one of the resources used to treatment muscle pain. Thus, there is a need to investigate therapeutic resources that combine different wavelengths as well as different light sources (LLLT and LED) in the same apparatus. The aim of the proposed study is to evaluate the effects of four different doses of phototherapy on pain, activity of the masticatory muscles (masseter and bilateral anterior temporal) and joint mobility in individuals with temporomandibular disorder. A further aim is to determine the cumulative effect 24 and 48 hours after a single session. **METHODS/DESIGN:** A placebo-controlled, double-blind, randomized, clinical trial will be carried out involving 72 women between 18 and 40 years of age with a diagnosis of myogenous TMD. The participants will then be randomly allocated to four groups totaling 18 individuals per group. Three groups will be submitted to a single session of phototherapy with different light sources, and one group will receive placebo therapy: Group A (2.62 Joules); Group B (5.24 Joules); Group C (7.86 Joules); and Group D (0 Joules). The following assessment tools will be administered on four separate occasions (baseline and immediately after, 24 h after and 48 h after phototherapy). Pain intensity will be assessed using the visual analog scale for pain, while pain thresholds will be determined using algometer, and electromyographic (EMG) analysis on the masseter and anterior temporal muscles. **DISCUSSION:** The study will contribute to the practice of the evidence-based use of phototherapy in individuals with a myogenous TMD. Data will be published after the study is completed. **TRIAL REGISTRATION:** This study is registered with the Brazilian Registry of Clinical Trials, NCT02018770, date of registration: 7 December 2013.

Trials 2014 15 491

<http://www.ncbi.nlm.nih.gov/pubmed/?term=25514875>

# Use of Low-Level Laser Therapy (808 nm) to Muscle Fatigue Resistance: A Randomized Double-Blind Crossover Trial.

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**Abstract Objective:** The purpose of this study was to investigate whether low-level laser (light) therapy (LLLT) can provide fatigue resistance via maximum repetitions (RM) with an isokinetic dynamometer, and decrease electromyography fatigue index (EFI). **BACKGROUND DATA:** LLLT has been used to increase muscle performance when applied before or after intense exercises. **MATERIALS AND METHODS:** This study was a randomized, double-blind, crossover trial with placebo. Seven young men (21+/-3 years of age) who were clinically healthy, were allocated into two groups: active laser (LLLT) and placebo laser (Placebo). Both groups were assessed at baseline, at one training session, and at the end of this study. Baseline and final assessments recorded the number of RM of knee flexion-extensions using an isokinetic dynamometer at 60 degrees/sec in conjunction with EFI recorded by median frequency. The training sessions consisted of three sets of 20 RM of knee flexion-extensions using an isokinetic dynamometer at 60 degrees/sec plus LLLT (808 nm, 100 mW, 4 J), or placebo, applied to quadriceps femoris muscles between sets, and after the last series of this exercise. After 1 week (washout period), all volunteers were exchanged among groups and then all assessments were repeated. **RESULTS:** LLLT group increased RM (52%;  $p=0.002$ ) with a small EFI for the vastus medialis ( $p=0.004$ ) and rectus femoris ( $p=0.004$ ). **CONCLUSIONS:** These results suggest an increased muscle fatigue resistance when LLLT is applied during rest intervals, and after the last series of intense exercises.

Photomed Laser Surg 2014 Dec 32(12) 678-85

<http://www.ncbi.nlm.nih.gov/pubmed/?term=25496083>

# Low-level Laser (Light) Therapy Increases Mitochondrial Membrane Potential and ATP Synthesis in C2C12 Myotubes with a Peak Response at 3-6 h.

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Low-level laser (light) therapy has been used before exercise to increase muscle performance in both experimental animals and in humans. However, uncertainty exists concerning the optimum time to apply the light before exercise. The mechanism of action is thought to be stimulation of mitochondrial respiration in muscles, and to increase adenosine triphosphate (ATP) needed to perform exercise. The goal of this study was to investigate the time course of the increases in mitochondrial membrane potential (MMP) and ATP in myotubes formed from C2C12 mouse muscle cells and exposed to light-emitting diode therapy (LEDT). LEDT employed a cluster of LEDs with 20 red (630 +/- 10 nm, 25 mW) and 20 near-infrared (850 +/- 10 nm, 50 mW) delivering 28 mW cm<sup>2</sup> for 90 s (2.5 J cm<sup>2</sup>) with analysis at 5 min, 3 h, 6 h and 24 h post-LEDT. LEDT-6 h had the highest MMP, followed by LEDT-3 h, LEDT-24 h, LEDT-5 min and Control with significant differences. The same order (6 h > 3 h > 24 h > 5 min > Control) was found for ATP with significant differences. A good correlation was found ( $r = 0.89$ ) between MMP and ATP. These data suggest an optimum time window of 3-6 h for LEDT stimulate muscle cells.

Photochem Photobiol 2014 Dec 1

<http://www.ncbi.nlm.nih.gov/pubmed/?term=25443662>

**Phototherapy with combination of super-pulsed laser and light-emitting diodes is beneficial in improvement of muscular performance (strength and muscular endurance), dyspnea, and fatigue sensation in patients with chronic obstructive pulmonary disease.**

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Phototherapy is an electrophysical intervention being considered for the retardation of peripheral muscular fatigue usually observed in chronic obstructive pulmonary disease (COPD). The objective of this study was to evaluate the acute effects of combination of super-pulsed laser and light-emitting diodes phototherapy on isokinetic performance in patients with COPD. Thirteen patients performed muscular endurance tests in an isokinetic dynamometer. The maximum voluntary isometric contraction (MVIC), peak torque (PT), and total work (TW) of the non-dominant lower limb were measured in two visits. The application of phototherapy or placebo (PL) was conducted randomly in six locations of femoral quadriceps muscle by using a cluster of 12 diodes (4 of 905 nm super-pulsed lasers, 0.3125 mW each; 4 of 875 nm LEDs, 17.5 mW each; and 4 of 640 nm LEDs, 15 mW each, manufactured by Multi Radiance Medical). We found statistically significant increases for PT (174.7 +/- 35.7 N . m vs. 155.8 +/- 23.3 N . m,  $p = 0.003$ ) and TW after application of phototherapy when compared to placebo (778.0 +/- 221.1 J vs. 696.3 +/- 146.8 J,  $p = 0.005$ ). Significant differences were also found for MVIC (104.8 +/- 26.0 N . m vs. 87.2 +/- 24.0 N . m,  $p = 0.000$ ), sensation of dyspnea (1 [0-4] vs. 3 [0-6],  $p = 0.003$ ), and fatigue in the lower limbs (2 [0-5] vs. 5 [0.5-9],  $p = 0.002$ ) in favor of phototherapy. We conclude that the combination of super-pulsed lasers and LEDs administered to the femoral quadriceps muscle of patients with COPD increased the PT by 20.2 % and the TW by 12 %. Phototherapy with a combination of super-pulsed lasers and LEDs prior to exercise also led to decreased sensation of dyspnea and fatigue in the lower limbs in patients with COPD.

*Lasers Med Sci* 2015 Jan 30(1) 437-43

<http://www.ncbi.nlm.nih.gov/pubmed/?term=25413975>

# Near-Infrared Light Therapy to Attenuate Strength Loss After Strenuous Resistance Exercise.

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Context : Near-infrared (NIR) light therapy is purported to act as an ergogenic aid by enhancing the contractile function of skeletal muscle. Improving muscle function is a new avenue for research in the area of laser therapy; however, very few researchers have examined the ergogenic effects of (NIR) light therapy and the influence it may have on the recovery process during rehabilitation. Objective : To evaluate the ergogenic effect of (NIR) light therapy on skeletal muscle function. Design : Crossover study. Setting : Controlled laboratory. Patients or Other Participants : Thirty-nine healthy men (n = 21) and women (n = 18; age = 20.0 +/- 0.2 years, height = 169 +/- 2 cm, mass = 68.4 +/- 1.8 kg, body mass index = 23.8 +/- 0.4 kg/m<sup>2</sup>). Intervention(s) : Each participant received active and sham treatments on the biceps brachii muscle on 2 separate days. The order of treatment was randomized. A class 4 laser with a cumulative dose of 360 J was used for the active treatment. After receiving the treatment on each day, participants completed an elbow-flexion resistance-exercise protocol. Main Outcome Measure(s) : The dependent variables were elbow range of motion, muscle point tenderness, and strength (peak torque). Analysis of variance with repeated measures was used to assess changes in these measures between treatments at baseline and at follow-up, 48 hours postexercise. Additionally, immediate strength loss postexercise was compared between treatments using a paired t test. Results : Preexercise to postexercise strength loss for the active laser treatment, although small, was less than with the sham treatment (P = .05). Conclusions : Applied to skeletal muscle before resistance exercise, (NIR) light therapy effectively attenuated strength loss. Therefore, NIR light therapy may be a beneficial, noninvasive modality for improving muscle function during rehabilitation after musculoskeletal injury. However, future studies using higher treatment doses are warranted.

J Athl Train 2014 Nov 14

<http://www.ncbi.nlm.nih.gov/pubmed/?term=25397864>

## The low level laser therapy (LLLT) operating in 660 nm reduce gene expression of inflammatory mediators in the experimental model of collagenase-induced rat tendinitis.

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Tendinopathy is a common disease with a variety of treatments and therapies. Laser therapy appears as an alternative treatment. Here, we investigate the effects of laser irradiation in an experimental model of tendinitis induced by collagenase injection on rats' Achilles tendon, verifying its action in important inflammatory markers. Male Wistar rats were used and divided into five groups: control saline (C), non-treated tendinitis (NT) and tendinitis treated with sodium diclofenac (D) or laser (1 J) and (3 J). The tendinitis was induced by collagenase (100 mug/tendon) on the Achilles tendon, which was removed for further analyses. The gene expression for COX-2; TNF-alpha; IL-6; and IL-10 (RT-PCR) was measured. The laser irradiation (660 nm, 100 mW, 3 J) used in the treatment of the tendinitis induced by collagenase in Achilles tendon in rats was effective in the reduction of important pro-inflammatory markers such as IL-6 and TNF-alpha, becoming a promising tool for the treatment of tendon diseases.

Lasers Med Sci 2014 Nov 8

<http://www.ncbi.nlm.nih.gov/pubmed/?term=25380666>

# Light-emitting diode therapy in exercise-trained mice increases muscle performance, cytochrome c oxidase activity, ATP and cell proliferation.

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Light-emitting diode therapy (LEDT) applied over the leg, gluteus and lower-back muscles of mice using a LED cluster (630 nm and 850 nm, 80 mW/cm<sup>2</sup>, 7.2 J/cm<sup>2</sup>) increased muscle performance (repetitive climbing of a ladder carrying a water-filled tube attached to the tail), ATP and mitochondrial metabolism; oxidative stress and proliferative myocyte markers in mice subjected to acute and progressive strength training. Six bi-daily training sessions LEDT-After and LEDT-Before-After regimens more than doubled muscle performance and increased ATP more than tenfold. The effectiveness of LEDT on improving muscle performance and recovery suggest applicability for high performance sports and in training programs. Positioning of the mice and light-emitting diode therapy (LEDT) applied on mouse legs, gluteus and lower-back muscles without contact.

J Biophotonics 2014 Nov 6 9999(9999)

<http://www.ncbi.nlm.nih.gov/pubmed/?term=25378263>



# Biophotonic effect of diode laser irradiance on tensile strength of diabetic rats.

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Low-energy laser irradiance at certain wavelengths is able to stimulate the tissue bio-reaction and enhance the healing process. Collagen deposition is one of the important aspects in healing process because it can increase the strength of the skin. This study was designed to examine the biophotonic effect of irradiance on collagen production of diabetic wound in rat model. The tensile strength of skin was employed as a parameter to describe the wound. Diabetic rat models were induced by streptozotocin via intravenous injection. Skin-breaking strength was measured using an Instron tensile test machine. The experimental animals were treated with 808-nm diode laser at two different powers-0.1 and 0.5 W/cm<sup>2</sup>-and 30, 60, and 120 s for each session. The tensile strength was optimized after treated with high-power diode laser. The photostimulation effect was revealed by accelerated healing process and enhanced tensile strength of wound. Laser photostimulation on tensile strength in diabetic wound suggests that such therapy facilitates collagen production in diabetic wound healing.

J Cosmet Laser Ther 2014 Oct 16 1-4

<http://www.ncbi.nlm.nih.gov/pubmed/?term=25260140>

# Effect of pre-irradiation with different doses, wavelengths, and application intervals of low-level laser therapy on cytochrome c oxidase activity in intact skeletal muscle of rats.

Albuquerque-Pontes GM, Vieira RD, Tomazoni SS, Caires CO, Nemeth V, Vanin AA, Santos LA, Pinto HD, Marcos RL, Bjordal JM, de Carvalho PD, Leal-Junior EC

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Modulation of cytochrome c oxidase activity has been pointed as a possible key mechanism for low-level laser therapy (LLLT) in unhealthy biological tissues. But recent studies by our research group with LLLT in healthy muscles before exercise found delayed skeletal muscle fatigue development and improved biochemical status in muscle tissue. Therefore, the aim of this study was to evaluate effects of different LLLT doses and wavelengths in cytochrome c oxidase activity in intact skeletal muscle. In this animal experiment, we irradiated the tibialis anterior muscle of rats with three different LLLT doses (1, 3, and 10 J) and wavelengths (660, 830, and 905 nm) with 50 mW power output. After irradiation, the analyses of cytochrome c oxidase expression by immunohistochemistry were analyzed at 5, 10, 30 min and at 1, 2, 12, and 24 h. Our results show that LLLT increased ( $p < 0.05$ ) cytochrome c oxidase expression mainly with the following wavelengths and doses: 660 nm with 1 J, 830 nm with 3 J, and 905 nm with 1 J at all time points. We conclude that LLLT can increase cytochrome c oxidase activity in intact skeletal muscle and that it contributes to our understanding of how LLLT can enhance performance and protect skeletal muscles against fatigue development and tissue damage. Our findings also lead us to think that the combined use of different wavelengths at the same time can enhance LLLT effects in skeletal muscle performance and other conditions, and it can represent a therapeutic advantage in clinical settings.

Lasers Med Sci 2014 Jun 24

<http://www.ncbi.nlm.nih.gov/pubmed/?term=24957189>

# Phototherapy in skeletal muscle performance and recovery after exercise: effect of combination of super-pulsed laser and light-emitting diodes.

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Recent studies with phototherapy have shown positive results in enhancement of performance and improvement of recovery when applied before exercise. However, several factors still remain unknown such as therapeutic windows, optimal treatment parameters, and effects of combination of different light sources (laser and LEDs). The aim of this study was to evaluate the effects of phototherapy with the combination of different light sources on skeletal muscle performance and post-exercise recovery, and to establish the optimal energy dose. A randomized, double-blinded, placebo-controlled trial with participation of 40 male healthy untrained volunteers was performed. A single phototherapy intervention was performed immediately after pre-exercise (baseline) maximum voluntary contraction (MVC) with a cluster of 12 diodes (4 of 905 nm lasers-0.3125 mW each, 4 of 875 nm LEDs-17.5 mW each, and 4 of 670 nm LEDs-15 mW each- manufactured by Multi Radiance Medical) and dose of 10, 30, and 50 J or placebo in six sites of quadriceps. MVC, delayed onset muscle soreness (DOMS), and creatine kinase (CK) activity were analyzed. Assessments were performed before, 1 min, 1, 24, 48, 72, and 96 h after eccentric exercise protocol employed to induce fatigue. Phototherapy increased ( $p < 0.05$ ) MVC was compared to placebo from immediately after to 96 h after exercise with 10 or 30 J doses (better results with 30 J dose). DOMS was significantly decreased compared to placebo ( $p < 0.05$ ) with 30 J dose from 24 to 96 h after exercise, and with 50 J dose from immediately after to 96 h after exercise. CK activity was significantly decreased ( $p < 0.05$ ) compared to placebo with all phototherapy doses from 1 to 96 h after exercise (except for 50 J dose at 96 h). Pre-exercise phototherapy with combination of low-level laser and LEDs, mainly with 30 J dose, significantly increases performance, decreases DOMS, and improves biochemical marker related to skeletal muscle damage.

Lasers Med Sci 2014 Jun 19

<http://www.ncbi.nlm.nih.gov/pubmed/?term=24942380>

# Acute effects of low-level laser therapy on physiologic and electromyographic responses to the cardiopulmonary exercise testing in healthy untrained adults.

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Despite the positive effects of low-level laser therapy (LLLT) on muscle fatigue before exercises using a single muscle group, the acute effects of LLLT on performance in cardiopulmonary exercise testing (CPET) are poorly understood. We aimed to assess the acute effects of LLLT on physiologic and electromyographic responses to the CPET in healthy adults. A randomized, double-blind, placebo-controlled crossover trial was performed with 18 untrained participants (nine males, 22 +/- 2 years). We applied LLLT or placebo on quadriceps and gastrocnemius 10 min before two rapidly incremental CPETs randomly performed in alternate days on a cycle ergometer. Participants received LLLT using a multidiode cluster, 20 s/site (850 nm, 100 mW/diode, 14 J/site). Physiological responses to the CPET were continuously monitored using a gas analyzer. The electromyographic fatigue threshold (EMGth) was assessed through surface electrodes on vastus lateralis. The root mean square (RMS) was plotted every 5 s against the exercise intensity, and its breakpoint values throughout the CPET was identified as EMGth. Compared to placebo, the LLLT significantly increased peak O<sub>2</sub> uptake ( $\dot{V}'\text{O}_2$  33 +/- 10 vs. 31 +/- 9 mL/min/kg). We observed a shallower slope of the Deltaheart rate/Delta $\dot{V}'\text{O}_2$  during the CPET after LLLT compared to placebo, i.e., increased cardiovascular efficiency (56 +/- 24 vs. 66 +/- 30 bpm/L/min). There were no LLLT-related changes in EMGth. The LLLT acutely increases exercise performance in healthy untrained adults probably due to increased O<sub>2</sub> extraction by peripheral muscles without causing a significant impact on muscle fatigue.

Lasers Med Sci 2014 Jun 13

<http://www.ncbi.nlm.nih.gov/pubmed/?term=24925070>

# Effectiveness of phototherapy incorporated into an exercise program for osteoarthritis of the knee: study protocol for a randomized controlled trial.

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**BACKGROUND:** Osteoarthritis is a chronic disease with a multifactor etiology involving changes in bone alignment, cartilage, and other structures necessary to joint stability. There is a need to investigate therapeutic resources that combine different wavelengths as well as different light sources (low-level laser therapy and light-emitting diode therapy) in the same apparatus for the treatment of osteoarthritis. The aim of the proposed study is to analyze the effect of the incorporation of phototherapy into a therapeutic exercise program for individuals with osteoarthritis of the knee. **METHODS:** A double-blind, controlled, randomized clinical trial will be conducted involving patients with osteoarthritis of the knee. Evaluations will be performed using functional questionnaires before and after the treatment protocols, in a reserved room with only the evaluator and participant present, and no time constraints placed on the answers or evaluations. The following functional tests will also be performed: stabilometry (balance assessment), dynamometry (muscle strength of gluteus medius and quadriceps), algometry (pain threshold), fleximeter (range of motion), timed up-and-go test (functional mobility), and the functional reach test. The participants will then be allocated to three groups through a randomization process using opaque envelopes: exercise program, exercise program + phototherapy, or exercise program + placebo phototherapy, all of which will last for eight weeks. **DISCUSSION:** The purpose of this randomized clinical trial is to analyze the effect of the incorporation of phototherapy into a therapeutic exercise program for osteoarthritis of the knee. The study will support the practice based on evidence to the use of phototherapy in individuals with a diagnosis of osteoarthritis of the knee. Data will be published after the study is completed. **Trial registration:** The protocol for this study has been submitted to Clinical Trials, registration number NCT02102347, on 29 March 2014.

Trials 2014 Jun 11 15(1) 221

<http://www.ncbi.nlm.nih.gov/pubmed/?term=24919587>

# Adjunctive use of combination of super-pulsed laser and light-emitting diodes phototherapy on nonspecific knee pain: double-blinded randomized placebo-controlled trial.

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Phototherapy with low-level laser therapy (LLLT) and light-emitting diode therapy (LEDT) has arisen as an interesting alternative to drugs in treatments of musculoskeletal disorders. However, there is a lack of studies investigating the effects of combined use of different wavelengths from different light sources like lasers and light-emitting diodes (LEDs) in skeletal muscle disorders. With this perspective in mind, this study aimed to investigate the effects of phototherapy with combination of different light sources on nonspecific knee pain. It was performed a randomized, placebo-controlled, double-blinded clinical trial. Eighty-six patients rated 30 or greater on the pain visual analogue scale (VAS) were recruited and included in study. Patients of LLLT group received 12 treatments with active phototherapy (with 905 nm super-pulsed laser and 875 and 640 nm LEDs, Manufactured by Multi Radiance Medical, Solon, OH, USA) and conventional treatment (physical therapy or chiropractic care), and patients of placebo group were treated at same way but with placebo phototherapy device. Pain assessments (VAS) were performed at baseline, 4th, 7th, and 10th treatments, after the completion of treatments and at 1-month follow-up visit. Quality of life assessments (SF-36(R)) were performed at baseline, after the completion of treatments and at 1-month follow-up visit. Our results demonstrate that phototherapy significantly decreased pain ( $p < 0.05$ ) from 10th treatment to follow-up assessments and significantly improved ( $p < 0.05$ ) SF-36(R) physical component summary at posttreatments and follow-up assessments compared to placebo. We conclude that combination of super-pulsed laser, red and infrared LEDs is effective to decrease pain and improve quality of life in patients with knee pain.

Lasers Med Sci 2014 May 21

<http://www.ncbi.nlm.nih.gov/pubmed/?term=24844921>

# Comparative analysis of low-level laser therapy (660 nm) on inflammatory biomarker expression during the skin wound-repair process in young and aged rats.

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The wound-healing process plays an essential role in the protective response to epidermal injury by tissue regeneration. In the elderly, skin functions deteriorate as a consequence of morphological and structural changes. This study aimed to evaluate and compare the effect of low-level laser therapy (LLLT) in cutaneous wound healing in young and aged rats. A total of 60 male rats comprising 30 young (+/-30 days) and 30 aged (+/-500 days) was used. The animals were divided into four experimental groups and underwent skin wound and/or treatment with LLLT (660 nm, 30 mW, 1.07 W/cm<sup>2</sup>, 0.028 cm<sup>2</sup>, 72 J/cm<sup>2</sup>, and 2 J). Analyses were conducted to verify the effects of LLLT in the tissue repair process, in the gene expression, and protein expression of TNF-alpha, IL-1beta, and IL-10, obtained in skin wound model. Results showed that there were significant differences between the young control group and the aged control group and their respective treated groups (LLLT young and LLLT aged). We conclude that LLLT has shown to be effective in the treatment of skin wounds in young and aged animals at different stages of the tissue repair process, which suggests that different LLLT dosimetry should be considered in treatment of subjects of different ages. Further clinical trials are needed to confirm these findings in clinical settings.

Lasers Med Sci 2014 May 7

<http://www.ncbi.nlm.nih.gov/pubmed/?term=24801057>

# Low level laser therapy reduces acute lung inflammation in a model of pulmonary and extrapulmonary LPS-induced ARDS.

Oliveira MC Jr, Greiffo FR, Rigonato-Oliveira NC, Custodio RW, Silva VR, Damaceno-Rodrigues NR, Almeida FM, Albertini R, Lopes-Martins RA, de Oliveira LV, de Carvalho Pde T, Ligeiro de Oliveira AP, Leal EC Jr, Vieira RP

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The present study aimed to investigate the effects low level laser therapy (LLLT) in a LPS-induced pulmonary and extrapulmonary acute respiratory distress syndrome (ARDS) in BALB/c mice. Laser (830nm laser, 9J/cm<sup>2</sup>), 35mW, 80s per point, 3 points per application) was applied in direct contact with skin, 1h after LPS administration. Mice were distributed in control (n=6; PBS), ARDS IT (n=7; LPS orotracheally 10μg/mouse), ARDS IP (n=7; LPS intra-peritoneally 100μg/mouse), ARDS IT+Laser (n=9; LPS intra-tracheally 10μg/mouse), ARDS IP+Laser (n=9; LPS intra-peritoneally 100μg/mouse). Twenty-four hours after last LPS administration, mice were studied for pulmonary inflammation by total and differential cell count in bronchoalveolar lavage (BAL), cytokines (IL-1beta, IL-6, KC and TNF-alpha) levels in BAL fluid and also by quantitative analysis of neutrophils number in the lung parenchyma. LLLT significantly reduced pulmonary and extrapulmonary inflammation in LPS-induced ARDS, as demonstrated by reduced number of total cells (p<0.001) and neutrophils (p<0.001) in BAL, reduced levels of IL-1beta, IL-6, KC and TNF-alpha in BAL fluid and in serum (p<0.001), as well as the number of neutrophils in lung parenchyma (p<0.001). LLLT is effective to reduce pulmonary inflammation in both pulmonary and extrapulmonary model of LPS-induced ARDS.

J Photochem Photobiol B 2014 May 5 134 57-63

<http://www.ncbi.nlm.nih.gov/pubmed/?term=24792475>



# Efficacy of pre-exercise low-level laser therapy on isokinetic muscle performance in individuals with type 2 diabetes mellitus: study protocol for a randomized controlled trial.

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**BACKGROUND:** Type 2 diabetes, also known non-insulin-dependent diabetes, is the most prevalent type of the disease and involves defects in the secretion and action of insulin. The aim of the proposed study is to evaluate the efficacy of pre-exercise low-level laser therapy (LLLT) on muscle performance of the quadriceps femoris in individuals with type 2 diabetes. **METHODS/DESIGN:** A double-blind, randomized, controlled clinical trial will be carried out in two treatment phases. In the first phase, quadriceps muscle performance will be evaluated using an isokinetic dynamometer and the levels of creatine kinase and lactate dehydrogenase (biochemical markers of muscle damage) will be determined. The participants will then be allocated to four LLLT groups through a randomization process using opaque envelopes: Group A (4 Joules), Group B (6 Joules), Group C (8 Joules) and Group D (0 Joules; placebo). Following the administration of LLLT, the participants will be submitted to an isokinetic eccentric muscle fatigue protocol involving the quadriceps muscle bilaterally. Muscle performance and biochemical markers of muscle damage will be evaluated again immediately after as well as 24 and 48 hours after the experimental protocol. One week after the last evaluation the second phase will begin, during which Groups A, B and C will receive the LLLT protocol that achieved the best muscle performance in phase 1 for a period of 4 weeks. At the end of this period, muscle performance will be evaluated again. The protocol for this study is registered with the World Health Organization under Universal Trial Number U1111-1146-7109. **DISCUSSION:** The purpose of this randomized clinical trial is to evaluate the efficacy of pre-exercise LLLT on the performance of the quadriceps muscle (peak torque, total muscle work, maximum power and fatigue index - normalized by body mass) in individuals with DM-2. The study will support the practice of evidence-based to the use of LLLT in improving muscle performance in Individuals with DM-2. Data will be published after the study is completed.

Trials 2014 15(1) 116

<http://www.ncbi.nlm.nih.gov/pubmed/?term=24716713>

# Effects of pre-irradiation of low-level laser therapy with different doses and wavelengths in skeletal muscle performance, fatigue, and skeletal muscle damage induced by tetanic contractions in rats.

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This study aimed to evaluate the effects of low-level laser therapy (LLLT) immediately before tetanic contractions in skeletal muscle fatigue development and possible tissue damage. Male Wistar rats were divided into two control groups and nine active LLLT groups receiving one of three different laser doses (1, 3, and 10 J) with three different wavelengths (660, 830, and 905 nm) before six tetanic contractions induced by electrical stimulation. Skeletal muscle fatigue development was defined by the percentage (%) of the initial force of each contraction and time until 50 % decay of initial force, while total work was calculated for all six contractions combined. Blood and muscle samples were taken immediately after the sixth contraction. Several LLLT doses showed some positive effects on peak force and time to decay for one or more contractions, but in terms of total work, only 3 J/660 nm and 1 J/905 nm wavelengths prevented significantly ( $p < 0.05$ ) the development of skeletal muscle fatigue. All doses with wavelengths of 905 nm but only the dose of 1 J with 660 nm wavelength decreased creatine kinase (CK) activity ( $p < 0.05$ ). Qualitative assessment of morphology revealed lesser tissue damage in most LLLT-treated groups, with doses of 1-3 J/660 nm and 1, 3, and 10 J/905 nm providing the best results. Optimal doses of LLLT significantly delayed the development skeletal muscle performance and protected skeletal muscle tissue against damage. Our findings also demonstrate that optimal doses are partly wavelength specific and, consequently, must be differentiated to obtain optimal effects on development of skeletal muscle fatigue and tissue preservation. Our findings also lead us to think that the combined use of wavelengths at the same time can represent a therapeutic advantage in clinical settings.

Lasers Med Sci 2014 Mar 21

<http://www.ncbi.nlm.nih.gov/pubmed/?term=24651950>

# Superpulsed low-level laser therapy protects skeletal muscle of mdx mice against damage, inflammation and morphological changes delaying dystrophy progression.

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**AIM:** To evaluate the effects of preventive treatment with low-level laser therapy (LLLT) on progression of dystrophy in mdx mice. **METHODS:** Ten animals were randomly divided into 2 experimental groups treated with superpulsed LLLT (904 nm, 15 mW, 700 Hz, 1 J) or placebo-LLLT at one point overlying the tibialis anterior muscle (bilaterally) 5 times per week for 14 weeks (from 6th to 20th week of age). Morphological changes, creatine kinase (CK) activity and mRNA gene expression were assessed in animals at 20th week of age. **RESULTS:** Animals treated with LLLT showed very few morphological changes in skeletal muscle, with less atrophy and fibrosis than animals treated with placebo-LLLT. CK was significantly lower ( $p=0.0203$ ) in animals treated with LLLT (864.70 U.l-1, SEM 226.10) than placebo (1708.00 U.l-1, SEM 184.60). mRNA gene expression of inflammatory markers was significantly decreased by treatment with LLLT ( $p<0.05$ ): TNF-alpha (placebo-control=0.51 microg/microl [SEM 0.12], - LLLT=0.048 microg/microl [SEM 0.01]), IL-1beta (placebo-control=2.292 microg/microl [SEM 0.74], - LLLT=0.12 microg/microl [SEM 0.03]), IL-6 (placebo-control=3.946 microg/microl [SEM 0.98], - LLLT=0.854 microg/microl [SEM 0.33]), IL-10 (placebo-control=1.116 microg/microl [SEM 0.22], - LLLT=0.352 microg/microl [SEM 0.15]), and COX-2 (placebo-control=4.984 microg/microl [SEM 1.18], LLLT=1.470 microg/microl [SEM 0.73]). **CONCLUSION:** Irradiation of superpulsed LLLT on successive days five times per week for 14 weeks decreased morphological changes, skeletal muscle damage and inflammation in mdx mice. This indicates that LLLT has potential to decrease progression of Duchenne muscular dystrophy.

PLoS One 2014 9(3) e89453

<http://www.ncbi.nlm.nih.gov/pubmed/?term=24599021>

# What is the ideal dose and power output of low-level laser therapy (810 nm) on muscle performance and post-exercise recovery? Study protocol for a double-blind, randomized, placebo-controlled trial.

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**BACKGROUND:** Recent studies involving phototherapy applied prior to exercise have demonstrated positive results regarding the attenuation of muscle fatigue and the expression of biochemical markers associated with recovery. However, a number of factors remain unknown, such as the ideal dose and application parameters, mechanisms of action and long-term effects on muscle recovery. The aims of the proposed project are to evaluate the long-term effects of low-level laser therapy on post-exercise musculoskeletal recovery and identify the best dose and application power/irradiation time. **DESIGN AND METHODS:** A double-blind, randomized, placebo-controlled clinical trial will be conducted. After fulfilling the eligibility criteria, 28 high-performance athletes will be allocated to four groups of seven volunteers each. In phase 1, the laser power will be 200 mW and different doses will be tested: Group A (2 J), Group B (6 J), Group C (10 J) and Group D (0 J). In phase 2, the best dose obtained in phase 1 will be used with the same distribution of the volunteers, but with different powers: Group A (100 mW), Group B (200 mW), Group C (400 mW) and Group D (0 mW). The isokinetic test will be performed based on maximum voluntary contraction prior to the application of the laser and after the eccentric contraction protocol, which will also be performed using the isokinetic dynamometer. The following variables related to physical performance will be analyzed: peak torque/maximum voluntary contraction, delayed onset muscle soreness (algometer), biochemical markers of muscle damage, inflammation and oxidative stress. **DISCUSSION:** Our intention, is to determine optimal laser therapy application parameters capable of slowing down the physiological muscle fatigue process, reducing injuries or micro-injuries in skeletal muscle stemming from physical exertion and accelerating post-exercise muscle recovery. We believe that, unlike drug therapy, LLLT has a biphasic dose-response pattern. **TRIAL REGISTRATION:** The protocol for this study is registered with the Protocol Registry System, ClinicalTrials.gov identifier NCT01844271.

Trials 2014 15 69

<http://www.ncbi.nlm.nih.gov/pubmed/?term=24576321>

# Effects of pre- or post-exercise low-level laser therapy (830 nm) on skeletal muscle fatigue and biochemical markers of recovery in humans: double-blind placebo-controlled trial.

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**OBJECTIVES:** The purpose of this study was to investigate the effect of low-level laser therapy (LLLT) before and after exercise on quadriceps muscle performance, and to evaluate the changes in serum lactate and creatine kinase (CK) levels. **METHODS:** The study was randomized, double blind, and placebo controlled. **PATIENTS:** A sample of 27 healthy volunteers (male soccer players) were divided into three groups: placebo, pre-fatigue laser, and post-fatigue laser. The experiment was performed in two sessions, with a 1 week interval between them. Subjects performed two sessions of stretching followed by blood collection (measurement of lactate and CK) at baseline and after fatigue of the quadriceps by leg extension. LLLT was applied to the femoral quadriceps muscle using an infrared laser device (830 nm), 0.0028 cm<sup>2</sup> beam area, six 60 mW diodes, energy of 0.6 J per diode (total energy to each limb 25.2 J (50.4 J total), energy density 214.28 J/cm<sup>2</sup>, 21.42 W/cm<sup>2</sup> power density, 70 sec per leg. We measured the time to fatigue and number and maximum load (RM) of repetitions tolerated. Number of repetitions and time until fatigue were primary outcomes, secondary outcomes included serum lactate levels (measured before and 5, 10, and 15 min after exercise), and CK levels (measured before and 5 min after exercise). **RESULTS:** The number of repetitions ( $p=0.8965$ ), RM ( $p=0.9915$ ), and duration of fatigue ( $p=0.8424$ ) were similar among the groups. Post-fatigue laser treatment significantly decreased the serum lactate concentration relative to placebo treatment ( $p<0.01$ ) and also within the group over time (after 5 min vs. after 10 and 15 min,  $p<0.05$  both). The CK level was lower in the post-fatigue laser group ( $p<0.01$ ). **CONCLUSIONS:** Laser application either before or after fatigue reduced the post-fatigue concentrations of serum lactate and CK. The results were more pronounced in the post-fatigue laser group.

Photomed Laser Surg 2014 Feb 32(2) 106-12

<http://www.ncbi.nlm.nih.gov/pubmed/?term=24456143>

# Effects of low-level laser therapy on biceps braquialis muscle fatigue in young women.

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**OBJECTIVE:** This study aims to investigate the effects of low-level laser therapy (LLLT) on biceps brachii muscular fatigue in 20 young females. **Background data:** Exhausting physical activity leads to muscular fatigue, which could decrease muscular strength, and may cause impairment in motor control and muscle pain. Several biochemical and biophysical resources have been studied in an attempt to accelerate the recovery of muscle fatigue. Among these, LLLT is emphasized. **METHODS:** Twenty subjects were randomized in one laser group and one placebo group in two sessions of a crossover design experimental procedure; the second session taking place within 7 days of the first. In the first session, subjects underwent a collection of surface electromyographic (SEMG) data of the biceps brachii muscle, followed by active or placebo LLLT at the same muscle, followed then by another EMG sample of biceps brachii. Blood samples were collected five times during the experimental procedure. Second session procedures were identical to the first, with exception of LLLT, which was the opposite of the first session. The fatigue protocol consisted of 60 sec of elbow flexion-extension movement performed with 75% of one maximum repetition. Blood lactate, EMG fatigue, and the number of elbow flexion-extension repetitions during the fatigue protocol were used to evaluate the effects of laser therapy (808 nm wavelength, 100 mW output power, power density of 35.7 W/cm<sup>2</sup>, 70 sec each point and 7 J/point on eight points). **RESULTS:** No statistical differences were found for electromyographic fatigue and blood lactate values between groups. Mean numbers of elbow flexion-extension repetitions were 22.6 +/- 7.58 after placebo, and 25.1 +/- 9.89 after active LLLT group, but these differences were not statistically significant (p=0.342). **CONCLUSIONS:** LLLT had limited effects on delaying muscle fatigue in a young female sample, although a tendency was observed in the active laser group toward showing lower electromyography fatigue of biceps brachii muscle. No intergroup differences were found in the number of muscle contractions and lactate concentration.

Photomed Laser Surg 2013 Dec 31(12) 586-94

<http://www.ncbi.nlm.nih.gov/pubmed/?term=24320801>

# Effect of caries removal techniques on the bond strength of adhesives to caries-affected primary dentin in vitro.

Yildiz E, Sirinkaraarslan E, Yegin Z, Cebe MA, Tosun G, Dejakum K, Piegger J, Plewka C, Gunkel A, Thumfart W, Kudaibergenova S, Goebel G, Kral F, Freysinger W

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**AIM:** The aim of this in vitro study is to evaluate the effects of three different caries removal techniques on the microtensile bond strength of adhesive materials to caries-affected dentin. **MATERIALS AND METHODS:** Thirty primary molar teeth were used. The teeth were randomly divided into three groups according to the caries removal technique employed: conventional steel bur (group 1); Er:YAG laser (group 2); chemomechanical method (group 3). Each group was divided into two subgroups according to bonding agents: one-step self-etch adhesive and etch-and-rinse adhesive. The teeth were restored with composite resin. Vertical sticks were obtained and subjected to tensile stress. Data were analyzed by two-way analysis of variance (ANOVA), Tukey's test and an independent samples t-test. **RESULTS:** The values for the laser groups were significantly lower than those of the bur groups for both bonding agents ( $p < 0.05$ ). There were no significant differences between the bur and chemomechanical groups ( $p > 0.05$ ). **CONCLUSION:** Bur and chemomechanical techniques in primary teeth were found more successful. Similar results were found according to the adhesives used for each caries removal techniques. The purpose of this study was to evaluate the effect of medium-level laser therapy in chronic tinnitus treatment. In a prospective double-blind placebo-controlled trial, either active laser (450 mW, 830 nm combined Ga-Al-As diode laser) or placebo irradiation was applied through the external acoustic meatus of the affected ear towards the cochlea. Forty-eight patients with chronic tinnitus were studied. The main outcome was measured using the Goebel tinnitus questionnaire, visual analogue scales measuring the perceived loudness of tinnitus, the annoyance associated with tinnitus, and the degree of attention paid to tinnitus as well as psycho-acoustical matches of tinnitus pitch and loudness. The results did show only very moderate temporary improvement of tinnitus. Moreover, no statistically relevant differences between laser and placebo group could be found. We conclude that medium-level laser therapy cannot be regarded as an effective treatment of chronic tinnitus in our therapy regime considering the limited number of patients included in our study.

Eur J Paediatr Dent Biomed Res Int 2013 Sep 2013 14(3) 209-14-324234

<http://www.ncbi.nlm.nih.gov/pubmed/?term=24295006>

# Light-emitting diode phototherapy improves muscle recovery after a damaging exercise.

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The goal of the present study was to determine the effect of light-emitting diode phototherapy (LEDT) at 630 nm on muscle recovery after a damaging eccentric exercise bout. Seventeen healthy young male volunteers, without previous experience with eccentric exercise, were included in a randomized double-blinded placebo-controlled trial. They were divided into a LEDT (n = 8) and a PLACEBO group (n = 9). To induce muscle damage, subjects performed 30 eccentric contractions with a load of 100 % of maximal voluntary isometric contraction strength of the elbow flexors of the non-dominant arm. LEDT group subjects received biceps brachii phototherapy ( $\lambda$  630 nm; total energy density, 20.4 J/cm<sup>2</sup>) immediately after the exercise bout. The LEDT in the placebo group was aimed at the muscle, but it remained turned off. Isometric muscle strength, muscle soreness, and elbow range of motion (ROM) were measured before and at 24, 48, 72, and 96 h after eccentric exercise bout and compared between groups. Our results showed that the muscle soreness, muscle strength loss, and ROM impairments were significantly reduced up to 96 h after a damaging eccentric exercise bout for the LEDT group compared with the PLACEBO group. A single LEDT (630 nm) intervention immediately after a damaging eccentric exercise bout was effective in terms of attenuating the muscle soreness and muscle strength loss and ROM impairments.

Lasers Med Sci 2013 Nov 21

<http://www.ncbi.nlm.nih.gov/pubmed/?term=24258312>



# Effect of phototherapy (low-level laser therapy and light-emitting diode therapy) on exercise performance and markers of exercise recovery: a systematic review with meta-analysis.

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Recent studies have explored if phototherapy with low-level laser therapy (LLLT) or narrow-band light-emitting diode therapy (LEDT) can modulate activity-induced skeletal muscle fatigue or subsequently protect against muscle injury. We performed a systematic review with meta-analysis to investigate the effects of phototherapy applied before, during and after exercises. A literature search was performed in Pubmed/Medline database for randomized controlled trials (RCTs) published from 2000 through 2012. Trial quality was assessed with the ten-item PEDro scale. Main outcome measures were selected as: number of repetitions and time until exhaustion for muscle performance, and creatine kinase (CK) activity to evaluate risk for exercise-induced muscle damage. The literature search resulted in 16 RCTs, and three articles were excluded due to poor quality assessment scores. From 13 RCTs with acceptable methodological quality ( $\geq 6$  of 10 items), 12 RCTs irradiated phototherapy before exercise, and 10 RCTs reported significant improvement for the main outcome measures related to performance. The time until exhaustion increased significantly compared to placebo by 4.12 s (95 % CI 1.21-7.02,  $p < 0.005$ ) and the number of repetitions increased by 5.47 (95 % CI 2.35-8.59,  $p < 0.0006$ ) after phototherapy. Heterogeneity in trial design and results precluded meta-analyses for biochemical markers, but a quantitative analysis showed positive results in 13 out of 16 comparisons. The most significant and consistent results were found with red or infrared wavelengths and phototherapy application before exercises, power outputs between 50 and 200 mW and doses of 5 and 6 J per point (spot). We conclude that phototherapy (with lasers and LEDs) improves muscular performance and accelerate recovery mainly when applied before exercise.

Lasers Med Sci 2013 Nov 19

<http://www.ncbi.nlm.nih.gov/pubmed/?term=24249354>

# Comparative analysis of two low-level laser doses on the expression of inflammatory mediators and on neutrophils and macrophages in acute joint inflammation.

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Synovial membrane inflammation plays an important role in osteoarthritis (OA) pathophysiology. The synovial tissue of patients with initial OA is characterized by mononuclear cell infiltration and the production of pro-inflammatory cytokines and other mediators of joint injury. The study aims to evaluate the effect of low-level laser therapy (LLLT) at doses of 2 and 4 J on joint inflammation in rats induced by papain through histopathological analysis, differential counts of inflammatory cells; gene expression of IL-1beta, IL-6, and IL-10; and TNF-alpha protein expression. Male Wistar rats (20) were randomly divided (5 animals each) into a negative control group, an inflammation injury positive control group, a 2-J LLLT group subjected to injury and treated with 2 J of LLLT, and a 4-J LLLT group subjected to injury and treated with 4 J of LLLT. The animals were subjected to joint inflammation (4 % papain solution) and treated with LLLT. On the day of euthanasia, articular lavage was collected and centrifuged. The supernatant was analyzed for TNF-alpha protein expression by ELISA and IL-1beta, IL-6, and IL-10 mRNA by RT-PCR. The joint tissue was also examined histologically. ANOVA with Tukey's post hoc test was used for comparisons. All data were expressed as means +/- S.D. ( $p < 0.05$ ). Both laser modalities were efficient in reducing cellular inflammation and decreasing the expression of IL-1beta and IL-6. However, the 2-J treatment led to more reduction in TNF-alpha than the 4-J treatment. A single application of LLLT with 2 J was more efficient in modulating inflammatory mediators and inflammatory cells.

Lasers Med Sci 2013 Oct 31

<http://www.ncbi.nlm.nih.gov/pubmed/?term=24173911>

# Effect of Low-Level Laser Therapy (808 nm) in Skeletal Muscle After Resistance Exercise Training in Rats.

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**Abstract Objective:** The aim of this study was to evaluate the effects of 808 nm laser applied after a resistance training protocol, on biochemical markers and the morphology of skeletal muscle in rats. **Background data:** Strenuous physical activity results in fatigue and decreased muscle strength, impaired motor control, and muscle pain. Many biochemical and biophysical interventions have been studied in an attempt to accelerate the recovery process of muscle fatigue. Among these, low-level laser therapy (LLLT) has been demonstrated to be effective in increasing skeletal muscle performance in in vivo studies and in clinical trials. However, little is known about the effects of LLLT on muscle performance after resistance training. **Methods:** Thirty Wistar rats were randomly divided into three groups: control group (CG), trained group (TG), and trained and laser-irradiated group (TGL). The resistance training program was performed three times per week for 5 weeks, and consisted of a climbing exercise, with weights attached to the tail of the animal. Furthermore, laser irradiation was performed in the middle region of tibialis anterior (TA) muscle of both legs, after the exercise protocol. **Results:** Analysis demonstrated that TGL demonstrated significantly reduced resting lactate level and decreased muscle glycogen depletion than the animals that were exercised only, and significantly increased the cross-section area of TA muscle fibers compared with those in the other groups. **Conclusions:** These results suggest that LLLT could be an effective therapeutic approach in increasing muscle performance during a resistance exercise protocol.

Photomed Laser Surg 2013 Oct 31(10) 492-8

<http://www.ncbi.nlm.nih.gov/pubmed/?term=24102167>

# Effect of Low Level Laser Therapy on the expression of inflammatory mediators and on neutrophils and macrophages in acute joint inflammation.

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**INTRODUCTION:** Inflammation of the synovial membrane plays an important role in the pathophysiology of osteoarthritis (OA). The synovial tissue of patients with initial OA is characterized by infiltration of mononuclear cells and production of pro-inflammatory cytokines and other mediators of joint injury. Our objective was to evaluate the effect of low level laser therapy (LLLT) operating at 50 mW and 100 mW on joint inflammation in rats induced by papain, through histopathological analysis, differential counts of inflammatory cells (macrophages and neutrophils), as well as gene expression of IL-1 $\beta$  and IL-6, and protein expression of Tumor necrosis factor alpha (TNF- $\alpha$ ). **Materials and Methods:** Male Wistar rats (60) were randomly divided into 4 groups of 15 animals, namely, a negative control group; an inflammation injury positive control group; a 50 mW LLLT group, subjected to injury and treated with 50 mW LLLT; and a 100 mW LLLT group, subjected to injury and treated with 100 mW LLLT. The animals were subject to joint inflammation (papain solution, 4%) and then treated with LLLT. On the day of euthanasia, articular lavage was collected and immediately centrifuged; the supernatant was saved for analysis of expression of TNF- $\alpha$  protein by ELISA and expression of IL-1 $\beta$  and IL-6 mRNA by RT-PCR. A histologic examination of joint tissue was also performed. For the statistical analysis, analysis of variance (ANOVA) with Tukey's post hoc test was used for comparisons between each group. All data are expressed as mean values and standard deviation, with  $p < 0.05$ . **RESULTS:** Both laser treatment modalities were efficient in reducing cellular inflammation, and both decreased the expression of IL-1 $\beta$  and IL-6. However, the 100 mW treatment led to a higher reduction of TNF- $\alpha$  compared to the 50 mW treatment. **CONCLUSION:** LLLT at 50 mW was more efficient in modulating inflammatory mediators (IL-1 $\beta$ , IL-6) and inflammatory cells (macrophages and neutrophils), which correlated with the histology that showed a reduction in the inflammatory process.

Arthritis Res Ther 2013 Sep 12 15(5) R116

<http://www.ncbi.nlm.nih.gov/pubmed/?term=24028507>

# Effect of low-level laser therapy on metalloproteinase MMP-2 and MMP-9 production and percentage of collagen types I and III in a papain cartilage injury model.

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Osteoarthritis (OA) resulting from injury or disease is associated with increased levels of several matrix metalloproteinases (MMPs), which degrade all components of the complex extracellular matrix in the cartilage. The objective of this study is to investigate the effect of low-level laser therapy (LLLT) on papain-induced joint damage in rats by histopathology and analysis of metalloproteinase 2 and 9 production. Sixty male Wistar rats were randomly distributed into four groups of 15 animals: (1) non-injury negative control, (2) injury positive control, (3) treated with LLLT at 50 mW, and (4) treated with LLLT at 100 mW. OA was induced in animals using papain (4 % solution) followed by treatment with LLLT. After 7, 14, and 21 days, the animals were euthanized. The articular lavage was collected and centrifuged; then, the supernatant was stored prior to protein analysis by western blot. The material was stained with hematoxylin and eosin for histopathological analysis, and Picrosirius Red was used to estimate the percentage of collagen fibers. To determine normal distribution, ANOVA and Tukey's post hoc test were used for comparison between and within each group at each time period. All data are expressed as mean and standard deviation values, with the null hypothesis considered as  $p < 0.05$ . Both laser groups (50 and 100 mW) were effective in tissue repair, decreasing collagen type III expression and increasing type I expression in all experimental periods; however, LLLT at 50 mW reduced metalloproteinase 9 more than at 100 mW in 21 days. LLLT at 50 mW was more efficient in the modulation of matrix MMPs and tissue repair.

Lasers Med Sci 2013 Aug 29

<http://www.ncbi.nlm.nih.gov/pubmed/?term=23990219>

# Evaluation of effect of low-level laser therapy on adolescents with temporomandibular disorder: study protocol for a randomized controlled trial.

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**BACKGROUND:** A number of problems involving the temporomandibular joint (TMJ) and associated structures can lead to temporomandibular disorder (TMD). The aim of the proposed study is to assess the effect of low-level laser therapy on occlusal contacts, mandibular movements, electromyography activity in the muscles of mastication and pain in adolescents with TMD. **METHODS/DESIGN:** A randomized, controlled, double-blind, clinical trial will be carried out involving 85 male and female adolescents between 15 and 18 years of age. The research diagnostic criteria for TMD will be used to assess all individuals who agree to participate. All participants will be submitted to a clinical examination and electromyographic analysis of the masseter muscles and anterior bundle of the temporal muscles bilaterally, to determine TMD. Based on the clinical findings, the participants will be classified as having or not having TMD. Those with TMD will be divided into four groups, three of which will receive low-level laser therapy and one of which will receive a placebo treatment. The treatments will involve the TMJ region alone, the masseter and temporal muscles alone, or both these regions together. The data will be submitted to descriptive statistical analysis. The chi-square test and Fisher's exact test will be used to determine associations among the categorical variables. The Student's t test and analysis of variance will be used for the comparison of mean electromyographic signals. Pearson's correlation coefficients will be calculated for the analysis of correlations among the continuous variables. **TRIAL REGISTRATION:** The protocol for this study has been submitted to Clinical Trials - registration number (NCT01846000).

Trials 2013 14 229

<http://www.ncbi.nlm.nih.gov/pubmed/?term=23876095>

# Light-emitting diode therapy induces analgesia in a mouse model of postoperative pain through activation of peripheral opioid receptors and the L-arginine/nitric oxide pathway.

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Light-emitting diode therapy (LEDT) has been clinically used as an alternative to low-level laser therapy; nevertheless, the molecular basis for LEDT effects remains unclear. The objective of this study was to evaluate the analgesic effect of LEDT in the mouse plantar incision (PI) model of postoperative pain, as well as to investigate some of the possible mechanisms involved in this effect, i.e., peripheral and central opioid receptors; migration of opioid-containing leukocytes to PI site and the L-arginine/nitric oxide (NO) pathway. To that end, mice were subjected to PI and treated with LEDT (950 nm, 80 mW/cm<sup>2</sup>, 1 through 13 J/cm<sup>2</sup>). Mechanical hypersensitivity was assessed as withdrawal frequency percentage to 10 presentations of a 0.4-g von Frey filament. In addition, the animals were pretreated with systemic (i.p.), intra-plantar (i.pl.), or intrathecal injection (i.t) of naloxone (a nonselective opioid receptor antagonist; 1 mg/kg, i.p.; 5 mug/right paw or 5 mug/site, respectively) or a systemic injection of fucoidin (100 mug/mouse, i.p., an inhibitor of leukocyte rolling through binding to L- and P-selectins). Our results demonstrate, for the first time, that LEDT induced a dose-response analgesic effect in the model of PI in mice. At the dose of 9 J/cm<sup>2</sup> LEDT presented the most significant results through (1) activation of peripheral opioid receptors which involve, at least partially, the recruitment of opioid-containing leukocytes to the PI site and; (2) activation of the L-arginine/NO pathway. These results extend previous literature data and suggest that LEDT might be useful in the treatment of postoperative pain.

Lasers Med Sci 2013 Jul 6

<http://www.ncbi.nlm.nih.gov/pubmed/?term=23832179>

# What is the best treatment to decrease pro-inflammatory cytokine release in acute skeletal muscle injury induced by trauma in rats: low-level laser therapy, diclofenac, or cryotherapy?

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Currently, treatment of muscle injuries represents a challenge in clinical practice. In acute phase, the most employed therapies are cryotherapy and nonsteroidal anti-inflammatory drugs. In the last years, low-level laser therapy (LLLT) has becoming a promising therapeutic agent; however, its effects are not fully known. The aim of this study was to analyze the effects of sodium diclofenac (topical application), cryotherapy, and LLLT on pro-inflammatory cytokine levels after a controlled model of muscle injury. For such, we performed a single trauma in tibialis anterior muscle of rats. After 1 h, animals were treated with sodium diclofenac (11.6 mg/g of solution), cryotherapy (20 min), or LLLT (904 nm; superpulsed; 700 Hz; 60 mW mean output power; 1.67 W/cm<sup>2</sup>; 1, 3, 6 or 9 J; 17, 50, 100 or 150 s). Assessment of interleukin-1beta and interleukin-6 (IL-1beta and IL-6) and tumor necrosis factor-alpha (TNF-alpha) levels was performed at 6 h after trauma employing enzyme-linked immunosorbent assay method. LLLT with 1 J dose significantly decreased ( $p < 0.05$ ) IL-1beta, IL-6, and TNF-alpha levels compared to non-treated injured group as well as diclofenac and cryotherapy groups. On the other hand, treatment with diclofenac and cryotherapy does not decrease pro-inflammatory cytokine levels compared to the non-treated injured group. Therefore, we can conclude that 904 nm LLLT with 1 J dose has better effects than topical application of diclofenac or cryotherapy in acute inflammatory phase after muscle trauma.

Lasers Med Sci 2013 Jun 30

<http://www.ncbi.nlm.nih.gov/pubmed/?term=23812849>



# Acute effects of light emitting diodes therapy (LEDT) in muscle function during isometric exercise in patients with chronic obstructive pulmonary disease: preliminary results of a randomized controlled trial.

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Patients with chronic obstructive pulmonary disease (COPD) are susceptible to early muscle fatigue. Light-emitting diodes therapy (LEDT) has been used to minimize muscle fatigue in athletes and healthy subjects. The aim of this study is to investigate the acute effects of LEDT on muscle fatigue and perception of effort in patients with COPD during isometric endurance test of the quadriceps femoris (QF). Ten patients (VEF1 50 +/- 13 % of predicted) underwent a single LEDT and sham application, 48 h apart, in a randomized crossover design. The LEDT and sham were applied in three localized areas of the QF (rectus femoris, vastus lateralis, and vastus medialis). Before and after exposure to LEDT and sham, the patients performed an isometric endurance test (60 % of the maximum voluntary isometric contraction), until the limit of tolerance concomitant to surface electromyography recording (median frequency as mean outcome). The slope obtained from linear regression analysis of the median frequency (MF) over endurance time was also used as an endurance index. Endurance time increased significantly after exposure to LEDT (from 26 +/- 2 to 53 +/- 5 s) as compared to sham (from 23 +/- 3 to 30 +/- 4 s) ( $F = 64$ ,  $P = 0.0001$ ). A greater decline in MF was observed during isometric endurance test after sham, compared to LEDT ( $F = 14.6$ ,  $P = 0.004$ ). The slope of the MF over time was lower post-LEDT compared to post-sham ( $-0.7 \pm 0.3$  vs.  $-1.5 \pm 0.8$ ;  $P = 0.004$ ). The dyspnea score corrected for endurance time was lower post-LEDT ( $P = 0.008$ ) but similar for fatigue both post-LEDT and post-sham. A single application of LEDT minimizes muscle fatigue and increases isometric endurance time.

Lasers Med Sci 2013 Jun 7

<http://www.ncbi.nlm.nih.gov/pubmed/?term=23743817>

# Effect of low-level laser therapy on types I and III collagen and inflammatory cells in rats with induced third-degree burns.

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Low-level laser therapy (LLLT) has been increasingly used to accelerate wound healing in third-degree burns. This study investigated the effects of lasers on the tissue repair process of third-degree burns. Burns were produced on the backs of male Wistar rats. The animals were divided into four groups ( $n = 12$ ): control, injury, LLLT 3 J/cm<sup>2</sup>, and LLLT 4 J/cm<sup>2</sup>. Each group was further divided into two subgroups; the rats in one subgroup were killed on day 8 and those in the other, on day 16 after injury. The animals in LLLT 3 J/cm<sup>2</sup> and LLLT 4 J/cm<sup>2</sup> were irradiated 1 h after injury, and irradiation was repeated every 48 h. Laser (660 nm, 35 mW) treatment at fluences of 3 and 4 J/cm<sup>2</sup> were used. After killing the rats, tissue fragments from the burnt area were removed for histological analysis. The LLLT-treated groups showed a significant decrease ( $p < 0.05$ ) in the number of inflammatory cells and increased collagen deposition compared to the injury group. Laser irradiation (both 3 and 4 J/cm<sup>2</sup>) resulted in reduction in the inflammatory process and improved collagen deposition, thereby ameliorating the healing of third-degree burns.

Lasers Med Sci 2013 May 16

<http://www.ncbi.nlm.nih.gov/pubmed/?term=23677436>

# Does phototherapy enhance skeletal muscle contractile function and postexercise recovery? A systematic review.

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**Context :** Recently, researchers have shown that phototherapy administered to skeletal muscle immediately before resistance exercise can enhance contractile function, prevent exercise-induced cell damage, and improve postexercise recovery of strength and function. **Objective :** To critically evaluate original research addressing the ability of phototherapeutic devices, such as lasers and light-emitting diodes (LEDs), to enhance skeletal muscle contractile function, reduce exercise-induced muscle fatigue, and facilitate postexercise recovery. **Data Sources :** We searched the electronic databases PubMed, SPORTDiscus, Web of Science, Scopus, and Rehabilitation & Physical Medicine without date limitations for the following key words: laser therapy, phototherapy, fatigue, exercise, circulation, microcirculation, and photobiomodulation. **Study Selection :** Eligible studies had to be original research published in English as full papers, involve human participants, and receive a minimum score of 7 out of 10 on the Physiotherapy Evidence Database (PEDro) scale. **Data Extraction :** Data of interest included elapsed time to fatigue, total number of repetitions to fatigue, total work performed, maximal voluntary isometric contraction (strength), electromyographic activity, and postexercise biomarker levels. We recorded the PEDro scores, beam characteristics, and treatment variables and calculated the therapeutic outcomes and effect sizes for the data sets. **Data Synthesis :** In total, 12 randomized controlled trials met the inclusion criteria. However, we excluded data from 2 studies, leaving 32 data sets from 10 studies. Twenty-four of the 32 data sets contained differences between active phototherapy and sham (placebo-control) treatment conditions for the various outcome measures. Exposing skeletal muscle to single-diode and multidiode laser or multidiode LED therapy was shown to positively affect physical performance by delaying the onset of fatigue, reducing the fatigue response, improving postexercise recovery, and protecting cells from exercise-induced damage. **Conclusions :** Phototherapy administered before resistance exercise consistently has been found to provide ergogenic and prophylactic benefits to skeletal muscle.

J Athl Train 2013 Jan-Feb 48(1) 57-67

<http://www.ncbi.nlm.nih.gov/pubmed/?term=23672326>

# Effects of light-emitting diodes on muscle fatigue and exercise tolerance in patients with COPD: study protocol for a randomized controlled trial.

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**BACKGROUND:** Light-emitting diodes (LED) have been used to minimize muscle fatigue in athletes and healthy subjects. Patients with chronic obstructive pulmonary disease (COPD) are susceptible to early muscle fatigue. **OBJECTIVE:** The objective of this study is to investigate the acute effects of LED on muscle function, exercise capacity and cardiorespiratory responses during isometric and dynamic exercise in patients with COPD. **METHODS:** This study will assess 30 patients with moderate to severe obstruction (forced expiratory volume-one second, FEV<sub>1</sub>  $\leq$  70% predicted). Isometric and dynamic protocols will be conducted in two visits each, for a total of four visits a week apart. First, venous blood will be taken from the patients. The isometric protocol will start with the determination of the maximum voluntary isometric contraction (MIVC) to determine the workload (60% of MIVC) for the isometric endurance test (IET). Patients will be randomized to receive either the placebo or LED application (each point will be irradiated for 30 s and the energy received at each point will be 41.7 J). Immediately after finishing this procedure, the patients will carry out the IET until the limit of tolerance or until a 20% fall of strength is observed. After the test, another blood draw will be taken. In another visit (one week later), the same order of procedures will be performed, except with the opposite (LED or placebo). For the dynamic endurance test (DET), the same procedures described above will be followed, except with 75% of the maximal workload obtained from the incremental cycle ergometer test used instead of the IET. The electromyography will be recorded during the isometric and dynamic protocols. Differences in muscle function, exercise capacity and cardiorespiratory responses between the LED and placebo applications will be analyzed. The therapeutic effects of LED could minimize muscle fatigue in patients with COPD by increasing exercise tolerance. **TRIAL REGISTRATION:** Trial registration number: NCT01448564.

Trials 2013 14 134

<http://www.ncbi.nlm.nih.gov/pubmed/?term=23663518>

# Low-level laser (light) therapy (LLLT) on muscle tissue: performance, fatigue and repair benefited by the power of light.

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The use of low level laser (light) therapy (LLLT) has recently expanded to cover areas of medicine that were not previously thought of as the usual applications such as wound healing and inflammatory orthopedic conditions. One of these novel application areas is LLLT for muscle fatigue and muscle injury. Since it is becoming agreed that mitochondria are the principal photoacceptors present inside cells, and it is known that muscle cells are exceptionally rich in mitochondria, this suggests that LLLT should be highly beneficial in muscle injuries. The ability of LLLT to stimulate stem cells and progenitor cells means that muscle satellite cells may respond well to LLLT and help muscle repair. Furthermore the ability of LLLT to reduce inflammation and lessen oxidative stress is also beneficial in cases of muscle fatigue and injury. This review covers the literature relating to LLLT and muscles in both preclinical animal experiments and human clinical studies. Athletes, people with injured muscles, and patients with Duchenne muscular dystrophy may all benefit.

Photonics Lasers Med 2012 Nov 1 1(4) 267-286

<http://www.ncbi.nlm.nih.gov/pubmed/?term=23626925>

# Wound-healing effects of low-level laser therapy in diabetic rats involve the modulation of MMP-2 and MMP-9 and the redistribution of collagen types I and III.

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The present study aimed to determine if LLLT restores the balance between mRNA expression of matrix metalloproteinases (MMP-2 and MMP-9) and also the balance between collagen types I and III during the healing process of diabetic wounds. One hundred and twenty male Wistar rats were distributed in Control (untreated non-diabetic rats: UND); Laser (laser treated in non-diabetic rats: LTND); Diabetic (diabetic rats non-laser treated rats: UD); and Diabetic+ Laser (diabetic rats laser treated: DLT) groups. The diabetes model using streptozotocin efficiently induced diabetes, as demonstrated through increased levels of blood glucose. Diode laser (50 mW, 660 nm, 4 J/cm<sup>2</sup>, 80 s) was applied a single time after scare induction. Twenty-four hours after LLLT application, rats were euthanized, the scarred areas were collected for MMP-2 and MMP-9 mRNA analysis and also for histological analysis (inflammation and types I and III collagen). The results demonstrated that scare in untreated diabetic rats significantly increased the MMP-2 and MMP-9 expression compared with that in non-diabetic rats ( $p < 0.05$ ), while LLLT significantly reduced MMP-2 and MMP-9 expression compared with that in untreated diabetic rats ( $p < 0.05$ ). To conclude, the results also showed that LLLT was able to alter the expression of MMP-9 as well as accelerate the production of collagen and increase the total percentage of collagen type III in diabetic animals.

J Cosmet Laser Ther 2013 Mar 6

<http://www.ncbi.nlm.nih.gov/pubmed/?term=23463906>

# Low-level light-emitting diode therapy increases mRNA expressions of IL-10 and type I and III collagens on Achilles tendinitis in rats.

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The present study investigated the effects of low-level light-emitting diode (LED) therapy (880 +/- 10 nm) on interleukin (IL)-10 and type I and III collagen in an experimental model of Achilles tendinitis. Thirty male Wistar rats were separated into six groups (n = 5), three groups in the experimental period of 7 days, control group, tendinitis-induced group, and LED therapy group, and three groups in the experimental period of 14 days, tendinitis group, LED therapy group, and LED group with the therapy starting at the 7th day after tendinitis induction (LEDT delay). Tendinitis was induced in the right Achilles tendon using an intratendinous injection of 100 µL of collagenase. The LED parameters were: optical power of 22 mW, spot area size of 0.5 cm<sup>2</sup>, and irradiation time of 170 s, corresponding to 7.5 J/cm<sup>2</sup> of energy density. The therapy was initiated 12 h after the tendinitis induction, with a 48-h interval between irradiations. The IL-10 and type I and III collagen mRNA expression were evaluated by real-time polymerase chain reaction at the 7th and 14th days after tendinitis induction. The results showed that LED irradiation increased IL-10 (p < 0.001) in treated group on 7-day experimental period and increased type I and III collagen mRNA expression in both treated groups of 7- and 14-day experimental periods (p < 0.05), except by type I collagen mRNA expression in LEDT delay group. LED (880 nm) was effective in increasing mRNA expression of IL-10 and type I and III collagen. Therefore, LED therapy may have potentially therapeutic effects on Achilles tendon injuries.

Lasers Med Sci 2013 Feb 13

<http://www.ncbi.nlm.nih.gov/pubmed/?term=23404386>

# Phototherapy and resistance training prevent sarcopenia in ovariectomized rats.

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The aim of this study was to histologically and biochemically analyze the effects of light-emitting diode therapy (LEDT) associated with resistance training to prevent sarcopenia in ovariectomized rats. Forty female Wistar rats (12 months old, 295-330 g) were bilaterally ovariectomized and divided into four groups (n = 10 per group): control-sedentary (C), resistance training (T), LEDT-sedentary (L), and LEDT plus resistance training (LT). Trained rats performed a 12-week water-jumping program (3 days per week) carrying a load equivalent to 50-80 % of their body mass strapped to their back. Depending on the group protocol, the LED device (850 nm, 100 mW, 120 J/cm<sup>2</sup>, spot size 0.5 cm<sup>2</sup>) was used either as the only method or after the resistance training had been performed. The device was used in the single point contact mode (for 10 min). The irradiated region was the center of the greater trochanter of the right femur and the middle third of the rectus femoris muscle was subsequently analyzed histomorphometrically. Significant increases (p < 0.05) were noted for the muscle volume of the T (68.1 +/- 19.7 %), the L (74.1 +/- 5.1 %), and the LT (68.2 +/- 11.5 %) groups compared to the C group (60.4 +/- 5.5 %). There were also significant increases in the concentrations of IGF-1, IL-1, and TNF-alpha in the muscles of the treated groups (p < 0.05). Animals in the LT group showed a significant increase in IL-6 compared to T, L, and C groups (p < 0.05). These findings suggest that resistance training and LEDT can prevent sarcopenia in ovariectomized rats.

Lasers Med Sci 2013 Jan 10

<http://www.ncbi.nlm.nih.gov/pubmed/?term=23307440>



# Effect of 808 nm low-level laser therapy in exercise-induced skeletal muscle fatigue in elderly women.

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Aging process involves several structural changes in muscle tissue which lead to decrease in musculoskeletal function. One of the most common physiological modifications is the increase in fatigability in elderly people, which leads to inability to maintain strength and motor control. In this context, low-level laser therapy (LLLT) has demonstrated positive results in reducing fatigue during physical exercise. Thus, this study aimed to investigate the effects of LLLT on skeletal muscle fatigue in elderly women. Twenty-four subjects divided in two groups entered a crossover randomized triple-blinded placebo-controlled trial. Active LLLT (808 nm wavelength, 100 mW, energy 7 J) or an identical placebo LLLT was delivered on the rectus femoris muscle immediately before a fatigue protocol. Subjects performed a fatigue protocol which consisted of voluntary isotonic contractions of knee flexion-extension performed with a load corresponding to 75 % of 1-MR (Maximum Repetition) during 60 s. Surface electromyography (SEMG) signals were recorded from rectus femoris muscle of dominant lower limb to evaluate peripheral fatigability using median frequency analysis of SEMG signal. The number of repetitions of flexion-extension during fatigue protocol was also compared between groups. The values of median frequency were used to calculate the slope coefficient. The results showed no difference in the slope comparing placebo LLLT and active LLLT groups ( $p = 0.293$ ). However, a significant difference was observed in the number of repetitions between groups, after active LLLT, subjects demonstrated significantly higher number of repetitions ( $p = 0.047$ ). In this study, LLLT was efficient in increasing the mean number of repetitions during knee flexion-extension exercise, although results have not shown delay electromyographic fatigue.

Lasers Med Sci 2013 Jan 8

<http://www.ncbi.nlm.nih.gov/pubmed/?term=23296713>

# Effect of low-level laser therapy on pain, quality of life and sleep in patients with fibromyalgia: study protocol for a double-blinded randomized controlled trial.

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**ABSTRACT: BACKGROUND:** Low-level laser therapy (LLLT) has been widely used as adjuvant strategy for treatment of musculoskeletal disorders. The light-tissue interaction (photobiostimulation) promotes analgesic and anti-inflammatory effects and improves tissue healing, which could justify the recommendation of this therapy for patients with fibromyalgia, leading to an improvement in pain and possibly minimizing social impact related to this disease. The present study proposes to evaluate the effect of LLLT on tender points in patients with fibromyalgia, correlating this outcome with quality of life and sleep. **METHODS:** One hundred and twenty patients with fibromyalgia will be treated at the Integrated Health Center and the Sleep Laboratory of the Post Graduate Program in Rehabilitation Sciences of the Nove de Julho University located in the city of Sao Paulo, Brazil. After fulfilling the eligibility criteria, a clinical evaluation and assessments of pain and sleep quality will be carried out and self-administered quality of life questionnaires will be applied. The 120 volunteers will be randomly allocated to an intervention group (LLLT, n = 60) or control group (CLLLT, n = 60). Patients from both groups will be treated three times per week for four weeks, totaling twelve sessions. However, only the LLLT group will receive an energy dose of 6 J per tender point. A standardized 50-minute exercise program will be performed after the laser application. The patients will be evaluated regarding the primary outcome (pain) using the following instruments: visual analog scale, McGill Pain Questionnaire and pressure algometry. The secondary outcome (quality of life and sleep) will be assessed with the following instruments: Medical Outcomes Study 36-item Short-Form Health Survey, Fibromyalgia Impact Questionnaire, Berlin Questionnaire, Epworth Sleepiness Scale and polysomnography. ANOVA test with repeated measurements for the time factor will be performed to test between-groups differences (followed by the Tukey-Kramer post hoc test), and a paired t test will be performed to test within-group differences. The level of significance for the statistical analysis will be set at 5% ( $P \leq 0.05$ ). Trial registration The protocol for this study is registered with the Brazilian Registry of Clinical Trials -- ReBEC (RBR-42gkzt).

Trials 2012 Nov 21 13(1) 221

<http://www.ncbi.nlm.nih.gov/pubmed/?term=23171567>

# Surgical Alternative for Treatment of Vertical Root fracture: A Case Report.

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Vertical root fracture (VRF) has been a great challenge in dentistry; most fractures often result in tooth extraction. Inflammation of tissues around the fractured root is the main reason for tooth extraction. Based on the strategic importance of some fractured teeth, treatment may be necessary and often complicated. However, performing a proper repair or even splinting the fractured segments may result in tooth preservation. Accordingly, in this case we report a new method for fractured tooth preservation. The surgical exposition of the fracture tooth was carried out through the radicular portion of the element via ultrasonic preparation, filling with composed resin and a synthetic hydroxyapatite graft. All these were performed around the tooth which received five sections of low-power laser. The patient was followed for two years with no signs or symptoms of inflammation and gingival recession. In conclusion, the used treatment protocol could be considered as a promising approach for VRF treatment, especially in cases where there is advanced or moderate bone loss in the surrounding sites of the fractured tooth.

Iran Endod J 2012 Winter 7(1) 40-4

<http://www.ncbi.nlm.nih.gov/pubmed/?term=23060913>

# Effects of Low-Level Laser Therapy (LLLT) and Diclofenac (Topical and Intramuscular) as Single and Combined Therapy in Experimental Model of Controlled Muscle Strain in Rats.

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Muscle injuries represent ca 30% of sports injuries and excessive stretching of muscle causes more than 90% of injuries. Currently the most used treatments are nonsteroidal anti-inflammatory drugs (NSAIDs), however, in last years, low-level laser therapy (LLLT) is becoming an interesting therapeutic modality. The aim of this study was to evaluate the effect of single and combined therapies (LLLT, topical application of diclofenac and intramuscular diclofenac) on functional and biochemical aspects in an experimental model of controlled muscle strain in rats. Muscle strain was induced by overloading tibialis anterior muscle of rats. Injured groups received either no treatment, or a single treatment with topical or intramuscular diclofenac (TD and ID), or LLLT (3 J, 810 nm, 100 mW) 1 h after injury. Walking track analysis was the functional outcome and biochemical analyses included mRNA expression of COX-1 and COX-2 and blood levels of prostaglandin E(2) (PGE(2) ). All treatments significantly decreased COX-1 and COX-2 gene expression compared with injury group ( $P < 0.05$ ). However, LLLT showed better effects than TD and ID regarding PGE(2) levels and walking track analysis ( $P < 0.05$ ). We can conclude that LLLT has more efficacy than topical and intramuscular diclofenac in treatment of muscle strain injury in acute stage.

Photochem Photobiol 2012 Sep 18

<http://www.ncbi.nlm.nih.gov/pubmed/?term=22989160>

# Low-Level Laser Therapy and Sodium Diclofenac in Acute Inflammatory Response Induced by Skeletal Muscle Trauma: Effects in Muscle Morphology and mRNA Gene Expression of Inflammatory Markers.

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Pharmacological therapy is widely used in the treatment of muscle injuries. On the other hand, low-level laser therapy (LLLT) arises as a promising nonpharmacological treatment. The aim of this study was to analyze the effects of sodium diclofenac (topical application) and LLLT on morphological aspects and gene expression of biochemical inflammatory markers. We performed a single trauma in tibialis anterior muscle of rats. After 1 h, animals were treated with sodium diclofenac (11.6 mg g<sup>-1</sup> of solution) or LLLT (810 nm; continuous mode; 100 mW; 3.57 W cm<sup>-2</sup>; 1, 3 or 9 J; 10, 30 or 90 s). Histological analysis and quantification of gene expression (real-time polymerase chain reaction-RT-PCR) of cyclooxygenase 1 and 2 (COX-1 and COX-2) and tumor necrosis factor-alpha (TNF-alpha) were performed at 6, 12 and 24 h after trauma. LLLT with all doses improved morphological aspects of muscle tissue, showing better results than injury and diclofenac groups. All LLLT doses also decreased ( $P < 0.05$ ) COX-2 compared to injury group at all time points, and to diclofenac group at 24 h after trauma. In addition, LLLT decreased ( $P < 0.05$ ) TNF-alpha compared both to injury and diclofenac groups at all time points. LLLT mainly with dose of 9 J is better than topical application of diclofenac in acute inflammation after muscle trauma.

Photochem Photobiol 2012 Sep 1

<http://www.ncbi.nlm.nih.gov/pubmed/?term=22937980>

# Low-level laser therapy in experimental model of collagenase-induced tendinitis in rats: effects in acute and chronic inflammatory phases.

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A variety of treatments for tendinopathies is currently used or has been trialed. However, in fact, there is a remarkably little evidence that any conventional therapies are effective. In the last years, low-level laser therapy (LLLT) has been showing interesting results in inflammatory modulation in different musculoskeletal disorders, but the optimal parameters and mechanisms behind these effects are not fully understood. The aim of this study is to investigate if the LLLT modulates the acute and chronic phase of collagenase-induced tendinitis in rat by interfering in mRNA expression for matrix metalloproteinases (MMP13 and MMP1), vascular endothelial growth factor (VEGF), and anti-inflammatory mediator (interleukin (IL)-10). For such, tendinitis was induced by collagenase injection in male Wistar rats. Animals were treated with LLLT (780 nm, potency of 22 mW, 107 mW/cm<sup>2</sup>, energy density of 7.5 J/cm<sup>2</sup>, and energy delivered of 1.54 J) with different number of treatments in accordance with the inflammatory phase analyzed. LLLT was able to modulate mRNA gene expression of IL-10, VEGF, MMP1, and MMP13 both in acute than in chronic inflammatory phase ( $p < 0.05$ ). Our results suggest that LLLT with parameters employed in the present study was able to modulate IL-10, VEGF, MMP1, and MMP13 mRNA gene expression both in acute than in chronic tendon inflammation. However, further studies are needed to establish optimal parameters for LLLT.

Lasers Med Sci 2012 Aug 28

<http://www.ncbi.nlm.nih.gov/pubmed/?term=22926534>

# Low-level laser therapy in collagenase-induced achilles tendinitis in rats: Analyses of biochemical and biomechanical aspects.

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NSAIDs are widely prescribed and used over the years to treat tendon injuries despite its well-known long-term side effects. In the last years several animal and human trials have shown that low-level laser therapy (LLLT) presents modulatory effects on inflammatory markers, however the mechanisms involved are not fully understood. The aim of this study was to evaluate the short-term effects of LLLT or sodium diclofenac treatments on biochemical markers and biomechanical properties of inflamed Achilles tendons. Wistar rats Achilles tendons (n = 6/group) were injected with saline (control) or collagenase at peritendinous area of Achilles tendons. After 1 h animals were treated with two different doses of LLLT (810 nm, 1 and 3 J) at the sites of the injections, or with intramuscular sodium diclofenac. Regarding biochemical analyses, LLLT significantly decreased ( $p < 0.05$ ) COX-2, TNF-alpha, MMP-3, MMP-9, and MMP-13 gene expression, as well as prostaglandin E(2) (PGE(2) ) production when compared to collagenase group. Interestingly, diclofenac treatment only decreased PGE(2) levels. Biomechanical properties were preserved in the laser-treated groups when compared to collagenase and diclofenac groups. We conclude that LLLT was able to reduce tendon inflammation and to preserve tendon resistance and elasticity. (c) 2012 Orthopaedic Research Society. Published by Wiley Periodicals, Inc. J Orthop Res.

J Orthop Res 2012 Jun 5

<http://www.ncbi.nlm.nih.gov/pubmed/?term=22674405>

# Effect of Low-Level Laser Therapy (660 nm) on Acute Inflammation Induced by Tenotomy of Achilles Tendon in Rats.

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In this study we aimed to analyze the effects of low-level laser therapy (LLLT) (660 nm) on levels of protein expression of inflammatory mediators after cutting Achilles tendon of rats. Thirty Wistar male rats underwent partial incisions of the left Achilles tendon, and were divided into three groups of 10 animals according to the time of euthanasia after injury: 6, 24 and 72 hours. Each group was then divided into control group and LLLT group (treated with 100 mW, 3.57 W/cm<sup>2</sup>, 0.028 cm<sup>2</sup>, 214 J/cm<sup>2</sup>, 6 J, 60 sec, single point). In LLLT group animals were treated once time per day until the time of euthanasia established for each group. The group treated with LLLT showed a significant reduction of IL-1beta compared to control groups at three time points (6h: p=0.0401; 24h: p=0.0015; 72h: p=0.0463). The analysis of IL-6 showed significant reduction only in the LLLT group at 72 h compared to control group (p=0.0179) while IL-10 showed a significant increase in the treated group compared with control group at three experimental times (6h: p=0.0007; 24h: p=0.0256; 72h: p<0.0001). We conclude that LLLT is an important modulator of inflammatory cytokines release after injury in Achilles tendon. (c) 2012 Wiley Periodicals, Inc. Photochemistry and Photobiology (c) 2012 The American Society of Photobiology.

Photochem Photobiol 2012 May 21

<http://www.ncbi.nlm.nih.gov/pubmed/?term=22621670>



# Low-level laser therapy in different stages of rheumatoid arthritis: a histological study.

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Rheumatoid arthritis (RA) is an autoimmune inflammatory disease of unknown etiology. Treatment of RA is very complex, and in the past years, some studies have investigated the use of low-level laser therapy (LLLT) in treatment of RA. However, it remains unknown if LLLT can modulate early and late stages of RA. With this perspective in mind, we evaluated histological aspects of LLLT effects in different RA progression stages in the knee. It was performed a collagen-induced RA model, and 20 male Wistar rats were divided into 4 experimental groups: a non-injured and non-treated control group, a RA non-treated group, a group treated with LLLT (780 nm, 22 mW, 0.10 W/cm<sup>2</sup>, spot area of 0.214 cm<sup>2</sup>, 7.7 J/cm<sup>2</sup>, 75 s, 1.65 J per point, continuous mode) from 12th hour after collagen-induced RA, and a group treated with LLLT from 7th day after RA induction with same LLLT parameters. LLLT treatments were performed once per day. All animals were sacrificed at the 14th day from RA induction and articular tissue was collected in order to perform histological analyses related to inflammatory process. We observed that LLLT both at early and late RA progression stages significantly improved mononuclear inflammatory cells, exudate protein, medullary hemorrhage, hyperemia, necrosis, distribution of fibrocartilage, and chondroblasts and osteoblasts compared to RA group ( $p < 0.05$ ). We can conclude that LLLT is able to modulate inflammatory response both in early as well as in late progression stages of RA.

Lasers Med Sci 2012 Apr 27

<http://www.ncbi.nlm.nih.gov/pubmed/?term=22538842>

# Effects of Low-Level Laser Therapy at Wavelengths of 660 nm and 808 nm in Experimental Model of Osteoarthritis.

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The aim of the present study was to analyze the influence of low-level laser radiation at wavelengths of 660nm and 808nm in an experimental model of osteoarthritis. The sample was composed of 36 male adult Wistar rats divided into three groups (G1, G2 and G3). For the induction of cartilage injury, three injections of 4% papain and 10mul of a cysteine solution were performed at right knee of the hind leg. Two weeks after the last injection, group G1 was treated with InGaAlP (660nm, 100 mW, 3.57 W/cm<sup>2</sup>), 40 sec) and G2 was treated with AsGaAl (808nm, 100 mW, 3.57 W/cm<sup>2</sup>), 40 sec) both with energy of 4J. There were significant differences in the type of squamous epithelium between days 7 and 14 in G2 (p<0.05) and on Day 14 between G1 and G2 (p<0.05). Moreover, statistically significant differences were found in formation of new blood vessels between G1 and G3 on Days 7 and 21 as well as between G2 and G3 on day 21. The formation of fibrotic tissue was greater in G3 (p<0.05). In conclusion, laser therapy, especially at a wavelength of 808nm, stimulated angiogenesis and reduced the formation of fibrosis in an experimental model of osteoarthritis.

Photochem Photobiol 2011 Nov 7

<http://www.ncbi.nlm.nih.gov/pubmed/?term=22053992>

# Infrared (810 nm) Low-Level Laser Therapy in Experimental Model of Strain-Induced Skeletal Muscle Injury in Rats: Effects on Functional Outcomes.

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Muscle strains are among the most prevalent causes for athletes' absence from sport activities. Low-level laser therapy (LLLT) has recently emerged as a potential contender to nonsteroidal anti-inflammatory drugs in muscle strain treatment. In this work we investigated effects of LLLT and diclofenac on functional outcomes in the acute stage after muscle strain injury in rats. Muscle strain was induced by overloading the tibialis anterior muscle of rats during anesthesia. The injured groups received either no treatment, or a single treatment with diclofenac 30 min prior to injury, or LLLT (810 nm, 100 mW) with doses of 1, 3, 6 or 9 J, at 1 h after injury. Functional outcome measures included a walking index and assessment of electrically induced muscle performance. All treatments (except 9 J LLLT) significantly improved the walking index 12 h postinjury compared with the untreated group. The 3 J group also showed a significantly better walking index than the drug group. All treatments significantly improved muscle performance at 6 and 12 h. LLLT dose of 3 J was as effective as the pharmacological agent in improving functional outcomes in the early phase after a muscle strain injury in rats.

Photochem Photobiol 2011 Nov 4

<http://www.ncbi.nlm.nih.gov/pubmed/?term=22053933>

# Effects of low-level laser therapy (808 nm) on isokinetic muscle performance of young women submitted to endurance training: a randomized controlled clinical trial.

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Low-level laser therapy (LLLT) has shown efficacy in muscle bioenergetic activation and its effects could influence the mechanical performance of this tissue during physical exercise. This study tested whether endurance training associated with LLLT could increase human muscle performance in isokinetic dynamometry when compared to the same training without LLLT. The primary objective was to determine the fatigue index of the knee extensor muscles (Flex<sub>t</sub>) and the secondary objective was to determine the total work of the knee extensor muscles (TW<sub>ext</sub>). Included in the study were 45 clinically healthy women (21 ± 1.78 years old) who were randomly distributed into three groups: CG (control group), TG (training group) and TLG (training with LLLT group). The training for the TG and TLG groups involved cycle ergometer exercise with load applied to the ventilatory threshold (VT) for 9 consecutive weeks. Immediately after each training session, LLLT was applied to the femoral quadriceps muscle of both lower limbs of the TLG subjects using an infrared laser device (808 nm) with six 60-mW diodes with an energy of 0.6 J per diode and a total energy applied to each limb of 18 J. VT was determined by ergospirometry during an incremental exercise test and muscle performance was evaluated using an isokinetic dynamometer at 240 degrees /s. Only the TLG showed a decrease in Flex<sub>t</sub> in the nondominant lower limb (P = 0.016) and the dominant lower limb (P = 0.006). Both the TLG and the TG showed an increase in TW<sub>ext</sub> in the nondominant lower limb (P < 0.001 and P = 0.011, respectively) and in the dominant lower limb (P < 0.000 and P < 0.000, respectively). The CG showed no reduction in Flex<sub>t</sub> or TW<sub>ext</sub> in either lower limb. The results suggest that an endurance training program combined with LLLT leads to a greater reduction in fatigue than an endurance training program without LLLT. This is relevant to everyone involved in sport and rehabilitation.

Lasers Med Sci 2011 Aug 26

<http://www.ncbi.nlm.nih.gov/pubmed/?term=21870127>

# Red (660 nm) and infrared (830 nm) low-level laser therapy in skeletal muscle fatigue in humans: what is better?

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In animal and clinical trials low-level laser therapy (LLLT) using red, infrared and mixed wavelengths has been shown to delay the development of skeletal muscle fatigue. However, the parameters employed in these studies do not allow a conclusion as to which wavelength range is better in delaying the development of skeletal muscle fatigue. With this perspective in mind, we compared the effects of red and infrared LLLT on skeletal muscle fatigue. A randomized double-blind placebo-controlled crossover trial was performed in ten healthy male volunteers. They were treated with active red LLLT, active infrared LLLT (660 or 830 nm, 50 mW, 17.85 W/cm<sup>2</sup>, 100 s irradiation per point, 5 J, 1,785 J/cm<sup>2</sup>) at each point irradiated, total 20 J irradiated per muscle) or an identical placebo LLLT at four points of the biceps brachii muscle for 3 min before exercise (voluntary isometric elbow flexion for 60 s). The mean peak force was significantly greater ( $p < 0.05$ ) following red (12.14%) and infrared LLLT (14.49%) than following placebo LLLT, and the mean average force was also significantly greater ( $p < 0.05$ ) following red (13.09%) and infrared LLLT (13.24%) than following placebo LLLT. There were no significant differences in mean average force or mean peak force between red and infrared LLLT. We conclude that both red than infrared LLLT are effective in delaying the development skeletal muscle fatigue and in enhancement of skeletal muscle performance. Further studies are needed to identify the specific mechanisms through which each wavelength acts.

Lasers Med Sci 2011 Jul 22

<http://www.ncbi.nlm.nih.gov/pubmed/?term=21814736>

# Low-level laser therapy improves skeletal muscle performance, decreases skeletal muscle damage and modulates mRNA expression of COX-1 and COX-2 in a dose-dependent manner.

de Almeida P, Lopes-Martins RA, Tomazoni SS, Junior JA, de Tarso Camillo de Carvalho P, Bjordal JM, Leal EC Junior

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We tested if modulation in mRNA expression of COX-1 and COX-2 can be related to protective effects of phototherapy in skeletal muscle. Thirty male Wistar rats were divided into five groups receiving either one of four laser doses (0.1, 0.3, 1.0 and 3.0 J) or a no-treatment control group. Laser irradiation (904 nm, 15 mW average power) was performed immediately before the first contraction for treated groups. Electrical stimulation was used to induce six tetanic tibial anterior muscle contractions. Immediately after sixth contraction, blood samples were collected in order to evaluate CK activity and muscles were dissected and frozen in liquid nitrogen in order to evaluate mRNA expression of COX-1 and COX-2. The 1.0 J and 3.0 J groups showed significant enhancement ( $p < 0.01$ ) in total work performed in 6 tetanic contractions compared to control group. All laser groups, except the 3.0 J group, presented significantly lower post-exercise CK activity than control group. Additionally, 1.0 J group showed increased COX-1 and decreased COX-2 mRNA expression compared to control group and 0.1, 0.3 and 3.0 J laser groups ( $p < 0.01$ ). We conclude that pre-exercise infrared laser irradiation with dose of 1.0 J enhances skeletal muscle performance and decreases post-exercise skeletal muscle damage and inflammation.

Photochem Photobiol 2011 Jul 12

<http://www.ncbi.nlm.nih.gov/pubmed/?term=21749398>

# Effects of infrared-LED illumination applied during high-intensity treadmill training in postmenopausal women.

Paolillo FR, Milan JC, Aniceto IV, Barreto SG, Rebelatto JR, Borghi-Silva A, Parizotto NA, Kurachi C, Bagnato VS

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**BACKGROUND DATA:** Technology and physical exercise can enhance physical performance during aging. **OBJECTIVE:** The purpose of this study was to investigate the effects of infrared-light-emitting diode (LED) illumination (850 nm) applied during treadmill training. **MATERIALS AND METHODS:** Twenty postmenopausal women participated in this study. They were randomly divided into two groups. The LED group performed treadmill training associated with infrared-LED illumination (n=10) and the control group performed only treadmill training (n=10). The training was performed during 3 months, twice a week during 30 min at intensities between 85 and 90% of maximal heart rate. The irradiation parameters were 31 mW/cm<sup>2</sup>, treatment time 30 min, 14,400 J of total energy and 55.8 J/cm<sup>2</sup> of fluence. Physiological, biomechanical, and body composition parameters were measured at the baseline and after 3 months. **RESULTS:** Both groups improved the time of tolerance limit (Tlim) (p<0.05) during submaximal constant-speed testing. The peak torque did not differ between groups. However, the results showed significantly higher values of power [from 56±10 to 73±8 W (p=0.002)] and total work [from 1,537±295 to 1,760±262 J (p=0.006)] for the LED group when compared to the control group [power: from 58±14 to 60±15 W (p>=0.05) and total work: from 1,504±404 to 1,622±418 J (p>=0.05)]. The fatigue significantly increased for the control group [from 51±6 to 58±5 % (p=0.04)], but not for the LED group [from 60±10 to 60±4 % (p>=0.05)]. No significant differences in body composition were observed for either group. **CONCLUSIONS:** Infrared-LED illumination associated with treadmill training can improve muscle power and delay leg fatigue in postmenopausal women.

Photomed Laser Surg 2011 Sep 29(9) 639-45

<http://www.ncbi.nlm.nih.gov/pubmed/?term=21749263>

# Low-level laser therapy (LLLT) in human progressive-intensity running: effects on exercise performance, skeletal muscle status, and oxidative stress.

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The aim of this work was to evaluate the effects of low-level laser therapy (LLLT) on exercise performance, oxidative stress, and muscle status in humans. A randomized double-blind placebo-controlled crossover trial was performed with 22 untrained male volunteers. LLLT (810 nm, 200 mW, 30 J in each site, 30 s of irradiation in each site) using a multi-diode cluster (with five spots - 6 J from each spot) at 12 sites of each lower limb (six in quadriceps, four in hamstrings, and two in gastrocnemius) was performed 5 min before a standardized progressive-intensity running protocol on a motor-drive treadmill until exhaustion. We analyzed exercise performance ( $\text{VO}_2$  max), time to exhaustion, aerobic threshold and anaerobic threshold), levels of oxidative damage to lipids and proteins, the activities of the antioxidant enzymes superoxide dismutase (SOD) and catalase (CAT), and the markers of muscle damage creatine kinase (CK) and lactate dehydrogenase (LDH). Compared to placebo, active LLLT significantly increased exercise performance ( $\text{VO}_2$  max  $p = 0.01$ ; time to exhaustion,  $p = 0.04$ ) without changing the aerobic and anaerobic thresholds. LLLT also decreased post-exercise lipid ( $p = 0.0001$ ) and protein ( $p = 0.0230$ ) damages, as well as the activities of SOD ( $p = 0.0034$ ), CK ( $p = 0.0001$ ) and LDH ( $p = 0.0001$ ) enzymes. LLLT application was not able to modulate CAT activity. The use of LLLT before progressive-intensity running exercise increases exercise performance, decreases exercise-induced oxidative stress and muscle damage, suggesting that the modulation of the redox system by LLLT could be related to the delay in skeletal muscle fatigue observed after the use of LLLT.

Lasers Med Sci 2011 Jul 8

<http://www.ncbi.nlm.nih.gov/pubmed/?term=21739259>



# Histomorphometric analysis of inflammatory response and necrosis in re-implanted central incisor of rats treated with low-level laser therapy.

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Low-level laser therapy is a tool employed in the management of post-operative inflammation process and in the enhancement of reparative process. The aim of the study was to perform histological evaluation of dental and periodontal ligament of rats central upper-left incisor teeth re-implanted and irradiated with low-level laser (InGaAl, 685 nm, 50 J/cm<sup>2</sup>) 15, 30, and 60 days after re-implantation. Seventy-two male rats had the central upper left incisor removed and kept for 15 min on dry gauze before replantation. Laser was irradiated over the root surface and empty alveolus prior replantation and over surrounding mucosa after the re-implantation. After histological procedures, all slices were analyzed regarding external resorption area and histological aspects. We observed an increase of root resorption ( $p < 0.05$ ) in the control group compared to the laser group at 15, 30, and 60 days. These results showed that the laser groups developed less root resorption areas than the control group in all experimental periods. Additionally, histological analysis revealed less inflammatory cells and necrotic areas in laser groups.

Lasers Med Sci 2011 May 27

<http://www.ncbi.nlm.nih.gov/pubmed/?term=21617972>

# Infrared (810-nm) low-level laser therapy on rat experimental knee inflammation.

Pallotta RC, Bjordal JM, Frigo L, Leal Junior EC, Teixeira S, Marcos RL, Ramos L, de Moura Messias F, Lopes-Martins RA

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Arthritis of the knee is the most common type of joint inflammatory disorder and it is associated with pain and inflammation of the joint capsule. Few studies address the effects of the 810-nm laser in such conditions. Here we investigated the effects of low-level laser therapy (LLLT; infrared, 810-nm) in experimentally induced rat knee inflammation. Thirty male Wistar rats (230-250 g) were anesthetized and injected with carrageenan by an intra-articular route. After 6 and 12 h, all animals were killed by CO<sub>2</sub> inhalation and the articular cavity was washed for cellular and biochemical analysis. Articular tissue was carefully removed for real-time PCR analysis in order to evaluate COX-1 and COX-2 expression. LLLT was able to significantly inhibit the total number of leukocytes, as well as the myeloperoxidase activity with 1, 3, and 6 J (Joules) of energy. This result was corroborated by cell counting showing the reduction of polymorphonuclear cells at the inflammatory site. Vascular extravasation was significantly inhibited at the higher dose of energy of 10 J. Both COX-1 and 2 gene expression were significantly enhanced by laser irradiation while PGE<sub>2</sub> production was inhibited. Low-level laser therapy operating at 810 nm markedly reduced inflammatory signs of inflammation but increased COX-1 and 2 gene expression. Further studies are necessary to investigate the possible production of antiinflammatory mediators by COX enzymes induced by laser irradiation in knee inflammation.

Lasers Med Sci 2011 Apr 12

<http://www.ncbi.nlm.nih.gov/pubmed/?term=21484455>

# Comparison between cold water immersion therapy (CWIT) and light emitting diode therapy (LEDT) in short-term skeletal muscle recovery after high-intensity exercise in athletes-preliminary results.

Leal Junior EC, de Godoi V, Mancalossi JL, Rossi RP, De Marchi T, Parente M, Grosselli D, Generosi RA, Basso M, Frigo L, Tomazoni SS, Bjordal JM, Lopes-Martins RA

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In the last years, phototherapy has becoming a promising tool to improve skeletal muscle recovery after exercise, however, it was not compared with other modalities commonly used with this aim. In the present study we compared the short-term effects of cold water immersion therapy (CWIT) and light emitting diode therapy (LEDT) with placebo LEDT on biochemical markers related to skeletal muscle recovery after high-intensity exercise. A randomized double-blind placebo-controlled crossover trial was performed with six male young futsal athletes. They were treated with CWIT (5 degrees C of temperature [SD +/-1 degrees ]), active LEDT (69 LEDs with wavelengths 660/850 nm, 10/30 mW of output power, 30 s of irradiation time per point, and 41.7 J of total energy irradiated per point, total of ten points irradiated) or an identical placebo LEDT 5 min after each of three Wingate cycle tests. Pre-exercise, post-exercise, and post-treatment measurements were taken of blood lactate levels, creatine kinase (CK) activity, and C-reactive protein (CRP) levels. There were no significant differences in the work performed during the three Wingate tests ( $p > 0.05$ ). All biochemical parameters increased from baseline values ( $p < 0.05$ ) after the three exercise tests, but only active LEDT decreased blood lactate levels ( $p = 0.0065$ ) and CK activity ( $p = 0.0044$ ) significantly after treatment. There were no significant differences in CRP values after treatments. We concluded that treating the leg muscles with LEDT 5 min after the Wingate cycle test seemed to inhibit the expected post-exercise increase in blood lactate levels and CK activity. This suggests that LEDT has better potential than 5 min of CWIT for improving short-term post-exercise recovery.

Lasers Med Sci 2010 Nov 19

<http://www.ncbi.nlm.nih.gov/pubmed/?term=21088862>

# Effects of low level laser therapy (808 nm) on physical strength training in humans.

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Recent studies have investigated whether low level laser therapy (LLLT) can optimize human muscle performance in physical exercise. This study tested the effect of LLLT on muscle performance in physical strength training in humans compared with strength training only. The study involved 36 men (20.8±2.2 years old), clinically healthy, with a beginner and/or moderate physical activity training pattern. The subjects were randomly distributed into three groups: TLG (training with LLLT), TG (training only) and CG (control). The training for TG and TLG subjects involved the leg-press exercise with a load equal to 80% of one repetition maximum (1RM) in the leg-press test over 12 consecutive weeks. The LLLT was applied to the quadriceps muscle of both lower limbs of the TLG subjects immediately after the end of each training session. Using an infrared laser device (808 nm) with six diodes of 60 mW each a total energy of 50.4 J of LLLT was administered over 140 s. Muscle strength was assessed using the 1RM leg-press test and the isokinetic dynamometer test. The muscle volume of the thigh of the dominant limb was assessed by thigh perimeter. The TLG subjects showed an increase of 55% in the 1RM leg-press test, which was significantly higher than the increases in the TG subjects (26%,  $P = 0.033$ ) and in the CG subjects (0.27%,  $P < 0.001$ ). The TLG was the only group to show an increase in muscle performance in the isokinetic dynamometry test compared with baseline. The increases in thigh perimeter in the TLG subjects and TG subjects were not significantly different (4.52% and 2.75%, respectively;  $P = 0.775$ ). Strength training associated with LLLT can increase muscle performance compared with strength training only.

Lasers Med Sci 2010 Nov 18

<http://www.ncbi.nlm.nih.gov/pubmed/?term=21086010>

# Effect of low-power gallium-aluminum-arsenium noncoherent light (640 nm) on muscle activity: a clinical study.

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**BACKGROUND DATA:** Studies have shown the significant effects of electromagnetic irradiation in the visible region, with laser as an irradiation source. However, the effect of LEDs (light-emitting diodes) irradiation in similar wavelengths is not known. **OBJECTIVE:** The purpose of this clinical study was to verify the effects of the LED (640 nm with 40 nm full bandwidth at half maximum) on muscle activity. **METHODS:** The study was done with 30 test subjects, of both genders, aged 23 +/- 3 years, with a mean weight of 60 kg, divided into three groups (n = 10). Fatigue was induced through the maximum power of a bite, for 60 s in two overlaid occlusal platforms, coupled to a load cell and to a biologic signal-acquisition device. LED irradiation of the right masseter muscle was applied to all subjects. The left muscle received placebo treatment. Irradiation was applied in eight points on the right masseter muscle (transcutaneous), 1.044 J per point, 2.088 J per point, or 3.132 J per point, 0.116 W, 0.522 cm(2) spot size, 0.816 cm spot O, continuous wave, perpendicular to the skin. **RESULTS:** An increase in muscle activity was observed after irradiation with 1.044 J per point ( $p < 0.05$ ). A significant increase ( $p < 0.01$ ) in the time before fatigue was observed in the irradiated muscle with 2.088 J per point, without a change in the force of contraction ( $p > 0.05$ ). This change was not observed with 1.044 J per point and 3.132 J per point. The results suggest a dose-dependent relation with this kind of noncoherent irradiation in the red region of the electromagnetic spectrum in the muscle-fatigue process. **CONCLUSION:** It was concluded that LED can be used as a clinical tool to increase muscle activity (1.044 J per point) and to prevent fatigue (2.088 J per point), without change in the muscle force.

Photomed Laser Surg 2010 Oct 28(5) 647-52

<http://www.ncbi.nlm.nih.gov/pubmed/?term=20961231>

# Assessment of the effect of the use of laser light or dantrolene on facial muscle under occlusal wear: a Raman spectroscopic study in a rodent model.

Lisboa MV, Lopes CB, Rocha R, Ramos TA, de Abreu ID, Cangussu MC, Pinheiro AL, dos Santos JN

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**OBJECTIVE:** The aim of the present study was to use Raman spectroscopy to measure levels of CaPi in muscles under occlusal wear and treated with laser phototherapy (LPT) or muscle-relaxant therapy or both on rodents. **BACKGROUND:** The etiology of temporomandibular disorders is multifactorial. Malocclusion may influence the masticatory muscles, causing fatigue. A major type of fatigue is the metabolic, caused by the increased accumulation of metabolites such as inorganic phosphate. Raman spectroscopy allows nondestructive analysis of the biochemical composition of tissues. **METHODS:** The 30 male Wistar rats were randomly divided into three groups: occlusal wear (G-1), occlusal wear + LPT (G-2), and occlusal wear + muscle relaxant (G-3). Ten untreated animals were used for baseline data. Under intraperitoneal general anesthesia, animals of groups 1, 2, and 3 had unilateral amputation of molar cusps to simulate an occlusal-wear situation. The masseter muscle of G-2 received LPT ( $\lambda$ 830 nm, 4 J/cm<sup>2</sup>, 40 mW,  $\phi$  approximately 2 mm) after the procedure and repeated every other day for 14-30 days. Animals of G-3 were treated with a daily injection of dantrolene (2.5 mg/kg in 0.5 ml of H<sub>2</sub>O) beginning 24 h after cusp removal. Animals were killed with an overdose of general anesthetics at days 14 and 30 after cusps removal, and the ipsilateral masseter muscle was excised and divided into two parts. One part was routinely processed and underwent histologic analysis; the other was kept in liquid nitrogen for Raman spectroscopy. The mean value of the intensity of the peak 958 per centimeter was determined. **RESULTS:** No morphologic changes were seen. Raman analysis showed significantly less Raman intensity in the laser group at 30 days ( $p < 0.01$ ). **CONCLUSION:** Occlusal wear did not caused morphologic alterations in the masseter muscle but resulted in changes of the levels of CaP(i) that were less compromising when the laser light was used.

Photomed Laser Surg 2010 Aug 28 Suppl 1 S135-41

<http://www.ncbi.nlm.nih.gov/pubmed/?term=20666575>

# Anti-inflammatory effects of low-level light emitting diode therapy on Achilles tendinitis in rats.

Xavier M, David DR, de Souza RA, Arrieiro AN, Miranda H, Santana ET, Silva JA Jr, Salgado MA, Aimbire F, Albertini R

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**BACKGROUND AND OBJECTIVES:** The present study investigated the effects of low-level light emitting diode (LED) therapy (880 +/- 10 nm) on inflammatory process in a experimental model of Achilles tendinitis induced by collagenase. **STUDY DESIGN/MATERIALS AND METHODS:** Fifty-six male Wistar were separated into seven groups (n = 8), three groups in the experimental period of 7 days and four groups in the experimental period of 14 days, the control group (CONT), tendinitis group (TEND), LED therapy group (LEDT) for both experimental periods, and LED therapy group 7th to 14th day (LEDT delay) for 14 days experimental period. The LED parameters was 22 mW CW of optical output power, distributed in an irradiation area of 0.5 cm(2), with an irradiation time of 170 seconds, the applied energy density was 7.5 J/cm(2) in contact. The therapy was initiated 12 hours after the tendinitis induction, with a 48-hour interval between the irradiations. The histological analysis and inflammatory mediators were quantified. **RESULTS:** Our results showed that LED decreases the inflammatory cells influx and mRNA expression to IL-1 beta, IL-6, tumor necrosis factor-alpha (TNF-alpha) in both phase, and cyclooxygenase -2 (COX-2) just in initial phase (P < 0.05). **CONCLUSION:** Our results suggest that the anti-inflammatory therapy with low-power LED (880 nm) enhanced the tissue response in all groups. We can conclude that the LED was able to reduce signs of inflammation in collagenase-induced tendinitis in rats by reducing the number of inflammatory cells and decrease mRNA expression of cytokines.

Lasers Surg Med 2010 Aug 42(6) 553-8

<http://www.ncbi.nlm.nih.gov/pubmed/?term=20662032>

# Effect of Light-Emitting Diodes Therapy (LEDT) on Knee Extensor Muscle Fatigue.

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**Abstract Objective:** The purpose of this study was to evaluate the effects of light-emitting diodes therapy (LEDT) on quadriceps muscle fatigue by using torque values from the isokinetic dynamometer as an outcome measure. **Background Data:** Light therapy is considered an innovative way to prevent muscle fatigue. Although positive results have been obtained in animal models and in clinical experiments, no results are available on the effects of this therapeutic modality on human performance studies with isokinetic dynamometry. **Materials and Methods:** Seventeen healthy and physically active male volunteers were included in a crossover randomized double-blinded placebo-controlled trial. They performed two sessions of an isokinetic fatigue test (30 maximal concentric knee flexion-extension contractions; range of motion, 90 degrees; angular velocity, 180 degrees per second) after LEDT or placebo treatment. Maximal knee extensor muscle isokinetic voluntary contractions were performed before (PRE-MVC) and after (POST-MVC) the fatigue test. LEDT treatment was performed with a multidiode cluster probe (34 red diodes of 660 nm, 10 mW; 35 infrared diodes of 850 nm, 30 mW) at three points of the quadriceps muscle, with a total irradiating dose of 125.1 J. **Results:** No differences were observed in the PRE-MVC between LEDT (284.81 +/- 4.52 Nm) and placebo (282.65 +/- 52.64 Nm) treatments. However, for the POST-MVC, higher torques ( $p = 0.034$ ) were observed for LEDT (237.68 +/- 48.82 Nm) compared with placebo (225.68 +/- 44.14 Nm) treatment. **Conclusion:** LEDT treatment produced a smaller maximal isometric torque decrease after high-intensity concentric isokinetic exercise, which is consistent with an increase in performance.

Photomed Laser Surg 2010 Jul 13

<http://www.ncbi.nlm.nih.gov/pubmed/?term=20626264>



# Low level laser therapy before eccentric exercise reduces muscle damage markers in humans.

Baroni BM, Leal Junior EC, De Marchi T, Lopes AL, Salvador M, Vaz MA

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The purpose of the present study was to determine the effect of low level laser therapy (LLLT) treatment before knee extensor eccentric exercise on indirect markers of muscle damage. Thirty-six healthy men were randomized in LLLT group (n = 18) and placebo group (n = 18). After LLLT or placebo treatment, subjects performed 75 maximal knee extensors eccentric contractions (five sets of 15 repetitions; velocity = 60 degrees  $\text{seg}^{-1}$ ; range of motion = 60 degrees). Muscle soreness (visual analogue scale-VAS), lactate dehydrogenase (LDH) and creatine kinase (CK) levels were measured prior to exercise, and 24 and 48 h after exercise. Muscle function (maximal voluntary contraction-MVC) was measured before exercise, immediately after, and 24 and 48 h post-exercise. Groups had no difference on kinanthropometric characteristics and on eccentric exercise performance. They also presented similar baseline values of VAS (0.00 mm for LLLT and placebo groups), LDH (LLLT = 186 IU/l; placebo = 183 IU/l), CK (LLLT = 145 IU/l; placebo = 155 IU/l) and MVC (LLLT = 293 Nm; placebo = 284 Nm). VAS data did not show group by time interaction (P = 0.066). In the other outcomes, LLLT group presented (1) smaller increase on LDH values 48 h post-exercise (LLLT = 366 IU/l; placebo = 484 IU/l; P = 0.017); (2) smaller increase on CK values 24 h (LLLT = 272 IU/l; placebo = 498 IU/l; P = 0.020) and 48 h (LLLT = 436 IU/l; placebo = 1328 IU/l; P < 0.001) post-exercise; (3) smaller decrease on MVC immediately after exercise (LLLT = 189 Nm; placebo = 154 Nm; P = 0.011), and 24 h (LLLT = 249 Nm; placebo = 205 Nm; P = 0.004) and 48 h (LLLT = 267 Nm; placebo = 216 Nm; P = 0.001) post-exercise compared with the placebo group. In conclusion, LLLT treatment before eccentric exercise was effective in terms of attenuating the increase of muscle proteins in the blood serum and the decrease in muscle force.

Eur J Appl Physiol 2010 Jul 3

<http://www.ncbi.nlm.nih.gov/pubmed/?term=20602109>

# Immediate effects of acupuncture on strength performance: a randomized, controlled crossover trial.

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The present study investigated the immediate efficacy of acupuncture compared to sham acupuncture and placebo laser acupuncture on strength performance. A total of 33 recreational athletes (25.2 +/- 2.8 years; 13 women) were randomized to receive acupuncture, sham acupuncture (needling at non-acupuncture points) and placebo laser acupuncture (deactivated laser device) in a double-blind crossover fashion with 1 week between trials. Assessment included bipedal drop jumps for maximum rebound height and quadriceps maximum isometric voluntary force (MIVF). Furthermore, surface electromyography (EMG) was used to measure the EMG activity of the rectus femoris muscle during a 30-s sustained MIVF of the knee extensors. Mean power frequency (MPF) analysis was applied to characterize muscular endurance. Measurements were performed at baseline and immediately after treatment by a blinded investigator. Repeated measures ANOVA and post hoc paired-sample t test with Bonferroni-Holm correction were used for statistical analysis. The difference in the mean change in MIVF from baseline between acupuncture (46.6 N) and sham laser acupuncture (19.6 N) was statistically significant ( $p < 0.05$ ), but no significant difference was found between acupuncture (46.6 N) and sham acupuncture (28.8 N). ANOVA did not show statistically significant treatment effects for drop jump height or MPF. The present study shows that a single acupuncture treatment was efficacious for improving isometric quadriceps strength in recreational athletes. These results might have implications not only for athletic performance enhancement, but also for rehabilitation programs aimed at restoring neuromuscular function.

Eur J Appl Physiol 2010 May 25

<http://www.ncbi.nlm.nih.gov/pubmed/?term=20499248>

# Effects of Low-Level Laser Therapy (LLLT) in the Development of Exercise-Induced Skeletal Muscle Fatigue and Changes in Biochemical Markers Related to Post-Exercise Recovery.

Leal Junior EC, Lopes-Martins RA, Frigo L, De Marchi T, Rossi RP, de Godoi V, Tomazoni SS, da Silva DP, Basso M, Filho PL, de Valls Corsetti F, Iversen VV, Bjordal JM

**STUDY DESIGN:** Randomized crossover double-blinded placebo-controlled trial. **OBJECTIVE:** To investigate if low level laser therapy (LLLT) can affect biceps muscle performance, fatigue development, and biochemical markers of post-exercise recovery. **BACKGROUND:** Cell and animal studies have suggested that LLLT can reduce oxidative stress and inflammatory responses in muscle tissue. But it remains uncertain whether these findings can translate into humans in sport and exercise situations. **METHODS:** Nine healthy male volleyball players participated in the study. They received either active LLLT (cluster probe with 5 laser diodes,  $\lambda=810$  nm, 200 mW power output, 30 seconds of irradiation, applied in 2 locations over the biceps of the non-dominant arm, 60 J of total energy) or placebo LLLT using an identical cluster probe. The intervention or placebo were applied 3 minutes before the performance of exercise. All subjects performed voluntary elbow flexion repetitions with a workload of 75% of their maximal voluntary contraction force (MVC) until exhaustion. **RESULTS:** Active LLLT increased the number of repetitions by 14.5% (mean of 39.56, SD +/- 4.33 versus 34.56 +/- 5.64,  $p=0.037$ ) and the elapsed time before exhaustion by 8.0% ( $p=0.034$ ), when compared to the placebo treatment. The biochemical markers also indicated that recovery may be positively affected by LLLT as indicated by post-exercise blood lactate levels ( $p<0.01$ ), Creatine Kinase (CK) activity ( $p=0.017$ ), and C-Reactive Protein (CRP) levels ( $p=0.047$ ) showing a faster recovery with LLLT application prior to the exercise. **CONCLUSION:** We conclude that pre-exercise irradiation of the biceps with an LLLT dose of 6 J per application location, applied in 2 locations, increased endurance for repeated elbow flexion against resistance, and decreased post-exercise levels of blood lactate, CK, and CRP. **LEVEL OF EVIDENCE:** Therapy, Level 1a. *J Orthop Sports Phys Ther*, Epub 12 April 2010. doi:10.2519/jospt.2010.3294.

*J Orthop Sports Phys Ther* 2010 Apr 12

<http://www.ncbi.nlm.nih.gov/pubmed/?term=20436237>

# Effect of low-level laser therapy (GaAs 904 nm) in skeletal muscle fatigue and biochemical markers of muscle damage in rats.

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We wanted to test if pre-exercise muscle irradiation with 904 nm laser affects the development of fatigue, blood lactate levels and creatine kinase (CK) activity in a rat model with tetanic contractions. Thirty male Wistar rats were divided into five groups receiving either one of four different laser doses (0.1, 0.3, 1.0 and 3.0 J) or a no-treatment control group. Laser irradiation was performed immediately before the first contraction for treated groups. Electrical stimulation was used to induce six tetanic tibial anterior muscle contractions with 10 min intervals between them. Contractions were stopped when the muscle force fell to 50% of the peak value for each contraction; blood samples were taken before the first and immediately after the sixth contraction. The relative peak forces for the sixth contraction were significantly better ( $P < 0.05$ ) in the two laser groups irradiated with highest doses [151.27% (SD +/- 18.82) for 1.0 J, 144.84% (SD +/- 34.47) for 3.0 J and 82.25% (SD +/- 11.69) for the control group]. Similar significant ( $P < 0.05$ ) increases in mean performed work during the sixth contraction for the 1.0 and 3.0 J groups were also observed. Blood lactate levels were significantly lower ( $P < 0.05$ ) than the control group in all irradiated groups. All irradiated groups except the 3.0 J group had significantly lower post-exercise CK activity than the control group. We conclude that pre-exercise irradiation with a laser dose of 1.0 J and 904 nm wavelength significantly delays muscle fatigue and decreases post-exercise blood lactate and CK in this rat model.

Eur J Appl Physiol 2009 Dec 19

<http://www.ncbi.nlm.nih.gov/pubmed/?term=20024577>

# Physiotherapy treatments for breast cancer-related lymphedema: a literature review.

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Breast cancer is the second most frequent cancer among women. Surgery is part of the therapeutic process to prevent metastases, but it can also cause some complications, including lymphedema. Physiotherapy contributes to its treatment, using different techniques that have been developed over the years. This systematic literature review aims to present physiotherapy modalities applied for lymphedema therapy. The literature review was conducted using textbooks and Lilacs, Pubmed and Scielo databases, from 1951 to 2009. Physiotherapy resources used for lymphedema treatment include complex decongestive therapy (CDT), pneumatic compression (PC), high voltage electrical stimulation (HVES) and laser therapy. The analyzed literature shows that better results are obtained with combined techniques. CDT is the most used protocol, and its association with PC has demonstrated efficacy. The new techniques HVES and laser present satisfactory results.

Rev Lat Am Enfermagem 2009 Sep-Oct 17(5) 730-6

<http://www.ncbi.nlm.nih.gov/pubmed/?term=19967225>

# The Effect of Equal Daily Dose Achieved by Different Power Densities of Low-Level Laser Therapy at 635 and 670 nm on Wound Tensile Strength in Rats: A Short Report.

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**Abstract Objective:** The aim of our study was to compare the effects of different power densities of LLLT at 635 and 670 nm achieving a daily dose of 5 J/cm<sup>2</sup> on wound tensile strength (TS) in rats. **Background Data:** Optimal parameters of low-level laser therapy (LLLT) are still unknown. **Materials and Methods:** Under general anesthesia, one full-thickness skin incision was performed on the back of each rat (n = 40) and immediately closed using an intradermal running suture. Rats were separated into five groups depending on treatment parameters: (1) sham irradiated control group (SIC); (2) 635 nm laser-treated group at 4 mW/cm<sup>2</sup> (L-635/4); (3) 635 nm laser-treated group at 15 mW/cm<sup>2</sup> (L-635/15); (4) 670 nm laser-treated group at 4 mW/cm<sup>2</sup> (L-670/4); and (5) 670 nm laser-treated group at 15 mW/cm<sup>2</sup> (L-670/15). The total daily dose was 5 J/cm<sup>2</sup>. Seven days after surgery each wound was removed for wound TS measurement. **Results:** The lowest wound TS results were measured in the SIC rats (10.5 +/- 2.8 g/mm<sup>2</sup>). Higher wound TS results were measured in group L-670/15 (11.5 +/- 2.5 g/mm<sup>2</sup>) and group L-635/4 (11.7 +/- 4.3 g/mm<sup>2</sup>) rats, while significantly higher results were found in group L-670/4 (15.8 +/- 4.4 g/mm<sup>2</sup>) and group L-635/15 (15.9 +/- 4.8 g/mm<sup>2</sup>). The differences were significant between certain groups (p < 0.01: SIC vs. L-635/15, SIC vs. L-670/4; p < 0.05: L-635/4 vs. L-635/15, L-635/4 vs. L-670/4, L-635/15 vs. L-670/15, L-670/4 vs. L-670/15). **Conclusion:** Both red lasers significantly increased wound TS at selected parameters. Whereas the 635 nm laser significantly improved wound healing by using the higher power density, the 670 nm laser improved healing using a lower power density.

Photomed Laser Surg 2009 Sep 11

<http://www.ncbi.nlm.nih.gov/pubmed/?term=19743962>

# Effect of cluster multi-diode light emitting diode therapy (LEDT) on exercise-induced skeletal muscle fatigue and skeletal muscle recovery in humans.

Leal Junior EC, Lopes-Martins RA, Rossi RP, De Marchi T, Baroni BM, de Godoi V, Marcos RL, Ramos L, Bjordal JM

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**BACKGROUND AND OBJECTIVES:** There are some indications that low-level laser therapy (LLLT) may delay the development of skeletal muscle fatigue during high-intensity exercise. There have also been claims that LED cluster probes may be effective for this application however there are differences between LED and laser sources like spot size, spectral width, power output, etc. In this study we wanted to test if light emitting diode therapy (LEDT) can alter muscle performance, fatigue development and biochemical markers for skeletal muscle recovery in an experimental model of biceps humeri muscle contractions. **STUDY DESIGN/MATERIALS AND METHODS:** Ten male professional volleyball players (23.6 [SD +/-5.6] years old) entered a randomized double-blinded placebo-controlled crossover trial. Active cluster LEDT (69 LEDs with wavelengths 660/850 nm, 10/30 mW, 30 seconds total irradiation time, 41.7 J of total energy irradiated) or an identical placebo LEDT was delivered under double-blinded conditions to the middle of biceps humeri muscle immediately before exercise. All subjects performed voluntary biceps humeri contractions with a workload of 75% of their maximal voluntary contraction force (MVC) until exhaustion. **RESULTS:** Active LEDT increased the number of biceps humeri contractions by 12.9% (38.60 [SD +/-9.03] vs. 34.20 [SD +/-8.68],  $P = 0.021$ ) and extended the elapsed time to perform contractions by 11.6% ( $P = 0.036$ ) versus placebo. In addition, post-exercise levels of biochemical markers decreased significantly with active LEDT: Blood Lactate ( $P = 0.042$ ), Creatine Kinase ( $P = 0.035$ ), and C-Reactive Protein levels ( $P = 0.030$ ), when compared to placebo LEDT. **CONCLUSION:** We conclude that this particular procedure and dose of LEDT immediately before exhaustive biceps humeri contractions, causes a slight delay in the development of skeletal muscle fatigue, decreases post-exercise blood lactate levels and inhibits the release of Creatine Kinase and C-Reactive Protein. *Lasers Surg. Med.* (c) 2009 Wiley-Liss, Inc.

*Lasers Surg Med* 2009 Sep 3

<http://www.ncbi.nlm.nih.gov/pubmed/?term=19731300>

# Effects of Low-Level Laser Irradiation on Rat Skeletal Muscle Injury after Eccentric Exercise.

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**Abstract Background and Objective:** The effect of photobiomodulation on delayed onset muscle soreness remains unknown. This study represents the first investigation of this treatment using an animal model. **Methods:** Seventy-two Sprague-Dawley rats were randomly divided into five groups: sedentary control group, exercise control group and three exercise-plus-laser groups. Downhill running was used to induce muscle injury in the gastrocnemius muscle. He-Ne laser irradiations were administered to the injured muscles immediately and at 18 and 42 h after exercise in the three exercise-plus-laser groups at 12, 28, and 43 J/cm<sup>2</sup>, respectively. Histological examination and serum creatine kinase (CK), muscle superoxide dismutase (SOD) and malondialdehyde (MDA) analyses were done at 24 and 48 h after exercise. **Results:** The exercise control group exhibited a marked inflammation in the gastrocnemius muscle and significant elevations in serum CK activity and muscle MDA level after downhill running. He-Ne laser irradiation at 43 J/cm<sup>2</sup> inhibited muscle inflammation, significantly enhanced muscle SOD activity and significantly reduced serum CK activity and muscle MDA level at both 24 and 48 h after exercise, whereas the irradiation at 12 or 28 J/cm<sup>2</sup> slightly inhibited muscle inflammation and significantly reduced serum CK activity at 48 h after exercise only ( $P < 0.05$ ). **Conclusions:** Low-level He-Ne laser therapy could exert therapeutic effects on eccentric exercise-induced rat muscle injury through enhancing muscle anti-oxidative capacity and reducing the inflammatory reaction. The photobiomodulation was dose-dependent, and the 43 J/cm<sup>2</sup> dose was the most efficient among the doses used.

Photomed Laser Surg 2009 Aug 21

<http://www.ncbi.nlm.nih.gov/pubmed/?term=19697999>



# Low-level laser therapy attenuates creatine kinase levels and apoptosis during forced swimming in rats.

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Studies suggest that high-intensity physical exercise can cause damage to skeletal muscles, resulting in muscle soreness, fatigue, inflammatory processes and cell apoptosis. The aim of this study was to investigate the effects of low-level laser therapy (LLLT) on a decrease in creatine kinase (CK) levels and cell apoptosis. Twenty male Wistar rats were randomly divided into two equal groups: group 1 (control), resistance swimming; group 2 (LLLT), resistance swimming with LLLT. They were subjected to a single application of indium gallium aluminum phosphide (InGaAlP) laser immediately following the exercise for 40 s at an output power of 100 mW, wavelength 660 nm and 133.3 J/cm<sup>2</sup>. The groups were subdivided according to sample collection time: 24 h and 48 h. CK was measured before and both 24 h and 48 h after the test. Samples of the gastrocnemius muscle were processed to determine the presence of apoptosis using terminal deoxynucleotidyl transferase (TdT)-mediated deoxyuridine triphosphate (dUTP) nick end labeling. (There was a significant difference in CK levels between groups ( $P < 0.0001$ ) as well as between the 24 h and 48 h levels in the control group, whereas there was no significant intra-group difference in the LLLT group at the same evaluation times. In the LLLT group there were 66.3 +/- 13.2 apoptotic cells after 24 h and 39.0 +/- 6.8 apoptotic cells after 48 h. The results suggest that LLLT influences the metabolic profile of animals subjected to fatigue by lowering serum levels of CK. This demonstrates that LLLT can act as a preventive tool against cell apoptosis experienced during high-intensity physical exercise.

Lasers Med Sci 2009 Jun 25

<http://www.ncbi.nlm.nih.gov/pubmed/?term=19554361>

# Comparison Between Single-Diode Low-Level Laser Therapy (LLLT) and LED Multi-Diode (Cluster) Therapy (LEDT) Applications Before High-Intensity Exercise.

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**Abstract Background Data and Objective:** There is anecdotal evidence that low-level laser therapy (LLLT) may affect the development of muscular fatigue, minor muscle damage, and recovery after heavy exercises. Although manufacturers claim that cluster probes (LEDT) maybe more effective than single-diode lasers in clinical settings, there is a lack of head-to-head comparisons in controlled trials. This study was designed to compare the effect of single-diode LLLT and cluster LEDT before heavy exercise. **Materials and Methods:** This was a randomized, placebo-controlled, double-blind cross-over study. Young male volleyball players (n = 8) were enrolled and asked to perform three Wingate cycle tests after 4 x 30 sec LLLT or LEDT pretreatment of the rectus femoris muscle with either (1) an active LEDT cluster-probe (660/850 nm, 10/30 mW), (2) a placebo cluster-probe with no output, and (3) a single-diode 810-nm 200-mW laser. **Results:** The active LEDT group had significantly decreased post-exercise creatine kinase (CK) levels (-18.88 +/- 41.48 U/L), compared to the placebo cluster group (26.88 +/- 15.18 U/L) (p < 0.05) and the active single-diode laser group (43.38 +/- 32.90 U/L) (p < 0.01). None of the pre-exercise LLLT or LEDT protocols enhanced performance on the Wingate tests or reduced post-exercise blood lactate levels. However, a non-significant tendency toward lower post-exercise blood lactate levels in the treated groups should be explored further. **Conclusion:** In this experimental set-up, only the active LEDT probe decreased post-exercise CK levels after the Wingate cycle test. Neither performance nor blood lactate levels were significantly affected by this protocol of pre-exercise LEDT or LLLT.

Photomed Laser Surg 2009 Mar 20

<http://www.ncbi.nlm.nih.gov/pubmed/?term=19302015>

## Effect of 830 nm low-level laser therapy applied before high-intensity exercises on skeletal muscle recovery in athletes.

Leal Junior EC, Lopes-Martins RA, Baroni BM, De Marchi T, Taufer D, Manfro DS, Rech M, Danna V, Grosselli D, Generosi RA, Marcos RL, Ramos L, Bjordal JM

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Our aim was to investigate the immediate effects of bilateral, 830 nm, low-level laser therapy (LLLT) on high-intensity exercise and biochemical markers of skeletal muscle recovery, in a randomised, double-blind, placebo-controlled, crossover trial set in a sports physiotherapy clinic. Twenty male athletes (nine professional volleyball players and eleven adolescent soccer players) participated. Active LLLT (830 nm wavelength, 100 mW, spot size 0.0028 cm<sup>2</sup>, 3-4 J per point) or an identical placebo LLLT was delivered to five points in the rectus femoris muscle (bilaterally). The main outcome measures were the work performed in the Wingate test: 30 s of maximum cycling with a load of 7.5% of body weight, and the measurement of blood lactate (BL) and creatine kinase (CK) levels before and after exercise. There was no significant difference in the work performed during the Wingate test ( $P > 0.05$ ) between subjects given active LLLT and those given placebo LLLT. For volleyball athletes, the change in CK levels from before to after the exercise test was significantly lower ( $P = 0.0133$ ) for those given active LLLT (2.52 U l<sup>-1</sup> +/- 7.04 U l<sup>-1</sup>) than for those given placebo LLLT (28.49 U l<sup>-1</sup> +/- 22.62 U l<sup>-1</sup>). For the soccer athletes, the change in blood lactate levels from before exercise to 15 min after exercise was significantly lower ( $P < 0.01$ ) in the group subjected to active LLLT (8.55 mmol l<sup>-1</sup> +/- 2.14 mmol l<sup>-1</sup>) than in the group subjected to placebo LLLT (10.52 mmol l<sup>-1</sup> +/- 1.82 mmol l<sup>-1</sup>). LLLT irradiation before the Wingate test seemed to inhibit an expected post-exercise increase in CK level and to accelerate post-exercise lactate removal without affecting test performance. These findings suggest that LLLT may be of benefit in accelerating post-exercise recovery.

Lasers Med Sci 2008 Dec 5

<http://www.ncbi.nlm.nih.gov/pubmed/?term=19057981>

# The effect of low-level laser therapy on electrically induced muscle fatigue: a pilot study.

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**OBJECTIVE:** The purpose of this pilot study is to determine if low-level laser therapy (LLLT) could attenuate skeletal muscle fatigue induced by surface neuromuscular electrical stimulation (NMES) in healthy volunteers. **MATERIALS AND METHODS:** Five college-age participants underwent three cross-over randomized trials: two (LLLT + NMES) test trials and a control trial (NMES only), in which NMES was applied to their dominant knee extensor muscle group. The LLLT doses, 500 mW at 808 nm, were either adjusted to deliver a total energy of 7 J for 10 min or 3 J for 5 min in a blinded fashion. Following LLLT irradiation, the NMES protocol was immediately delivered for 3 min to induce fatigue in the knee extensor muscle group. **RESULTS:** The five participants completed the three trials. After the control trial, torque significantly decreased (62%;  $p < 0.0001$ ) at the end of 3 min. There was no significant difference between the 7 J and 3 J trials on muscle fatigue. Following both LLLT trials, torque significantly decreased (51%;  $p < 0.0001$ ) at the end of 3 min. Although there was a difference (11%) in fatigue between the two LLLT trials and the control trial, this difference did not attain statistical significance ( $p = 0.63$ ). **CONCLUSION:** LLLT did not attenuate muscle fatigue evoked by NMES, but this needs to be further addressed in human studies and clinical settings. The lack of significant findings could be explained by the small sample size and the selection of LLLT parameters.

Photomed Laser Surg 2008 Oct 26(5) 501-6

<http://www.ncbi.nlm.nih.gov/pubmed/?term=18922091>

# Effect of 655-nm low-level laser therapy on exercise-induced skeletal muscle fatigue in humans.

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**OBJECTIVE:** To investigate if development of skeletal muscle fatigue during repeated voluntary biceps contractions could be attenuated by low-level laser therapy (LLLT). **BACKGROUND DATA:** Previous animal studies have indicated that LLLT can reduce oxidative stress and delay the onset of skeletal muscle fatigue. **MATERIALS AND METHODS:** Twelve male professional volleyball players were entered into a randomized double-blind placebo-controlled trial, for two sessions (on day 1 and day 8) at a 1-wk interval, with both groups performing as many voluntary biceps contractions as possible, with a load of 75% of the maximal voluntary contraction force (MVC). At the second session on day 8, the groups were either given LLLT (655 nm) of 5 J at an energy density of 500 J/cm<sup>2</sup> administered at each of four points along the middle of the biceps muscle belly, or placebo LLLT in the same manner immediately before the exercise session. The number of muscle contractions with 75% of MVC was counted by a blinded observer and blood lactate concentration was measured. **RESULTS:** Compared to the first session (on day 1), the mean number of repetitions increased significantly by 8.5 repetitions (+/- 1.9) in the active LLLT group at the second session (on day 8), while in the placebo LLLT group the increase was only 2.7 repetitions (+/- 2.9) ( $p = 0.0001$ ). At the second session, blood lactate levels increased from a pre-exercise mean of 2.4 mmol/L (+/- 0.5 mmol/L), to 3.6 mmol/L (+/- 0.5 mmol/L) in the placebo group, and to 3.8 mmol/L (+/- 0.4 mmol/L) in the active LLLT group after exercise, but this difference between groups was not statistically significant. **CONCLUSION:** We conclude that LLLT appears to delay the onset of muscle fatigue and exhaustion by a local mechanism in spite of increased blood lactate levels.

Photomed Laser Surg 2008 Oct 26(5) 419-24

<http://www.ncbi.nlm.nih.gov/pubmed/?term=18817474>

# Effect of 830 nm low-level laser therapy in exercise-induced skeletal muscle fatigue in humans.

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This study aimed to investigate the effect of 830 nm low-level laser therapy (LLLT) on skeletal muscle fatigue. Ten healthy male professional volleyball players entered a crossover randomized double-blinded placebo-controlled trial. Active LLLT (830 nm wavelength, 100 mW output, spot size 0.0028 cm<sup>2</sup>, 200 s total irradiation time) or an identical placebo LLLT was delivered to four points on the biceps humeri muscle immediately before exercises. All subjects performed voluntary biceps humeri contractions with a load of 75% of the maximum voluntary contraction (MVC) force until exhaustion. After active LLLT the mean number of repetitions was significantly higher than after placebo irradiation [mean difference 4.5, standard deviation (SD) +/- 6.0, P = 0.042], the blood lactate levels increased after exercises, but there was no significant difference between the treatments. We concluded that 830 nm LLLT can delay the onset of skeletal muscle fatigue in high-intensity exercises, in spite of increased blood lactate levels.

Lasers Med Sci 2008 Jul 23

<http://www.ncbi.nlm.nih.gov/pubmed/?term=18649044>

# Central nervous system abnormalities in fibromyalgia and chronic fatigue syndrome: new concepts in treatment.

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Fibromyalgia (FM) and chronic fatigue syndrome (CFS) are poorly understood disorders that share similar demographic and clinical characteristics. The etiology and pathophysiology of these diseases remain unclear. Because of the similarities between both disorders it was suggested that they share a common pathophysiological mechanisms, namely, central nervous system (CNS) dysfunction. Current hypotheses center on atypical sensory processing in the CNS and dysfunction of skeletal muscle nociception and the hypothalamic-pituitary-adrenal (HPA) axis. Researches suggest that the (CNS) is primarily involved in both disorders in regard to the pain, fatigue and sleep disturbances. Many patients experience difficulty with concentration and memory and many others have mood disturbance, including depression and anxiety. Although fibromyalgia is common and associated with substantial morbidity and disability, there are no US Food and Drug Administration (FDA)-approved treatments except pregabalin. Recent pharmacological treatment studies about fibromyalgia have focused on selective serotonin and norepinephrine (NE) reuptake inhibitors, which enhance serotonin and NE neurotransmission in the descending pain pathways and lack many of the adverse side effects associated with tricyclic medications. CFS is a descriptive term used to define a recognisable pattern of symptoms that cannot be attributed to any alternative condition. The symptoms are currently believed to be the result of disturbed brain function. To date, no pharmacological agent has been reliably shown to be effective treatment for CFS. Management strategies are therefore primarily directed at relief of symptoms and minimising impediments to recovery. This chapter presents data demonstrating CFS, abnormal pain processing and autonomic nervous system (ANS) dysfunction in FM and CFS and concludes by reviewing the new concepts in treatments in CFS and FM.

Curr Pharm Des 2008 14(13) 1274-94

<http://www.ncbi.nlm.nih.gov/pubmed/?term=18537652>

## Effect of phototherapy on delayed onset muscle soreness.

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**OBJECTIVE:** The purpose of this study was to investigate the effects of phototherapy on delayed onset muscle soreness (DOMS) as measured using the Visual Analog Scale (VAS), McGill Pain Questionnaire, Resting Angle (RANG), and girth measurements. **BACKGROUND DATA:** Previous research has failed to prove the beneficial effects of phototherapy on DOMS. **METHODS:** This was a randomized double-blind controlled study with 27 subjects (18-35 years) assigned to one of three groups. The experimental group received 8 J/cm<sup>2</sup> of phototherapy each day for five consecutive days using super luminous diodes with wavelengths of 880 and visible diodes of 660 nm at three standardized sites over the musculotendinous junction of the bicep. The sham group received identical treatment from a dummy cluster. The controls did not receive treatment. The study was completed over five consecutive days: on day one baseline measurements of RANG and upper arm girths were recorded prior to DOMS induction. On days 2-5, RANG, girth, and pain were assessed using VAS and the McGill Pain Questionnaire. **RESULTS:** The experimental group exhibited a significant decrease in pain associated with DOMS compared to the control ( $p=0.01$ ) and sham groups ( $p=0.03$ ) based upon the VAS at the 48-h period. The McGill Pain Questionnaire showed a significant difference in pain scores at the 48-h period between the experimental and the sham groups ( $p=0.01$ ). There were no significant differences day to day and between the groups with respect to girth and RANG. **CONCLUSION:** The results of this study provide scientific evidence that phototherapy as used in this study provides a beneficial effect to patients who may experience DOMS after a novel exercise session.

Photomed Laser Surg 2006 Jun 24(3) 377-82

<http://www.ncbi.nlm.nih.gov/pubmed/?term=16875447>



# Effect of low-level laser (Ga-Al-As 655 nm) on skeletal muscle fatigue induced by electrical stimulation in rats.

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We investigated whether low-level laser therapy (LLLT) can reduce muscular fatigue during tetanic contractions in rats. Thirty-two male Wistar rats were divided into four groups receiving either one of three different LLLT doses (0.5, 1.0, and 2.5 J/cm<sup>2</sup>) or a no-treatment control group. Electrical stimulation was used to induce six tetanic muscle contractions in the tibial anterior muscle. Contractions were stopped when the muscle force fell to 50% of the initial value for each contraction (T50%). There was no significant difference between the 2.5 J/cm<sup>2</sup> laser-irradiated group and the control group in mean T50% values. Laser-irradiated groups (0.5 and 1.0 J/cm<sup>2</sup>) had significantly longer T50% values than the control group. The relative peak force for the sixth contraction in the laser-irradiated groups were significantly higher at 92.2% (SD 12.6) for 0.5 J/cm<sup>2</sup>, 83.2% (SD 20.5) for 1.0 J/cm<sup>2</sup>, and 82.9% (SD 18.3) for 2.5 J/cm<sup>2</sup> than for the control group [50% (SD 15)]. Laser groups receiving 0.5 and 1.0 J/cm<sup>2</sup> showed significant increases in mean performed work compared with both the control group and their first contraction values. Muscle damage was indirectly measured by creatine kinase levels in plasma. A distinct dose-response pattern was found in which 1.0 and 2.5 J/cm<sup>2</sup> LLLT groups had significantly lower creatine kinase levels than the 0.5 J/cm<sup>2</sup> LLLT group and the control group. We conclude that LLLT doses of 0.5 and 1.0 J/cm<sup>2</sup> can prevent development of muscular fatigue in rats during repeated tetanic contractions.

J Appl Physiol 2006 Jul 101(1) 283-8

<http://www.ncbi.nlm.nih.gov/pubmed/?term=16627677>

# Pain reduction by infrared light-emitting diode irradiation: a pilot study on experimentally induced delayed-onset muscle soreness in humans.

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The present pilot study investigated the analgesic efficacy of light-emitting diode (LED). In view of a standardised and controlled pain reduction study design, this in vivo trial was conducted on experimentally induced delayed-onset muscle soreness (DOMS). Thirty-two eligible human volunteers were randomly assigned to either an experimental (n=16) or placebo group (n=16). Immediately following the induction of muscle soreness, perceived pain was measured by means of a visual analog scale (VAS), followed by a more objective mechanical pain threshold (MPT) measurement and finally an eccentric/concentric isokinetic peak torque (IPT) assessment. The experimental group was treated with infrared LED at one of both arms, the other arm served as control. Irradiation lasted 6 min at a continuous power output of 160 mW, resulting in an energy density of 3.2 J/cm<sup>2</sup>. The subjects of the placebo group received sham irradiation at both sides. In post-treatment, a second daily assessment of MPT and VAS took place. The treatment and assessment procedure (MPT, VAS and IPT) was performed during 4 consecutive days. Statistical analysis (a general linear model followed by post hoc least significant difference) revealed no apparent significant analgesic effects of LED at the above-described light parameters and treatment procedure for none of the three outcome measures. However, as the means of all VAS and MPT variables disclose a general analgesic effect of LED irradiation in favour of the experimental group, precaution should be taken in view of any clinical decision on LED. Future research should therefore focus on the investigation of the mechanisms of LED action and on the exploration of the analgesic effects of LED in a larger randomised clinical trial and eventually in more clinical settings.

*Lasers Med Sci* 2006 Apr 21(1) 38574

<http://www.ncbi.nlm.nih.gov/pubmed/?term=16538423>

# Laser application effects on the bite strength of the masseter muscle, as an orofacial pain treatment.

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**OBJECTIVE:** The present research studies the effects of AsGaAl (low-intensity laser) on the bite strength of the masseter muscle in order to evaluate the contribution of laser therapy in patients with orofacial pain. **BACKGROUND DATA:** Studies on laser therapy suggest its usefulness in the treatment of temporomandibular disorders. This paper presents the effects of low-intensity laser in the contraction of the masseter muscle in patients with neuromuscular discomfort. **METHODS:** Fifteen patients of both genders, ages 19-29, suffering from pain in the masseter muscle, were exposed to laser application (AsGaAl) applied from a 2-mm distance. **RESULTS:** All patients showed improvement in muscle contraction strength of about 2.51-3.01 kgf on the right and left masseter muscle. **CONCLUSIONS:** These results suggest that low-level laser application is an effective tool for the treatment of patients with orofacial pain.

Photomed Laser Surg 2005 Aug 23(4) 373-6

<http://www.ncbi.nlm.nih.gov/pubmed/?term=16144479>

# Effects of low power laser and low dose amitriptyline therapy on clinical symptoms and quality of life in fibromyalgia: a single-blind, placebo-controlled trial.

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The purpose of this study was to examine the effectiveness of low power laser (LPL) and low-dose amitriptyline therapy and to investigate effects of these therapy modalities on clinical symptoms and quality of life (QOL) in patients with fibromyalgia (FM). Seventy-five patients with FM were randomly allocated to active gallium-arsenide (Ga-As) laser (25 patients), placebo laser (25 patients), and amitriptyline therapy (25 patients). All groups were evaluated for the improvement in pain, number of tender points, skin fold tenderness, morning stiffness, sleep disturbance, muscular spasm, and fatigue. Depression was evaluated by a psychiatrist according to the Hamilton Depression Rate Scale and DSM IV criteria. Quality of life of the FM patients was assessed according to the Fibromyalgia Impact Questionnaire (FIQ). In the laser group, patients were treated for 3 min at each tender point daily for 2 weeks, except weekends, at each point with approximately 2 J/cm<sup>2</sup> using a Ga-As laser. The same unit was used for the placebo treatment, for which no laser beam was emitted. Patients in the amitriptyline group took 10 mg daily at bedtime throughout the 8 weeks. Significant improvements were indicated in all clinical parameters in the laser group ( $P = 0.001$ ) and significant improvements were indicated in all clinical parameters except fatigue in the amitriptyline group ( $P = 0.000$ ), whereas significant improvements were indicated in pain ( $P = 0.000$ ), tender point number ( $P = 0.001$ ), muscle spasm ( $P = 0.000$ ), morning stiffness ( $P = 0.002$ ), and FIQ score ( $P = 0.042$ ) in the placebo group. A significant difference was observed in clinical parameters such as pain intensity ( $P = 0.000$ ) and fatigue ( $P = 0.000$ ) in favor of the laser group over the other groups, and a significant difference was observed in morning stiffness ( $P = 0.001$ ), FIQ ( $P = 0.003$ ), and depression score ( $P = 0.000$ ) after therapy. A significant difference was observed in morning stiffness ( $P = 0.001$ ), FIQ ( $P = 0.003$ ), and depression ( $P = 0.000$ ) in the amitriptyline group compared to the placebo group after therapy. Additionally, a significant difference was observed in depression score ( $P = 0.000$ ) in the amitriptyline group in comparison to the laser group after therapy. Our study suggests that both amitriptyline and laser therapies are effective on clinical symptoms and QOL in fibromyalgia and that Ga-As laser therapy is a safe and effective treatment in cases with FM. Additionally, the present study suggests that the Ga-As laser therapy can be used as a monotherapy or as a supplementary treatment to other therapeutic procedures in FM.

Rheumatol Int 2002 Sep 22(5) 188-93

<http://www.ncbi.nlm.nih.gov/pubmed/?term=12215864>

# Efficacy of low power laser therapy in fibromyalgia: a single-blind, placebo-controlled trial.

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Low energy lasers are widely used to treat a variety of musculoskeletal conditions including fibromyalgia, despite the lack of scientific evidence to support its efficacy. A randomised, single-blind, placebo-controlled study was conducted to evaluate the efficacy of low-energy laser therapy in 40 female patients with fibromyalgia. Patients with fibromyalgia were randomly allocated to active (Ga-As) laser or placebo laser treatment daily for two weeks except weekends. Both the laser and placebo laser groups were evaluated for the improvement in pain, number of tender points, skinfold tenderness, stiffness, sleep disturbance, fatigue, and muscular spasm. In both groups, significant improvements were achieved in all parameters ( $p < 0.05$ ) except sleep disturbance, fatigue and skinfold tenderness in the placebo laser group ( $p > 0.05$ ). It was found that there was no significant difference between the two groups with respect to all parameters before therapy whereas a significant difference was observed in parameters as pain, muscle spasm, morning stiffness and tender point numbers in favour of laser group after therapy ( $p < 0.05$ ). None of the participants reported any side effects. Our study suggests that laser therapy is effective on pain, muscle spasm, morning stiffness, and total tender point number in fibromyalgia and suggests that this therapy method is a safe and effective way of treatment in the cases with fibromyalgia.

Lasers Med Sci 2002 17(1) 57-61

<http://www.ncbi.nlm.nih.gov/pubmed/?term=11845369>

## 830-nm irradiation increases the wound tensile strength in a diabetic murine model.

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**BACKGROUND AND OBJECTIVE:** The purpose of this study was to investigate the effects of low-power laser irradiation on wound healing in genetic diabetes. **STUDY DESIGN/MATERIALS AND METHODS:** Female C57BL/Ksj/db/db mice received 2 dorsal 1 cm full-thickness incisions and laser irradiation (830 nm, 79 mW/cm<sup>2</sup>, 5.0 J/cm<sup>2</sup>/wound). Daily low-level laser therapy (LLLT) occurred over 0-4 days, 3-7 days, or nonirradiated. On sacrifice at 11 or 23 days, wounds were excised, and tensile strengths were measured and standardized. **RESULTS:** Nontreated diabetic wound tensile strength was 0.77 +/- 0.22 g/mm<sup>2</sup> and 1.51 +/- 0.13 g/mm<sup>2</sup> at 11 and 23 days. After LLLT, over 0-4 days tensile strength was 1.15 +/- 0.14 g/mm<sup>2</sup> and 2.45 +/- 0.29 g/mm<sup>2</sup> (P = 0.0019). Higher tensile strength at 23 days occurred in the 3- to 7-day group (2.72 +/- 0.56 g/mm<sup>2</sup>) LLLT vs. 1.51 +/- 0.13 g/mm<sup>2</sup> nontreated; P < or = 0.01). **CONCLUSION:** Low-power laser irradiation at 830 nm significantly enhances cutaneous wound tensile strength in a murine diabetic model. Further investigation of the mechanism of LLLT in primary wound healing is warranted.

Lasers Surg Med 2001 28(3) 220-6

<http://www.ncbi.nlm.nih.gov/pubmed/?term=11295756>

# Lack of effect of combined low intensity laser therapy/phototherapy (CLILT) on delayed onset muscle soreness in humans.

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**BACKGROUND AND OBJECTIVES:** This study, which was approved by the University's Ethical committee, was conducted to investigate the effectiveness of Combined Low Intensity Laser Therapy/Phototherapy (CLILT) in alleviating the signs and symptoms of Delayed Onset Muscle Soreness (DOMS) over an 11-day period. **STUDY DESIGN/MATERIALS AND METHODS:** Thirty-six subjects (18 M: 18 F) were randomly allocated, under strictly controlled double-blind conditions, to one of three experimental conditions: Control, Placebo, and CLILT (660-950 nm; 11 J/cm<sup>2</sup>; pulsed at 73 Hz). DOMS was induced in a standardised fashion in the non-dominant elbow flexors using repeated eccentric contractions until exhaustion was reached. Subjects returned on five consecutive days, and two days during the following week, for treatment according to group, and assessment of outcome variables including range of motion, pain, and tenderness. **RESULTS:** While analysis of results using repeated measures and one factor ANOVA with post-hoc tests showed significant changes in all variables over time ( $P < 0.05$ ) as a result of the induction procedure, there were no significant differences observed between groups. **CONCLUSIONS:** CLILT failed to show any beneficial treatment effect on DOMS, at least at the parameters used here. These results therefore provide no evidence for the claimed biostimulating effects of such therapy.

Lasers Surg Med 1999 24(3) 223-30

<http://www.ncbi.nlm.nih.gov/pubmed/?term=10229153>

# Delayed-onset muscle soreness: lack of effect of combined phototherapy/low-intensity laser therapy at low pulse repetition rates.

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A double-blind, placebo-controlled study using male subjects ( $n = 60$ ), was conducted to investigate the efficacy of three different frequencies of combined phototherapy/low-intensity laser therapy (CLILT) in alleviating the signs and symptoms of delayed-onset muscle soreness (DOMS). The study was approved by the University's ethical committee. After screening for relevant pathologies, recent analgesic or steroid drug usage, current pain, diabetes, or current involvement in regular weight-training activities, subjects were randomly allocated to one of five experimental groups: Control, Placebo, or 2.5-Hz, 5-Hz, or 20-Hz CLILT groups (660-950 nm; 31.7 J/cm<sup>2</sup>; pulsed at the given frequencies for a duration of 12 min;  $n = 12$  all groups). Once baseline measurements were obtained, DOMS was induced in the nondominant arm, which was exercised in a standardized fashion until exhaustion, using repeated eccentric contractions of the elbow flexors. The procedure was repeated twice more to ensure exhaustion was achieved, after which subjects were treated according to group allocation. In the CLILT/placebo groups, the treatment head was applied directly to the affected arm at the level of the musculotendinous junction. Subjects returned on two consecutive days for further treatment and assessment. The range of variables used to assess DOMS included range of movement (universal goniometer), mechanical pain threshold/tenderness (algometer) and pain (visual analogue scale and McGill Pain Questionnaire). Measurements were taken before and after treatment on each day, except for the McGill Pain questionnaire, which was completed at the end of the study. Analysis of results using repeated measures and one-factor analysis of variance with relevant post hoc tests showed significant changes in ranges of movement accompanied by increases in subjective pain and tenderness for all groups over time ( $p = 0.0001$ ); however, such analysis failed to show any significant differences between groups on any of the days. These results thus provide no convincing evidence for any putative hypoalgesic effect of CLILT upon DOMS at the parameters used here.

J Clin Laser Med Surg 1996 Dec 14(6) 375-80

<http://www.ncbi.nlm.nih.gov/pubmed/?term=9467328>



## Helium-neon laser irradiation at fluences of 1, 2, and 4 J/cm<sup>2</sup> failed to accelerate wound healing as assessed by both wound contracture rate and tensile strength.

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**BACKGROUND AND OBJECTIVE:** Reports in the literature indicate that low energy laser irradiation has a biostimulatory effect on wound healing; however, no mechanism of this effect has been elucidated. **STUDY DESIGN/MATERIALS AND METHODS:** We attempted to establish a model from which to study the mechanism of biostimulation. The effects of low energy helium-neon irradiation on wound healing were observed in two rat models. In the first model, 1.5 cm diameter full thickness excisional skin defects were created in the dorsal midline of rats (n = 32). All animals were anesthetized and all eschars were debrided daily. Wound area was determined by caliper measurements for 2 weeks postoperatively. Rats that received a treatment of 1 J/cm<sup>2</sup> had two defects in the dorsal skin. One wound was treated and the second was used as its own control. These measurements were not blinded. Rats that received 2 J/cm<sup>2</sup>, 4 J/cm<sup>2</sup>, or anesthesia alone had one defect on the dorsal skin. Caliper measurements of these wounds were blinded. We were unable to demonstrate any difference in the rate of wound contracture in rats that received a daily dose of 1 J/cm<sup>2</sup>, 2 J/cm<sup>2</sup>, 4 J/cm<sup>2</sup>, or anesthesia alone (P > 0.8 by student's t-test). In the second model, a single 2 cm longitudinal full thickness skin incision was created in the dorsal midline of each rat (n = 24). No difference was found between rats that received anesthesia alone and those treated daily with 2 J/cm<sup>2</sup> as assessed by tensile strength measurements on postoperative days 7 and 14 (P > 0.8 by student's t-test between groups at both time points). These determinations were blinded. **RESULTS:** Despite our intentions of studying the mechanism of low energy HeNe biostimulation, we were unable to demonstrate a beneficial effect. **CONCLUSION:** In this study, helium-neon laser irradiation produced no measurable benefit on wound healing.

*Lasers Surg Med* 1997 20(3) 340-5

<http://www.ncbi.nlm.nih.gov/pubmed/?term=9138263>

## Muscle fiber formation in vitro is delayed by low power laser irradiation.

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The myogenic cell culture provides a good in vitro model for studying the differentiation process of the muscle tissue. Although the growth of the mononucleated myoblasts is predetermined, in that they will fuse to form multinucleated muscle fibers, some control on the process of fusion can be achieved in vitro. The low power laser irradiation (LPLI) has been shown to enhance in cultured mammalian cells DNA synthesis and motility of cells. In our rat myogenic cell line (L8) system the LPLI induced a delay of 5 to 6 hours in the onset of fusion of the myoblasts compared to the nonirradiated cells. The creatine kinase activity and the incorporation of labelled thymidine of the irradiated cultures were similar to the pattern of behaviour of these parameters in the control cultures. Thus, we have extended the longevity of the myoblasts population. We assume that the delay in fusion was induced by the increase of the motility of the myoblasts in culture, so that rearrangements of physical contacts or of membrane components were needed to resume fusion.

J Photochem Photobiol B 1993 Mar 17(3) 287-90

<http://www.ncbi.nlm.nih.gov/pubmed/?term=8492246>

# Suprascapular neuropathy during progressive resistive exercises in a cardiac rehabilitation program.

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A 56-year-old man developed left shoulder pain three weeks after starting a cardiac rehabilitation program, which consisted of submaximal aerobic and progressive resistive exercises. Pain in the left shoulder intensified and weakness developed one week later. He sought medical attention ten weeks after the onset. Physical examination showed only weakness of left shoulder abduction and external rotation with mild atrophy of the left supraspinatus and infraspinatus muscles. Electrodiagnostic study showed fibrillation potentials and positive sharp waves in the left supraspinatus and infraspinatus muscles with delayed conduction to the supraspinatus. The left suprascapular notch was injected with local steroid. Within one week, improvement occurred, and one month later the patient was pain free and stronger. The motor latency returned to normal, and no fibrillations nor positive waves were seen. The patient returned to his previous functional level. Suprascapular neuropathy should be considered as a cause of shoulder pain and weakness in a person involved in any strengthening exercise program. A steroid injection of the suprascapular notch performed early may avoid the need for surgery.

Arch Phys Med Rehabil 1992 Nov 73(11) 1107-11

<http://www.ncbi.nlm.nih.gov/pubmed/?term=1444779>

# APPLICATION OF LOW REACTIVE-LEVEL LASER THERAPY (LLLT) IN PATIENTS WITH CEREBRAL PALSY OF THE ADULT TENSION ATHETOSIS TYPE

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In patients with cerebral palsy of the tension athetosis type, a number of symptoms may be observed, including not only the fairly constant involuntary athetotic movements but also myotonic disorders of the motor function of all four limbs and trunk, vocalization and motions associated with eating such as mastication and swallowing. Aggravation of involuntary movements and pain in the neck and back are also seen in many cases. Existing conservative treatment methodologies have proved to be more or less ineffective, and limitations in functional training in adults have made treatment extremely difficult. We first employed low reactive-level laser therapy (LLLT) in a case of spastic cerebral palsy in 1994 with good results. In the present study, we applied laser irradiation (830 nm, 60 mW continuous wave) to all myotonic sites around the face and neck region where myotonia was severe in 20 patients with cerebral palsy of the adult tension athetosis type for which there was no effective treatment for their neck and back pain. Improvement of myotonia was seen in 19 patients while improvement of pain in the neck and back was seen in all the 16 patients who had pain in these regions. Suppression of myotonia reduced tonic vocalization making words easily heard; moreover, suppression of myotonia and involuntary movements improved working efficiency enabling the patient to perform fairly complex tasks such as word processing. Insomnia and dysuria also improved. Even in the most severe cases, assisting the patient became easier and breathing improved. LLLT with the 830 nm diode laser provides a new and effective treatment modality in this extremely problematic condition, has no serious side effects, and has the potential to improve these patients' quality of life.

Key words: Low reactive-level laser therapy, cerebral palsy, adult tension athetosis type, rehabilitation, pain attenuation, functional training

## Introduction

We have reported that low reactive-level laser therapy (LLLT) suppressed tonic muscle spasm in children with spastic cerebral palsy and improved the efficiency of their functional training.<sup>(1,2)</sup> Pain of the neck and back is often observed in patients with cerebral palsy of the

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adult tension athetosis type and at present there is no really effective conservative conventional therapy. In-

deed some treatment methods result in aggravation of the involuntary constant slow writhing movements associated with athetosis, and the pain caused by increased myotonia. We have used ULT in patients affected by this disease to suppress neck and back pain as well as systemic myotonia since 1994, and obtained

Manuscript received: June, 1995

# The effect of GaAlAs laser irradiation on the recovery process of muscular strength following muscle fatigue

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## Abstract

Low reactive-level laser therapy (LLLT) has been reported to reduce chronic and acute pain. Recently, some studies have shown that LLLT may also delay skeletal muscle fatigue during high-intensity exercise. We have hypothesized that laser irradiation may also attenuate muscle fatigue or pain experienced after sports or exercise. However, only a few reports have described the use of lasers in sports medicine. This study was conducted to determine the effectiveness of LLLT in aiding the recovery from exercise-induced skeletal muscle fatigue. **Subjects and Methods:** Isometric plantar flexion was repeatedly performed on 9 students until the force output declined to 50% maximal voluntary contraction (MVC). Subjects were assigned to perform 3 experiments under different LLLT conditions: laser irradiation to the neck (NKL), to the muscle (MSL), and no laser irradiation (CON). MVC and muscle hardness, girth, blood oxygen saturation, and heart rate were measured during the pre-exercise, post-exercise, and recovery phases. The neck and muscle were irradiated for 15 s using the Oh-Lase HT 2001 semi-conductor laser (830 nm; 60 mW, continuous wave), immediately after MVC measurement during the post-exercise phase.

**Results:** The total exercise time and mean output forces were analyzed using repeated-measures and one-factor ANOVA with post-hoc tests; no significant differences were observed among the 3 conditions for the pre and post-exercise MVC levels before irradiation (NKL, 68.1% MVC; MSL, 66.4% MVC; CON, 66.1% MVC). However, the MVC at 5 and 10 min after exercise was significantly greater in the NKL and MSL groups than in the CON group (MVC after 5 min: 80.4%, 76.9%, and 69.7% for the NKL, MSL, and CON groups, respectively; MVC after 10 min: 81.8%, 81.2%, and 74.4%). Further, no significant differences were observed in the MVC recorded at 15 and 30 min. Therefore, compared to the CON group, the NKL and MSL groups exhibited early muscle-strength recovery from fatigue caused by repeated contractions.

**Conclusion:** We concluded that LLLT at the parameters used in the present study effectively promoted the recovery of the isometric force output after muscle fatigue induced by repeated contractions, especially in the acute-exhaustion phase.

Laser Therapy. 2010, Vol. 19, No. 1, p.11-22 .

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