Low Level Laser Therapy for Stimulating Muscle Regeneration Following Injury

Nicole McBrier, PhD, ATC • Pennsylvania State University and Jennifer A. Olczak, ATC • Chatham University

Light amplification of stimulated emission of radiation (LASER) has been used in European countries for over 40 years to treat various pathologies, including soft tissue wounds, tendinopathies, osteoarthritis, musculoskeletal pain, and various sports injuries.1,2 Low level laser therapy (LLLT) was recently approved in the United States for treatment of minor chronic neck and shoulder pain of musculoskeletal origin and hand/wrist pain associated with carpal tunnel syndrome.3-6 European-based research focused on muscle injury and regeneration has demonstrated beneficial effects. The purpose of this report is to review research pertaining to the effects of LLLT on the regeneration process following muscle trauma.

Background

There are 4 commonly used types of LASERS: (a) neodymium yttrium aluminum garnet (Nd:YAG), (b) helium neon (He-Ne), (c) gallium arsenide (GaAs), and (d) gallium aluminum arsenide (GaAlAs). The most commonly used wavelengths in clinical practice are 632.8 nm (HeNe), 820 to 830 nm (GaAlAs), and 904 nm (GaAs).4 The wavelength is clinically important, because it determines the depth of penetration of the LASER energy, and therefore, the potential for a physiological response.4 The longer the wavelength, the deeper the energy penetration.5 The physiologic mechanisms of LLLT therapeutic benefit are still vague, but the limited research suggests that it induces a photochemical reaction at the cellular level without inducing a temperature change.4,7 Therapeutic effects include reduction of pain, accelerated resolution of the inflammatory process, and facilitation of tissue repair.2

The pulsed energy delivered by LLLT is believed to be absorbed by structures within cell membranes and cell organelles.8 The cell absorbs photons, or light energy packets, and transforms the energy derived from light into adenosine triphosphate (ATP). The newly formed ATP enhances the homeostatic functions of the cell and may facilitate mitosis and proliferation.3 Evidence from in vitro (i.e., cell culture) studies indicate that LLLT facilitates collagen synthesis, keratinocyte cell motility, and growth factor release9 and transforms fibroblasts into myofibroblasts.10 The next step in determining the effect of LASER on muscle regeneration is in vivo (living organism) research. A recent meta-analysis was conducted by Enwemeka et al.11 to evaluate the efficacy of LLLT on both tissue repair and pain. All studies involved animals or human subjects, and effects sizes for 34 peer-reviewed studies were calculated. The meta-analysis determined that LLLT has a beneficial effect on both tissue repair (ES = 1.81) and pain (ES = 1.11). No distinction was made concerning the type of LASER, but wavelength was documented. The results indicated that a wavelength of 632.8 nm had the greatest treatment effect for tissue repair, which is a typical wavelength for HeNe lasers. The greatest treatment effect for pain was found for a wavelength of 830 nm, which is a typical wavelength for GaAlAs lasers. Thus, the specific type of laser may influence the treatment outcome. A limitation of the
The clinical applicability of the meta-analysis findings is the non-specific nature of “tissue healing” that was associated with superficial wounds, connective tissue, muscle, etc. We have chosen to focus this review on muscle healing. The reviewed studies were selected and grouped on the basis of muscle pathology: myotoxin injury, cold induced injury, and single-impact trauma.

Models of Injury

A number of methods are used to induce injury to skeletal muscle for research on the effects of therapeutic interventions. Myotoxin injection will produce injury along the entire length of a muscle fiber, rather than focal damage created by impact trauma. Degeneration of the muscle occurs almost immediately, with a decrease in force output within 2 hours. Tissue regeneration is typically complete within 60 days. Cold-induced injury is another reproducible method to induce a standardized acute injury in an animal model. The most frequently used method involves liquid nitrogen cooling of a copper rod that is placed in direct contact with the muscle tissue. Single-impact trauma is another reproducible form of skeletal muscle injury that produces a focal lesion. The latter two types of induced injury produce a relatively small area of damage in comparison to the amount of undamaged tissue within the muscle.

Therapeutic Effect of LLLT

Among the studies we reviewed (see Table 1), four involved the use of the HeNe laser, three involved the use of the GaAs laser, and one that did not specify the type appeared to involve use of the HeNe laser. The greatest therapeutic benefit in terms of muscle healing was derived from the HeNe laser. The results of the studies we reviewed were consistent with the findings of the Enwemeka et al. meta-analysis, which indicated that the 632.8 wavelength had the greatest treatment effect for tissue healing. Amaral et al. studied the effect of the HeNe laser at doses of 2.6, 8.4, and 25 J/cm² on markers of muscle regeneration. Only the 2.6 J/cm² dosage produced significant changes when compared to a control condition. The results of this study suggested that low intensity is more effective than high intensity in promoting tissue healing. High dosage of LLLT may actually be detrimental to the healing process. Bibikova et al. utilized the same HeNe laser treatment parameters in three studies that demonstrated enhanced healing following injury. Two of the studies examined markers of muscle regeneration and the third study focused on angiogenesis. A 2.5-fold increase in angiogenesis was observed when the injured muscle was treated with laser compared to a control condition at postinjury day 9. Revascularization is clearly important for tissue regeneration and may be responsible for the observed increase in skeletal muscle regeneration markers reported for the other two studies. Both single and multiple doses of irradiation were found to provide beneficial effects on muscle regeneration markers, but a differing dose-dependent effect was observed for multiple irradiation treatments performed with different laser types. Repeated treatments were actually detrimental to the muscle regeneration process for trials that utilized a GaAs laser. Overall, multiple irradiations did not result in maximal promotion of regeneration. A single laser treatment may be sufficient to trigger a cascade of physiologic responses that facilitate tissue regeneration.

An important theme to recognize is that not all laser treatment parameters are effective. Fisher et al. studied the effects of LLLT on rats following blunt trauma to the gastrocnemius muscle. The type of laser used was not clearly specified, but it appears to have been the HeNe type. Following treatment, there was no difference in contractile protein levels between experimental and control groups. There was an increase in collagenous protein in the laser-treated injured group compared to an untreated injured group, but the difference was not significant. Further research is needed to rule out the possibility that laser treatments might lead to increased scar tissue formation within muscle tissue.

Oliveira et al. evaluated the treatment effect of a GaAs (904 nm) laser after having used a myotoxin injection to induce injury of the tibialis anterior muscles in mice. An increase in overall mass of the animals was observed, but it was not attributable to an increase in the mass of the tibialis anterior muscle. Enwemeka et al. reported a meta-analysis effect size of 1.09 for the 904 nm laser wavelength, but Oliveira et al. did not find doses of 3 and 10 J/cm² to be effective for stimulation of the tissue regeneration process.